IFB FQ15237R/GG

metro

Washington Metropolitan Area Transit Authority

Six (6) Tie Breaker Stations Upgrade Orange and Blue Lines VA, DC and MD

Contract No. FQ15237R

IFB Issued: March, 2016

Volume 2 -Technical Provisions

Volume 2 Technical Provision
Table of Contents

SECTION 01110

SCOPE OF WORK

PART 1. GENERAL

1.1 SUMMARY

A. The scope includes all work required to furnish, install, connect, test and energize tie breaker station equipment and appurtenances to ensure safe, complete, workable and operational tie breaker station in facilities of the WMATA Metro Rail System, including furnishing and Provide ancillary material as required.

B. Refer to Section 16051D for detailed SCADA scope of work

C. Related specification sections include the following:

D. Work includes removal of identified equipment as part of replacement tasks. Protection, salvage, and/or disposal of removed equipment shall be performed per the requirements of the special provisions of this contract.

E. Work also includes modification to or extension of existing-to-remain equipment as indicated on drawings, and furnishing and Provide contractor-furnished equipment and materials as indicated on drawings.

F. The work shall include furnishing, installing, connecting, energizing and testing of all materials, equipment, labor, transportation and handling, construction equipment, tools and all other incidentals necessary for the execution, testing, connection, interconnection and energizing of the following:

1. Equipment:

a. Receiving, unloading, and inspection: The equipment shall be unloaded by the Contractor at designated facilities. The Contractor shall verify the correctness of the material received against bill of materials and also inspect for any damage. Receiving and inspection, particularly the removal and verification of impact recording meters, shall be done in presence of the Authorized Representative. The Authorized Representative shall be promptly notified of any damage or discrepancy in the material received. The Authorized Representative shall decide if the material is acceptable or not.

b. Contractor shall coordinate with Authority Representative for access of equipment into the facility as well as delivery of the equipment to the site. After the equipment is received by the contractor and verified by the Authority Representative, the Contractor shall assume responsibility for its protection from damage and security during movement into and inside the facility and installation.

c. The Contractor shall install all required equipment. The work shall be in accordance with the contract drawings and specifications included in this contract and comply with equipment vendor drawings.

d. The Contractor shall protect the equipment. In equipment such as switchgear and bus ducts in which there are internal space heaters, the space heaters shall be kept energized. If permanent power for the space heaters is not available, the Contractor shall provide the necessary temporary power.

e. Existing-to-remain equipment shown on drawings is shown to facilitate reconnection of control circuits to existing equipment and to facilitate other work in the vicinity of the existing equipment.

f. Contractor is responsible for verifying the interchangeability test of DC switchgear cubicles and breakers before equipment is delivered to job site(s) and shall only install cubicles and breakers that have been tested and pass the interchangeability test at the manufacturer's facility.

2. Equipment, Material and Work Included in this Contract Specification:

a. The Contractor shall furnish, install and test all material specified elsewhere in this specification including, but not limited to, the following:

1) Metal-Enclosed DC Switchgear

2) Human Machine Interface (HMI)

3) Fiber Patch Panels

4) Fiber Cables

5) Wire and Cable

6) Digital Trace Recorder

7) Remote Terminal Unit (RTU)

8) Digital Input Output Modules

9) UPS, battery, charger and accessories/components.

10) Battery Monitors

11) Shield Cable Monitor (SCM)

12) Miscellaneous materials including conduit, cable tray, support hardware, and wiring system, subfloor pouring/finishing, floor finishing and insulating topping, panel boards, grounding, etc., as shown and specified in Section 16052.

13) Grounding and bonding as shown and specified.

14) Cutting, patching and core drilling: The Contractor shall provide wall and floor openings or enlarge openings as required to accommodate bus duct, cable tray or conduit furnished. All unused conduit, sleeves, openings, cable trays etc. shall be sealed using fireproof material to meet occupancy jurisdictional codes for the room and shall be sealed for water infiltration.

15) Fabrication of glastic sheets to close sections around bus duct passing through floor opening.

16) Provide anchors for securing temporary and permanent equipment as indicated. Replacement and new equipment shall be anchored to existing

floor or new insulation pads in accordance with manufacturer's recommendations using epoxy grouted anchors.

17) Assembly of equipment: switchgear shipping sections shall be assembled for proper alignment, leveling, and bonding of adjacent sections. Electrical connections between shipping breaks shall be made according to manufacturer's shop drawings.

18) Training program as specified in special provisions and specifications.

19) SCADA training as specified in section 16051D

20) Relocation of equipment: Existing equipment such as light fixtures, ground bus, conduit, panels, boxes, mechanical ducts, etc., interfering with the installation work under this contract, shall be relocated as directed by the Authorized Representative at no additional cost to the Authority.

21) Removal and disposal of all excess material from jobsite as directed by the Authorized Representative.

22) Temporary jumper cables (per specification 16343B) to facilitate temporary power provisions during replacement or temporary removal of existing DC switchgear.

23) Where existing DC switchgear is replaced, contractor shall submit plans and procedures for temporary support and protection of cables, and eventual reconnection to new equipment.

24) Protection of existing materials and equipment: Contractor's work will necessarily involve work in the proximity of considerable WMATA equipment and materials which are to remain undisturbed. Significant examples include but are not limited to insulated floor topping, mechanical equipment, DC switchgear, UPS/Battery Charger, battery plants. Any damage to such equipment or materials during the work is to be repaired by the contractor at no additional cost to the Authority.

25) Replacement and new equipment shall be anchored to existing or new floor or concrete pads in accordance with manufacturer's recommendations using epoxy grouted anchors.

26) Control and alarm circuits to existing switchgear shall be removed and replaced to provide new connections to the re-installed and replacement equipment. Replaced control/alarm circuits shall be rung out and tested by the contractor.

27) Contractor shall adhere to Authority safety certification requirements as well as applicable local building codes and OSHA requirements when working in the vicinity of wholly or partially energized substation equipment.

28) Site access: Access for movement of equipment into or out of underground substations will in some cases require temporary street closure and/or traffic control measures to facilitate opening and reclosure of equipment access shafts. Coordinate with Authority and local jurisdictions; repair disturbed conditions (pavement, utilities) to restore to existing conditions after completion of work.

29) For location where the existing Annunciator panels are scheduled to be replaced, a Human Machine Interface panels (HMI) shall be provided (Per Performance specification 16291A).

1.2 REFERENCES

A. Codes, regulation, reference standards and specifications.

1. Codes and regulation jurisdictional authorities.

2. NEC

3. IEEE: 141,242

4. ANSI: C57.94,C57.93,C57.06

5. ASTM: D877

6. OSHA

1.3 SYSTEM DESCRIPTION

A. The work to be performed under this Contract includes the furnishing, delivering or arranging transportation via WMATA rail system to job site, and Provide metal-enclosed dc switchgear assemblies, as complete switchgear lineups, Insulation pad, DC breaker test cabinet, battery bank, battery charger, battery monitors, isolation transformer, AC and DC panelboards, RTU, DC trace recorder, Human Machine Interface, DIO, SCM, , lighting fixture, and other auxiliary equipment for tie breaker stations on the WMATA system. The work shall generally include the following:

1. Furnishing and delivery to work site of traction power and auxiliary equipment to accomplish equipment replacements and capacity upgrades. The equipment shall be delivered as completely engineered, fabricated, assembled units, inspected and tested ready for installation and connection to external circuits. All designs and extensions shall be performed in such a manner as to minimize down time of existing equipment. The equipment shall include but not be limited to the following:

a. DC switchgear lineups with DIO, DTR and SCM as indicated.

b. The contractor shall only provide DC switchgear cubicles and DC circuit breakers that have been tested for interchangeability in the manufacturer facility

c. The contractor shall only provide DTR, DIO and SCM that have been factory installed in the provided DC switchgear and tested for correct operation indicated in their respective specifications and as indicated in section 16051DBattery plant, battery charger as indicated.

d. Battery Monitor as indicated

e. AC and DC Panel boards.

f. Human Machine Interface as indicated.

g. Isolation transformer as indicated.

h. RTU as indicat d.DC trace recorder as indicated

i. Shield Cable Monitor as indicated

j. Room Temperature Monitor as indicated

k. Any other auxiliary equipment as indicated.

2. Provide traction power and auxiliary equipment to accomplish equipment replacements and capacity upgrades. The contractor's work shall include but not be limited to provide the following equipment:

a. Replacement DC switchgear, as complete switchgear lineups, as indicated.

b. Replacing existing DC switchgear insulation pad as indicated.

c. Replacing existing annunciator panel with HMI panel as indicated

d. Improvements and equipment replacements associated with Battery Charger, auto-transfer switch, battery plants, DC panelboards, and related circuits, as indicated on drawings.

e. Replacing existing lighting fixture and add new lighting fixture as indicated.

f. Provide RTU

g. Provide new power circuits (wire and conduit) within the tie-breaker stations Sub-600 volt AC circuits (e.g., 277/480 volt, 120/208 volt, and 120 volt) 125 VDC (nominal) circuits.

h. Provide DC trace recorder

i. Provide Shield Cable Monitor

j. Provide Room temperature seonsor

k. Verify the number of connecting points between existing grounding bus to grounding grid. Notify authority if less than two connecting points are identified. Measure the ground resistance of the existing grounding grid and report the result to WMATA. Grounding of equipment as indicated or required.

l. Equipment replacements, and panelboard and feeder capacity upgrades as indicated on drawings.

m. Provide equipment and materials to provide ungrounded 120 VAC power circuits from normal power sources to supply heaters within DC switchgear assemblies.

n. Work shall include coordination with WMATA through the Authorized Representative to establish work periods and scheduling. Particular attention is required for replacement of DC switchgear.

o. Removal and replacement of existing power feeders and branch circuits as indicated. Where existing wiring is to be de-energized and abandoned, existing wiring shall be removed under this contract if the wiring is accessible for removal without disturbing existing circuits. Existing exposed conduit containing abandoned circuits shall be removed unless re-used for new (replacement) circuits.

p. Existing-to-remain low voltage (below 600 volts) AC and DC branch circuit wiring to existing equipment (DC switchgear) which is being replaced shall be disconnected and re-connected to replacement equipment. Replacement equipment shall be provided to facilitate reconnecting of existing wire. Splicing of these branch circuit wiring will be subject to review and approval by the AR and will be accepted only where absolute necessary. Splices shall be made in contractor-furnished boxes. All re-connected wiring, whether spliced or un-spliced, shall be thoroughly tested and clearly marked by the contractor.

q. Calibration and setting of existing and new protective relays and devices. Settings will be provided by the Authority in conjunction with work at individual tie breaker station.

r. Vendor drawings and other relevant engineering drawings and information for each station will be provided by the Authority to the extent possible, as the contract progresses. These drawings are not conformed or field verified. The contractor shall assure the suitability of these drawings to perform the required work by appropriate field surveys and checks.

s. Provide shop-drawings and test-plans.

t. Provide manufacturer's field-engineering assistance during installation, field-testing and initial energizing. The services of qualified manufacturer's engineering representatives shall be made available in phases, during the entire life of the installation contract. A full-time factory expert shall be provided on-site in the Washington DC area for a period of as required in the contract.

u. Provide services of manufacturer’s engineering representative during initial energization for verification of all equipment functions during train operation.

v. Make all changes on the equipment which may result from manufacturing discrepancies noted during equipment installation at no additional cost to the Authority.

w. Manufacturer's engineering representative shall be provided during Training specified in Special Provisions and Specifications. The exact schedule and location shall be coordinated with the Authority and the Contractor.

B. The equipment shall be designed and fabricated for connection per general arrangement shown on the Contract Drawings. The arrangements shall result in minimum space requirements for the tie breaker stations, adequate clearances and accessibility and suitability of arrangement with other equipment. Components, design and construction shall be chosen to provide a pleasing and homogeneous appearance. Units shall be as low in profile as possible. Units of the same type and rating shall be identical and interchangeable. Contract drawings represent the best available information regarding existing conditions, but actual field conditions may vary. The contractor will be required to deal with unexpected field conditions as part of this contract.

C. The Contractor shall be responsible for field survey of each tie breaker station identified in this contract for which new or replacement equipment is to be provided. Survey work shall include the following:

1. Determination of existing physical characteristics of facility and existing equipment:

a. Clearances for movement, installation, and servicing of equipment. New equipment shall be installed to facilitate maintenance and servicing, and the Provide the new equipment within the identified facilities. Equipment installations shall not preclude or restrict future servicing of existing equipment.

b. The manufactured equipment shall be manufactured with shipping splits and dimensions which will not preclude installation in the identified existing tie breaker station; field measurements shall be made to verify adequate access for installation at each individual site. Any problem situations shall be notified to the Authority Representative.

c. Verification or measurement of existing interface points (e.g., cable connections, arrangements, configurations, and dimensions) to facilitate development and fabrication of manufactured components (e.g., enclosures) that must match to existing equipment.

d. Additional equipment shall be designed to allow for placement into service without requiring removal or disturbance to existing operating equipment. Contractor must adhere to limits imposed by existing openings, access ways, doorways, space between existing equipment and access shafts which are available to move the equipment into its final location.

e. Structural floor design of existing facilities generally allows for loading of up to 250 pounds per square foot. Manufactured equipment shall be manufactured with suitable structural provisions and supports so as to limit floor loading during movement and final installation to not greater than 250 pounds per square foot for the entire floor. Transformers shall be designed with a rectangular base which will spread the weight of the transformer over a floor area of not less than 10.0 square feet.

f. Restricted openings (height, width, or depth) may require manufacture of equipment which can be field assembled within the substation rooms. This is particularly applicable to indoor dry transformers; the limited height, width, and depth of access doors, shafts, or pathways may require that the transformers be partially disassembled prior to movement into the substation spaces, and reassembled on site. Transformer enclosures shall be manufactured to facilitate such installation where dictated by individual site conditions. This disassembly/ reassembly of dry type indoor transformers will only be used when the Authority Representative approves of such methods.

g. Dimensions indicated on contract drawings are generally based on field survey data. However, the Contractor shall make independent measurements of available clearances, access openings, etc. to provide for manufacture of equipment which can be installed in the available spaces thru the available and existing access pathways.

h. New equipment shall be designed and manufactured to meet all existing field conditions. Any field revision of existing equipment or materials (e.g., shortening of feeder cables to match the termination requirements of the new equipment) shall be performed by contractor at no additional cost to the Authority.

2. Determination or measurement of existing electrical characteristics of equipment, to include:

a. Determination of cable connection requirements (locations, configurations, wire sizes/types, etc.) to facilitate extension and/or reconnection to new equipment.

b. Other electrical data pertaining to existing electrical equipment as required.

c. Establishment of left-to -right cubicle arrangements for DC switchgear, shown in the contract drawings, must be verified and confirmed by the contractor during field survey before the manufacturing of the switchgear. Where such discrepancies exist between the field survey data and the contract drawings, field survey data of the station arrangements shall govern.

d. Verify the entrance of existing power cables (top or bottom). New equipment shall be designed and manufactured so that no field splice of existing power cables is required.

3. The Authority will provide available shop drawings of existing equipment to the Contractor to facilitate determination of electrical and mechanical interfaces. However, the accuracy or availability of shop drawings is not guaranteed.

D. The Contractor shall be responsible for providing all required support from equipment manufacturers (for equipment furnished under this contract) during field-assembly, installation, testing and start-up of each traction power facility. This effort will include, but not be limited to, the following:

1. Provide shop-drawings and test-plans.

2. Provide manufacturer's field-engineering assistance during installation, field-testing, initial energization; and up to 1 day after initial energization to resolve any operational issues. The services of qualified manufacturer's engineering representative shall be made available if there are issues concerning equipment operation after installation under warranty.

3. Provide services of manufacturer's engineering representative during initial energization for verification of all equipment functions during train operation.

4. Make all changes on the equipment which may result from manufacturing discrepancies noted during equipment installation at no additional cost to the Authority.

5. Manufacturers' engineering representatives shall be provided during Operations and Maintenance Training specified in Special Provisions and specifications. The exact schedule and location shall be coordinated with the Authority and the Contractor.

E. The work shall generally include the following (this description of work does vary by site according to requirements defined on the drawings):

1. Furnish and install equipment and materials as indicated to accomplish equipment replacements and capacity upgrades.

2. Provide new power circuits (wire and conduit) within the substations:

a. Sub-600 volt AC circuits (e.g., 277/480 volt, 120/208 volt, and 120 volt)

b. 125 VDC (nominal) circuits

c. Provide 125VDC control Power to RTU and HMI

d. Provide 120VAC power to RTU receptacle and lighting

3. Provide new fiber optical cables between each microprocessor based relay and the substation network switch as specified in section 16051D.

4. Verification of number of grounding points between existing substation ground bus and grounding grid. Provide visual check of exposed grounding connections. Notify Authority if less than two connecting points are identified. Measure the ground resistance of the existing grounding grid and report the result to WMATA. Corrective action shall be taken by contactor if measured grounding resistance is less than specified in the design criteria. Provide

grounding of equipment as indicated or required.

5. Improvements and equipment replacements associated with Uninterruptible Power Systems, battery plants, Provide communication cables and related circuits, as indicated on drawings.

6. Provide substation Remote Terminal Units (RTU)

7. Provide DC Digital Trace Recorder

8. Improvements, equipment replacements, and panelboard and feeder capacity upgrades as indicated on drawings.

9. Provide equipment and materials to provide ungrounded 120 VAC power circuits from normal power sources to supply heaters within DC switchgear assemblies

10. Provide new Human Machine Interface Panel (HMI)

11. Work shall include coordination with WMATA through the Authorized Representative to establish work periods and scheduling. Particular attention is required for the following work:

    a. Temporary removal of existing DC switchgear, required on a temporary basis at those sites where the existing DC switchgear insulated topping is to be repaired.

    b. Replacement of DC switchgear

12. The tie breaker station will be de-commissioned during the replacement of the DC switchgears. Temporary jumper cables between track 1 third rails and track 2 third rails shall be installed.

13. Removal and replacement of existing power feeders and branch circuits as indicated. Where existing wiring is to be de-energized and abandoned, existing wiring shall be removed under this contract if the wiring is accessible for removal without disturbing existing circuits. Existing exposed conduit containing abandoned circuits shall be removed unless re-used for new (replacement) circuits.

14. Vendor drawings and other relevant engineering drawings and information for each TBS will be provided by the Authority after Provide each location, as the contract progresses. These drawings shall be conformed or field verified. The contractor shall assure the suitability of these drawings to perform the required work by appropriate field surveys and checks.

15. Refer to section 16051D and 16149 for SCADA system scope of work and installation.

1.4 SUBMITTALS

Submit the following for approval in accordance with Special Conditions and with the additional requirements as specified for each:

A. Submittals (general requirements)

1. Provide technical submittals for all equipment and materials furnished under this contract.

2. Do not ship any materials or equipment to job site(s) without first providing appropriate respective submittals to WMATA, and obtaining written approval by WMATA.

B. Shop drawings:

1. For equipment, materials, and work included in this contract, provide complete shop drawings and documentation as required elsewhere in these specifications.

2. Arrangement drawings: The contractor shall submit equipment arrangement drawings for all substations. Contractor's equipment shall be designed to fit within the building dimensions with appropriate minimum clearances (code compliant and satisfactory for maintenance by the Authority).

3. Within 40 days after receipt of NTP, submit a schedule of all shop drawing submittals. Include in the schedule, as a minimum, all items listed in Table 16051C-I.

4. Submit drawings of required modifications to existing equipment based on observations and measurements by contractor of field conditions. Include drawings showing modifications and interconnections to existing relaying and control systems at existing-to-remain equipment to accommodate the new furnished equipment.

5. In addition submit to the Authority Representative five (5) sets of shop drawings for complete substation/equipment room layout, including all major equipment items, elementary wiring diagrams, and interconnection diagrams, for approval. Existing equipment and materials shall also be shown on these drawings to indicate interfaces between new and existing equipment, to indicate access/installation pathways, or to indicate respective locations.

6. Update equipment interconnection wiring diagrams provided by equipment manufacturers to include panelboard circuit designations for control power, connections to ETS and DTS cabinets, connections to annunciator/HMI , battery, control and interlock wiring between equipment, etc. connection to the substation RTU and connection to cubicle DIO. Develop and submit composite interconnection diagrams showing terminal blocks, cable type, size and routing, and appropriate cross-references at both ends of cable terminations, to the Engineer for approval.

7. In addition submit to the Authorized Representative five (5) sets of shop drawings for TBS equipment control cable tray, elementary wiring and interconnection diagrams for approval.

8. Provide shop drawings for the following equipment. Make individual submittals for each site, except as indicated:

   a. DC switchgear and DC breakers

   b. Annunciator/Human Machine Interface (HMI) Panel

   c. RTU /Network Switch

   d. DC Digital trace Recorder

   e. Digital Input/output modules

   f. Shield Cable Monitor

9. In addition submit to the Authority Representative five (5) sets of shop drawings for complete station equipment layout, including recommended communication control cable tray layout, elementary wiring and interconnection diagrams for approval. Existing equipment and materials need not be shown on these drawings, except to indicate interfaces between new and existing equipment, to indicate access/installation pathways, or to indicate respective locations.

C. Site Specific Work Plan:

1. Per Special Provisions

D. Documentation in Addition to Special Provisions:

1. Design and factory test plans and documentation:

a. Submit design and factory test plans 60 days prior to testing of equipment, with accompanying documentation in the form of test data recording sheets and list of proposed test equipment for approval by the Authorized Representative.

b. The approved test plan shall be used for design and factory testing.

c. Authority reserves the right to witness any or all of the design and factory tests. Submit test schedule to Authorized Representative not later than 21 days prior to the anticipated test date.

d. Accompanying documentation to include standard data recording sheets as used in manufacturer’s in-plant testing of equipment and devices or as used by major utilities or large industrial users of specified equipment.

e. Submit certified copies of test data, indexed by facility within ten days after completion of testing.

2. Field test plan and documentation:

a. Submit field test plan for all field tests 90 days prior to testing of equipment, with accompanying documentation in the form of test data recording sheets and list of proposed test equipment for approval by the Authorized Representative.

b. The approved test plan shall be used for field-testing during installation

c. Indicate in scope of test plan how equipment will be tested to ensure safe and orderly transition from installation, through initial energizing, to specified field testing.

d. Accompanying documentation to include standard data recording sheets as used in manufacturer's in-plant testing of equipment and devices or as used by major utilities or large industrial users of specified equipment. Go/no-go acceptance criteria shall be stated in field test plans.

e. Submit certified copies of test data, indexed by facility within ten days after completion of testing.

1) Include oscillograph recordings of currents with dc switchgear protective device characteristics superimposed in the test reports.

2) Verify schematic diagrams for interconnecting wiring, device labeling and proper operation.

3) Submit one complete set of marked-up (“red-lined”) schematics 3 days prior to initial energizing of equipment.

f. Refer to section 16051D and 16149 for SCADA system field test plan and documentation requirements.

3. As-Built drawings

a. Per Special Provisions.

E. Operation and Maintenance Manuals: In accordance with Special Provisions.

F. Final As-Built drawings: In accordance with Special Provisions.

1.5 QUALITY ASSURANCE

A. Per Special Provisions.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Deliver and handle equipment as specified in Special Provisions.

B. Store all equipment in secure and dry storage facility before installation at no additional cost to the Authority.

1.7 SALVAGE AND DISPOSAL: PER SPECIAL PROVISIONS.

PART 2 PRODUCTS

2.1 EQUIPMENT

A. As specified in other sections of these specifications.

B. DC 2000 volt (traction power) 1000 KCMIL temporary feeders: Non-shielded cables.

PART 3 EXECUTION

3.1 DELIVERY AND INSTALLATION

A. Ship each unit securely packaged, braced and labeled for safe handling in shipment and to avoid damage or distortion.

B. Temporary Bracing: Where necessary, brace switchgear for hoisting, lowering and skidding into position. Label temporary internal bracing: TEMPORARY SHIPPING BRACE - REMOVE BEFORE OPERATION.

C. Protection against Concealed Damage: For DC switchgear, include within shipping container mechanical impact recorder of rating recommended by manufacturer for shipment by railroad and submit impact record chart with manufacturer's instructions for disposition of damaged material.

D. Assembly for Shipment:

1. Design enclosures to permit lifting by jacks or slings and moving horizontally on rollers or skidding in any direction.

2. Maximum dimensions of shipping sections to be coordinated with the dimensions of passage doorways in the substations and other areas which the switchgear is moved through. Movement of equipment through the Authority's structures and/or tunnels shall not damage any Authority equipment, structures, tiles, edges, or tunnels.

3. Draw-out relays mounted in their proper cases with moving parts properly secured and packed for shipment.

4. Removable circuit breaker elements packaged separately.

5. For shipping split, interconnecting wiring coiled on one side of the shipping split with matching terminal block on other side of split. Wiring and terminal block points identified for

re-connection.

E. Provide oversight and supervision to ensure that all equipment are installed in accordance with manufacturers' recommendations and approved shop drawings.

F. Install equipment as shown and specified in other sections of this specification.

G. Manufacturer's Engineering Representative:

1. Arrange for assistance of manufacturer's engineering representative(s) during field assembly, installation and adjustment/calibration of major equipment items furnished under this contract.

2. Initial energizing of the tracks and each station to be under guidance of manufacturer's engineering representative who will advise Authority personnel on step-by-step procedure.

3. Energizing equipment at each substation shall be the Contractor's responsibility with guidance from equipment manufacturer's engineering representative.

3.2 FIELD QUALITY CONTROL (IN ADDITION TO REQUIREMENTS IN INDIVIDUAL SPECIFICATIONS)

A. Field Testing and Inspection:

1. General requirements:

a. Conduct field testing and inspection at each substation to ensure proper operation of equipment provided.

b. Correct any deficiencies found during field testing and retest at no additional cost to the Authority.

c. Relays and trip device setting: Set protective relays and trip devices in accordance with approved coordination study and their calibration for proper operation during field testing.

1) Initial operation is expected to be eight-car trains at two-minute headway; each eight-car train, when accelerating will draw a peak current of 12,900

2. Field Inspection

a. Prior to field testing, check equipment installation in accordance with manufacturer's recommendations and IEEE 141 as applicable including, but not limited to, verification of the following:

1) Integrity of bus insulation.

2) Tightness of connections.

3) Adequate support of bus bars.

4) Correct grounding, anchoring and alignment of switchgear in accordance with manufacturer's drawings. Correct insulation of dc switchgear from ground.

5) Ease of racking draw out breakers in and out of cubicle

6) Physical interchangeability of similar circuit breakers.

7) Adjustment of circuit breaker main and secondary contacts.

8) Functioning of interlock and closing of safety shutter with breaker in disconnect or withdrawn position.

9) Tightness of bolted bus joints by calibrated-torque-wrench method, based on manufacturers recommended values.

3. Field Testing:

a. The Contractor shall coordinate with the Authorized Representative to establish the specific testing schedule for each facility. Notify the Authorized Representative one week in advance of each test. Conduct tests in presence of Authorized Representative.

b. Provide miscellaneous materials and hand tools and services of supporting field crew (licensed journeyman electricians) as indicated below to conduct field testing, to include all required test equipment. The Contractor shall coordinate with the Authorized Representative to establish the specific testing schedule for each facility. Contractor shall integrate equipment tests with installation work. Furnish test equipment, and labor to perform specified tests.

c. Submit certified test reports within ten days of substantial completion inspection. For each item, submit for approval and perform approved tests but not limited to those specified.

d. For existing systems affected by the work, perform tests of existing systems prior to beginning work, and perform tests of existing systems after restoration to existing condition (if applicable.) Provide written record of test results to Authority Representative. Examples of these tasks include but are not limited to:

1) Access into station spaces in some cases is via ventilation shaft(s) at which existing damper assemblies may require removal prior to movement of equipment into or out of the substation space. Test existing damper assemblies and systems for proper operation prior to temporary removal. If existing damper assembly is not properly operational, notify Authority Representative and do not commence work affecting existing dampers until authorized. Also test existing damper assemblies and systems for proper operation after re-installation.

2) Where WMATA operation department permits complete removal of a tie breaker station from revenue services, temporary power provisioning (specification 16343) shall require reconnection and reconfiguration of ETS systems. Prior to commencing work on ETS systems, test existing ETS systems to verify proper operation. If existing ETS system is not properly operational, notify Authority Representative and do not commence work affecting ETS system until authorized. After reconnection of ETS systems

to restore original system operation, test ETS systems to verify proper operation.

e. Perform insulation resistance test of 60-second duration on all equipment in accordance with the following requirements:

Test voltage as follows:

1) Voltage Rating — Test Voltage

	Voltage Rating	Test Voltage
a)	150-600V	1,000V, dc
b)	601-5,000V	2,500V, dc

2) Insulation resistance: kV rating plus one megohm but not less than minimum value recommended by manufacturer.

3) Ensure insulation resistance is equal to or greater than minimum value specified before performing dielectric withstand test.

f. Perform functional and set-up tests on metering, control, interlocking, blocking and supervisory circuits, including verification of interconnections between equipment and interface points. Verification of these tests to be substantiated by lined-in schematics, signed by the Contractor and the Authorized Representative.

g. Metal-enclosed dc switchgear:

1) Test protective devices/relays in accordance with IEEE 141 procedures.

2) Test operation of each Digital Input / Output module in accordance with section 16605 terminal block assignments tables

3) Test operation of each circuit and control in accordance with approved sequence.

4) Test interlock system as follows:

a) Make closure attempt on locked-open devices.

b) Make opening attempt on locked-closed devices.

5) For replacement DC switchgear: perform dielectric withstand test of one minute duration on entire assembled and erected switchgear, with breakers and switching devices in connected position and closed. Test at a voltage of 2775 volts, rms, 60 Hertz or 3900 volts dc on live parts and 1500 volts, rms, 60 Hertz on control wiring. Isolate all electronic timers and devices during the test.

6) Check the operation of enclosure ground detection system to initiate alarm for grounding of the metal enclosure and to initiate alarm and tripping of all dc breakers and lockout relay in the event of structure energized condition

7) Coordinate with the SCADA system integrator to test the DC switchgear relay, positive DTR per section 16051D point assignment charts for DC Switchgear.

h. At tie breaker stations where the existing DC switchgear is to be replaced, and tie breaker stations at which the existing DC switchgear insulated floor topping is to be replaced, test switchgear enclosure insulation to ground after replacement/repair to demonstrate proper enclosure insulation from ground. Test at 2500 volts, 60 Hertz from enclosure to ground for duration of one minute. Disconnect enclosure ground detection relaying during the test. Minimum allowable resistance to ground: 2000 megohms. The test is to be performed after the switchgear has been set into place and fully anchored to the floor.

i. Test ETS system for proper operation. Testing shall verify that wayside ETS boxes trip correct feeder breakers when activated and that breakers do not reclose when tripped. Perform tests as follows:

1) Test existing ETS systems prior to commencing any work which affects operation of the existing systems. Do not commence work to modify existing systems until existing system has tested satisfactorily.

2) Test modified system after modifications. Do not proceed with any work to provide temporary DC power to contact rails until modified system has tested satisfactorily.

3) Test restored system after work to restore original ETS system operation.

j. Verify that settings of all protective relays (new and existing-to-remain) at DC switchgear are in accordance with recommendations of Authority-furnished settings.

k. Verify that all DC breakers of a given type and rating are interchangeable with all switchgear cubicles of matching type and rating.

l. Verify that all DC breakers of a given type and rating are blocked from insertion into all switchgear cubicles of a different type or rating.

m. Testing of SCADA system: Perform all SCADA system RTU, HMI, DTR and communication network testing per section 16051D and 16149. As these circuits involve control or indication at a remote WMATA facility, this work will necessarily require close coordination with WMATA and SCADA system integrator.

n. Contractor is prohibited from using any power sources (AC, or DC) owned by the Authority. The contractor shall provide all power supplies required for testing and for construction.

B. Field Testing Personnel:

1. Provide services of qualified engineering representatives of the equipment manufacturers to conduct specified field testing program.

2. When more than one representative is involved, the Contractor is responsible for coordination of testing effort.

C. The tests shall be planned for minimum interference with Authority's train testing or other track use, and shall be totally accomplished, including all instrumentation and removal, in a total period of three (3) days or less per facility. The actual period shall be coordinated with and established by the Authority.

D. Submit five (5) “hard” (printed) copies and (5) electronic copies (on CD) of certified test reports within 10 days of Substantial Completion (SCI) for each substation.

TABLE 01110-I

SCHEDULE OF SHOP DRAWING REQUIREMENTS

Item	Description	To be Furnished Within Days
A	Outline dimensions for typical units of major equipment items (DC switchgear) including weights and foundation requirements for all equipment furnished	90 after NTP
B	Front views, typical floor plans, and mounting details for all equipment furnished	90 after NTP
C	One line diagrams	90 after NTP
D	List of standard symbols and nomenclature	60 after NTP
E	Elementary and control schematic diagrams and description of operation	90 after NTP
F	Interconnection wiring diagrams	120 after NTP
G	Wiring diagrams, showing internal wiring of all equipment furnished	120 after NTP
H	Wiring diagram, showing interconnection between shipping breaks	
I	Cross sections showing internal construction of equipment	90 after NTP
K	Certified Design Test Reports (45 days after test completion)	
O	DC Switchgear Data, including: 1. Duty cycles before required maintenance: No-load Full-load Rated fault current interruptions 2. Weight of circuit breaker only 3. Certified Design Test Reports	60 after NTP
P	Control Power Data for each substation including: 1. Continuous 125-Volt dc load 2. Continuous 115-Volt ac load 3. Closing and Tripping loads of: a. 700-Volt dc circuit breakers, for each rating	90 after NTP

S	Technical Description of Equipment Operation, Control and Protective Functions	90 after NTP
T	Bill of Material, with reference to all components indicating part numbers, manufacturer name, and listing agency of device	90 after NTP
U	Equipment Arrangement Drawing; Plan and Elevation for each tie breaker station sizes and elevation and cable tray plan and elevation for space coordination purposes	120 after NTP)
V	Field Test Plans	90 after NTP
AA	Wire and Cable.	45 after NTP.
BB	UPS, battery and components	60 after NTP.
CC	Basic materials and methods: Cable trays and mounting details, Panelboard, steel panels, glastic barrier/fire stop	45 after NTP.
DD	Equipment required for temporary power work (per section 16343B)	45 after NTP.
EE	Certified factory test reports.	15 after test Completion.
FF	Certificates from manufacturers Verifying that products conform to Specified requirements.	45 after NTP.
GG	Manufacturers’ catalog cuts and Literature.	45 after NTP.

END OF SECTION

SECTION 16051D
SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA) SCOPE OF WORK

PART 1 – GENERAL

1.1 SUMMARY

A. The scope of this section includes the design, furnishing, installing and testing of equipment and network to support the protection, control and monitoring of Tie-breaker Stations (TBS) equipment by the Advanced Information Management System (AIM), Supervisory Control and Data Acquisition (SCADA) and Automated Energy Management System (AEMS) in JGB/CTF OCC.

B. The network will serve a purpose of a remote controlling or status monitoring of equipment inside the facilities as specified here or in the other sections. The network will connect together various devices like Multi-purpose Protection Relays (MPR) and other Intelligent Electronics Devices (IED) specified here and in other sections to the SCADA system via the SCADA RTU installed in each station. The scope further includes furnishing of gateways (network switches or routers), Programmable Relays, Timers, etc… as required to meet the functional requirement as defined here and on the other sections of SCADA Specifications.

C. The TBS local area network serves as a communication medium between station devices like protective/metering devices, HMI and distributed I/O of the station electrical system and the station SCADA RTU. Each device in the station connects with the Wide Area Network (WAN) through the station Network Switch to provide remote control and monitoring from the OCC and remote monitoring from Engineering/Maintenance consoles.

D. The SCADA system inside TBS will mainly control and/or monitor as applicable DC switchgear, Digital trace recorders, uninterruptable power supplies (UPS), battery cycle monitor, emergency trip system, feeder cable shield monitor, and ancillary equipment installed inside the station.

E. Related Sections:

1. Section 01110 - Scope of Work
2. Section 16052 - Basic Materials and Methods for Traction Power.
3. Section 16149 - Wire, Cable and Termination Panel For SCADA System
4. Section 16265 - Battery and Battery Monitoring Systems
5. Section 16291A - Human Machine Interface (HMI) Panel For Traction Power
6. Section 16341 - Metal Enclosed D.C. Switchgear For Traction Power
7. Section 16602 - R T U for Traction and AC room Systems.
8. Section 16603 - D C Digital Trace Recorder for Traction Power.
9. Section 16604 - Network Switch For SCADA and Automation Systems
10. Section16605 - Distributed input output (DIO) module for Traction Power
11. Section 16606 - SCADA Systems Site Acceptance Test Plan
12. Section 16266 - Battery Charger

1.2 REFERENCES

A. Drawings: This specification should be read in conjunction with the following design directive drawings;
   1. Contract drawings.

B. Tables:

   1. SCADA Point Assignment Charts (PACs)

C. Codes and Regulations:

   1. Authority Having Jurisdiction (AHJ).

   2. NEC 2008.

   3. ANSI C37.2 Electrical Power System Device function Numbers and Contact Designation.

   4. IEEE 802.3 Standard for LAN interfaces and protocols.

   5. IEEE std. 1815-2010 Standard for Electric Power Systems Communications - Distributed Network Protocol (DNP3)

   6. NFPA 130, 2003.

   7. WMATA Information Technology/ Network & Communications Services (IT/NCS) specification section: Infrastructure design & wiring standards

1.3 QUALITY ASSURANCE

A. The SCADA System shall be furnished by a Contractor who shall assume responsibility for providing a complete and integrated system.

B. All SCADA equipment, components and materials required for the TBS shall be furnished by the Contractor who shall assume the responsibility for adequacy and performance of all items.

C. It is the Contractor responsibility to ensure that the provided RTU is designed and configured in such a way that it is fully compatible to tie into the existing Advanced Information Management System (AIM) and SCADA server using DNP3 communication protocol. SCADA Servers are provided independent of this Contract.

D. The Contractor shall supply its company's Quality Assurance Plan, and for components that are not of its manufacture, the component manufacturer's Quality Assurance Plan. The plans shall include but not necessarily be limited to: method of testing methods of documentation, station control, "Burn-In", final tests and serialization coding and packaging.

E. Minimum Qualifications:

1. Have at least five years continuous experience in designing, implementing, supplying and supporting instrumentation and control systems that are comparable to the SCADA System in terms of hardware, software and complexity.

2. Have manufactured and supported standard lines of microprocessor based control and monitoring equipment and application software continuously for the last five years.

3. Have in existence at the time of bid, an experienced engineering and technical staff capable of designing, implementing, supplying and supporting the SCADA System and handling the SCADA System submittal and training requirements.

4. Provide system hardware components and software packages of fully developed, field proven standardized designs and therefore shall furnish a system that is not a highly unique, custom one- of-a-kind system.

5. Have a minimum of five years of experience in hardware application and programming of Remote Terminal Units and data highway systems.

6. Provide standard course offerings in general control applications and in operation, programming and maintenance of the control system and equipment.

7. Have a system of traceability of the manufactured units, of "Burn-In" for all components and available supportive documentation which proves that the proposed equipment meets all of the manufacturer’s testing codes and standards, operational, functional, environmental (physical and electrical) and configuration requirements of these specifications.

8. Have a demonstrated record of prompt response to field failures, documented program of failure analysis.

9. Have a record of prompt shipments in accordance with contract obligations required for previous projects.

10. Have a certificate that show the proposed Remote Terminal Unit conforms to IEC 61850 communication networks and systems in substation at the time of bid.

F. Technical Requirements:

1. Have at least three completed utility or transit projects utilizing RTU and control equipment identical to or similar to that specified. Indicate owner, value, completion date, names and phone numbers of owner’s representatives familiar with each project.

2. Provide a general system configuration drawing and include designations for model numbers and types of the proposed SCADA System and all other proposed system components.

3. Provide descriptive literature and manufacturer's catalog information covering all aspects of the hardware design, functions and capabilities of the specific system proposed for the SCADA System.

4. Provide certification for IEC61850 protocol.

5. Describe standard software packages proposed, including any customized software required to meet the functional intent of the system specifications. Descriptions shall address the following:

   a. Overview of system software including the functions, organization and interrelationship of the major software modules provided.

b. Estimated memory requirements to accomplish the specified graphic display, logging, reporting and alarming functional requirements.

c. Real-time data logging and reporting software features and capabilities including examples of logs and reports, procedures for automatic reporting and logging file setups, limitations on sampling and computing frequency for data acquisition and logging, and utilities for log file and report modifications and file maintenance.

d. Alarm handling software features and capabilities including an alarm display example, methods of defining alarms and alarm files, acknowledgements and return to normal conditions, chronological sorting and time-tagging of alarms, and alarm file maintenance utilities.

e. SCADA system programming and documentation software features and capabilities, including screen display and printout examples for a fully annotated and cross-referenced ladder diagram and ladder and function block elements.

f. All RTU programming including database shall be provided to establish communication between the RTU and SCADA Servers that are provided independent of this Contract.

g. All RTU programs and Human Machine Interface (HMI) software configuration documents, features and capabilities, including screen display.

h. Use of system level diagnostics for monitoring the performance of and detecting and reporting faults associated with the SCADA.

G. Successful completion of System Acceptance Testing that proves that the equipment functions properly when connected to the AIM and SCADA servers located in JGB/CTF. This testing shall be done at the WMATA engineering LAB.

H. RTU and Distributed Input Output modules (DIO) acceptance testing shall be done at the manufacturer's facility and witnessed by the Contracting Officer Representative and System Integration Engineer. The contractor shall provide to WMATA a twenty- one (21) days minimum advance notice date of testing.

I. Specification language related to RTU, MPR, DIO, IED's, Ethernet switches, server devices and other solid state devices will be located in the equipment specification sections in which they appear.

J. Training: Provide information and literature of proposed training. Indicate the qualifications of the factory training staff.

K. Start-Up and Field Testing: Indicate how the availability demonstration will be accomplished.

L. Maintenance: Provide the following information:

1. Location of service facility along with minimum and maximum response time.

2. Location of parts facility with delivery time and method.

M. Contractor Responsibility:

1. Design, fabrication, installation, implementation and applications programming of the SCADA

and all subsystems in accordance with the Contract Documents and all referenced standards and codes.

2. Proper interfacing of the SCADA System hardware, software, field devices and panels, including required interfacing with electrical equipment and devices furnished and installed by other equipment suppliers with the TBS systems.

3. Supervision of the installation of SCADA System, instruments, HMI, RTU cabinets, wiring and other components required.

4. Calibration, testing and start-up of the SCADA System.

5. Training of OWNER'S personnel in operation and maintenance of the monitoring and control system.

6. Handling of all warranty obligations for the control system components.

7. Programming of the RTU's and HMI used in the SCADA System in accordance with the approved control descriptions provided by the CONTRACTOR.

1.4 SUBMITTALS

A. Shop Drawings:
   a. General :
      i. Shop drawing submittals shall be in accordance with the requirements of the Contract Documents.
      ii. Shop Drawings preparation shall not commence until after the Pre-Submittal Conference specified below.
      iii. Manufacture of the SCADA System shall not commence until related submittals have been approved by the WMATA SCADA ENGINEER.
      iv. Shop Drawings shall be submitted in complete packages grouped to permit review of related items as generally outlined below.
      v. Review of Shop Drawings will be for conformance with Contract Documents and with regard to functions specified to be provided.
      vi. Final and approved copies of all Shop Drawings shall be provided in AutoCAD format on a CD-ROM.

B. Pre-Submittal Meeting:
   a. CONTRACTOR shall arrange and conduct a Pre-Submittal meeting on the SCADA System.
   b. Purpose of the Pre-Submittal meeting shall be to review informally and accept the manner in which the SCADA System Contractor intends to respond to the requirements of the Contract Documents before any submittals are prepared.
   c. For the proposed RTU to be compatible with existing systems, the contractor is required to program the RTU according to the WMATA standard Point Assignment Charts. Copy of WMATA standard Point Assignment Charts (Scan Sheet) will be provided and discussed with the contractor.

   d. CONTRACTOR shall prepare the items listed below for presentation at the Pre-Submittal meeting. The information shall be submitted to Contracting Officer Representative three weeks prior to the date of the meeting.
      i. List of equipment and materials required for the SCADA System and the brand and model, which CONTRACTOR proposes to use for each item.
      ii. List of proposed exceptions to the Contract Documents along with a brief

explanation of each. Approval shall be subject to a formal submittal.

iii. Sample of each type of submittal specified herein. The samples may be submittals prepared for other projects.

iv. A flow chart showing the steps to be taken in preparing and coordinating each control system submittal to ENGINEER, and a list of proposed submittals.

v. Gantt chart type schedule for all SCADA System related activities from the Pre-Submittal meeting through start-up and training. Particular emphasis shall be given to dates relative to submittals, design, fabrication, programming, factory testing, deliveries, installation and field-testing. The schedule shall be subdivided to show activities relative to each major item or group of items when everything in a given group is on the same schedule.

vi. General outline of the type of tests to be performed to verify that all sensors/transducers, instruments and digital processing equipment are functioning properly.

vii. Outline of system integration and testing.

e. Submit product information for all RTU, MPR's, IED's and other solid state devices selected to be used for the remote control and monitoring purpose along with their configuration information (control/status mapping).

f. Submit SCADA design drawings including but not limited to layout drawings, riser diagrams, cable schedules, assembly drawings, cable tray layouts, interconnection diagrams, termination diagrams…etc. for approval by WMATA's System Integration Engineer.

g. Submit three copies of as-built drawings in electronic format (AutoCAD and pdf) and paper format (11X17)

h. Provide software, licenses and documentation required for the configuration and integration of each Intelligent Electronic Device provided.

i. Provide spare parts list.

j. Submit Integration Test procedure and test report for installations. Fiber test report are reviewed and approved by WMATA IT network prior to commencing acceptance tests.

k. Submit MPR's, IED's mapping document to comply with WMATA approved Point Assignment Chart.

1.5 SCADA SYSTEM FACTORY TESTING

A. CONTRACTOR shall provide all labor, materials, equipment and incidentals as shown, specified and required to perform factory testing, before shipment, at the manufacturer's facility to verify that system components are functioning properly and that they meet the functional and performance requirements of the Contract Documents.

B. CONTRACTOR shall submit information on factory testing procedures to verify that testing shall fulfill the requirements as specified herein. Submittal to shall be made at least two months in advance of any scheduled testing and shall include dates of scheduled tests.

C. CONTRACTOR shall notify WMATA, in writing, at least three weeks before expected initiation of tests. Contracting Officer Representative may elect to be present at CONTRACTOR'S facilities during operational test of system equipment, either for individual units or as an integrated system. Presence of Contracting Officer Representative during testing does not relieve CONTRACTOR from conforming to the requirements of the Contract Documents and shall in no way imply acceptance of the equipment.

D. Factory Testing shall not begin until all related Supervisory Control and Data Acquisition (SCADA) System shop drawings have been submitted and approved.

1.6 SCADA SYSTEM TRAINING

A. CONTRACTOR shall provide all labor, materials, equipment and incidentals as shown, specified and required to perform and coordinate all required training at times acceptable to WMATA. No part of the training shall be construed as a substitution for complete and comprehensive Operations and Maintenance (O&M) manuals, but should follow the same organizational structure as the O&M manuals.

B. CONTRACTOR shall retain the services of the RTU Manufacturer or their authorized representative (the SCADA System Integrator) to provide training for all SCADA equipment as specified herein.

C. For equipment items not manufactured by the RTU manufacturer, the Supplier shall provide for on- site training by an authorized representative of the equipment manufacturer as part of the Supplier's services. The manufacturer's representative shall be fully knowledgeable in the engineering, operation and maintenance of the equipment.

D. CONTRACTOR shall be responsible for all costs for training OWNER personnel and shall provide all required materials, texts and required supplies. All OWNER training shall be conducted at the OWNER’s facility.

E. All training shall be conducted to meet the needs of the OWNER personnel during all shifts.

F. CONTRACTOR shall submit his plan for training OWNER maintenance Personnel and engineers. Included in the plan shall be course outlines and schedules for training to be provided at the Owner's facilities.

G. SCADA SYSTEM MAINTENANCE TRAINING COURSE:

a. Provide on-site operation and maintenance training by Supplier and the equipment manufacturer representatives prior to placing the equipment in continuous operation. The services of equipment manufacturer’s representatives shall be provided for a minimum of eight hours for each type of instrument provided or as specified in the general section of the contract.

b. Provide course covering preventive and troubleshooting maintenance for the system components. The course shall familiarize the student with diagnostic capabilities of the system, both software and hardware, and also the routine maintenance procedures on the system and the common peripheral devices.

c. Training shall cover the following topics:

1. System overview description including the power subsystems and logic

components of the processor bus.

2. Description of the maintenance and troubleshooting aids of the system. Provide instruction covering procedures for routine, preventive and troubleshooting maintenance including equipment calibration.

3. Description of peripheral and interface devices.

4. Development and use of system displays.

5. Provide instruction covering use and operation of the equipment to perform the intended functions.

6. Explain procedures for placing the equipment in and out of operation and replacing equipment/components.

7. Explain necessary actions and precautions to be taken regarding the overall facility monitoring and control system.

8. Provide all instructions necessary to operate and utilize all system components.

9. Provide all instruction necessary to monitor and control the system from the HMI panel.

10. Provide instructions for regular caretaking operations.

H. ENGINEER TRAINING:

a. The SCADA System Supplier shall retain the services of the SCADA RTU manufacturer or their authorized representative to provide training as follows:

1. Provide an overview of system hardware and software.

2. Overview of systems functional capabilities.

3. Equipment overview including system component functions, operating principals and proper use.

4. Loading and start-up of the digital system hardware components.

5. Training in configuration, operation, use of system commands and programming processors.

6. The emphasis shall be placed on how to perform set point changes, programming, programming changes, range changes, diagnostics and upkeep of documentation.

7. Description of the maintenance and troubleshooting aids of the system, including software diagnostic programs.

8. Description and review of all RTU and SCADA system software programs

1.7 GENERAL SYSTEM DESCRIPTION

The SCADA system provides for remote control and monitoring of the Tie Breaker Station systems from the Operational Control Centre (OCC) and from the SCADA /Automated Energy Management System (AEMS) located in the Jackson Graham Building and Carmen Turner Facility (JGB/CTF). Block diagram of the SCADA architecture is provided separately for reference. A dedicated fiber optic WAN connects the SCADA master stations at the JGB/CTF to SCADA systems at remote sites like tie breaker stations.

A. At each site a SCADA RTU is provided to act as a data concentrator. Network Switches shall also be provided to connect all fiber and Ethernet cables from traction power and Electrical Room equipment also serves as a gateway to connect the site LAN to the SCADA WAN router. The CONTRACTOR will provide the RTU, HMI, fiber and copper products as specified and shown in the drawings for each site unless otherwise specified by the general section of the contract.

B. WMATA will provide the network switches unless otherwise specified by the general section of the contract.

C. Through the SCADA system, each remote site equipment can be accessed, monitored and/or controlled as applicable from the SCADA Master Station, OCC Master Station, engineer/Maintenance consoles, and locally from HMI panels installed adjacent to access doors where possible.

D. The new SCADA system shall be designed in such a way that it will be fully compatible to tie in to the existing Advanced Information Management System (AIM) and Automated Energy Management System (AEMS) using DNP3 communication protocol.

E. All hard-wired connections to the SCADA system are made through the SCADA RTU.

F. All Ethernet (fiber or copper) connections to the SCADA are made through the Network Switch directly.

1.8 SCOPE OF THE WORK:

A. CONTRACTOR shall provide all labor, materials, equipment and incidentals as shown, specified and required to furnish, install, program, calibrate, test, start-up and place in satisfactory operation a complete Supervisory Control and Data Acquisition (SCADA) System.

B. CONTRACTOR shall retain the services of the SCADA RTU manufacturer or their authorized representative to be the system integrator, supervise and/or perform check-out and start-up of all system components. As part of these services, the contractor shall include for those equipment items not manufactured by the RTU manufacturer, the services of an authorized manufacturers' representative to check the equipment installation and place the equipment in operation. The manufacturers' representative shall be thoroughly knowledgeable about the installation, operation and maintenance of the equipment.

C. SCADA System shall be designed to control, monitor, store, display and log process and equipment operating information and to perform various control functions and generate various reports.

D. Specifications of this Section and the other SCADA Standards that illustrate and describe the MINUMUM overall SCADA System functional and operational requirements.

E. Any exceptions the CONTRACTOR may wish to take to these standards require the review and preapproval of WMATA SCADA engineering.

F. Coordinate with WMATA Information Technology/Network & Communication Services for Configuration and set up of the network switches for each site.

1.9 DELIVERY, STORAGE AND HANDLING

A. Deliver a fully tested network of microprocessor-based devices, switches, cables and other devices which provide a remote control/monitoring system for Station Electrical, Traction Power equipment, tunnel fans and Drainage pumping station equipment

B. Licenses for any software used in or the setup and configuration of devices and equipment shall be provided.

C. Store network of microprocessor-based devices, switches, and temperature sensitive equipment in a dry, climate controlled area before field installation.

1.10 GENERAL DESIGN REQUIREMENTS

A. Provide SCADA equipment and devices specified on the contract SCADA equipment schedule drawing.

B. MPR, DIO, RTU, DTR, and Cable Shield monitor system shall connect to the Network Switches using Multimode Optical Fibers type OM3 50/125µm and shall be provided with 100 Base FX Ethernet ports.

C. Battery Monitors, HMI, UPS and other Ethernet copper devices shall connect to the Network Switches using 100 Base TX Ethernet.

D. UPS, Battery Charger, Inverter and HVAC system communication module shall connect to the SCADA RTU using RS-485 and form “C” contacts hard wired to the SCADA RTU.

E. ETS relays normally open contact (closed when in operation) shall connect to the RTU using copper wire.

F. Installation contractor shall provide multiconductor cables between the existing DTS cabinet and the RTU to re-route DTS controls and indications to the RTU. The cables shall be pulled and coiled inside of the DTS and RTU cabinets for termination by WMATA later.

G. The CONTRACTOR shall be responsible for all RTU and HMI annunciator displays, configurations, testing and commissioning unless otherwise specified by the general section of the contract.

H. Single mode fiber optical cable from Communication room to TBS shall be furnished and installed by the contractor at the following locations:
  a. Greenwich ST TBS
  b. Benning Rd TBS

I. The CONTRACTOR shall provide Multi-mode fiber cable, fiber patch panels and all necessary materials needed to meet the functional requirements as specified in this, other related sections and WMATA's standard drawings.

J. For each facility, the contractor shall provide a room temperature sensor type: Rotronic Hygroflex3 HF320-WT6XXXXX.

K. For details of interconnection, mode of operation, SCADA protocols supported by each device, refer to the related device specification, contract drawings and the SCADA assignment point table in Part 4.0 of this specification.

PART 2 – PRODUCTS

2.1 GENERAL REQUIREMENTS

A. Select devices and equipment specified in their related specification sections.

B. All devices to communicate with the SCADA RTU either through a direct hard-wire connection or using the Modbus TCP, IEC6185 or DNP 3.0 protocol over TCP/IP Ethernet or RS485 serial connection.

C. Devices on the LAN/WAN shall use assigned IP addresses provided by WMATA. Use of Dynamic Host Configuration Protocol (DHCP) is not permitted.

D. Devices to operate from 125V DC power supply.

2.2 PRODUCT FEATURE REQUIREMENTS

This section lists the features required for products to form part of the remote control and monitoring system and the SCADA system.

A. Laptop Computer: Provide one laptop for use in setup and configuration of RTUs, HMI, MPRs and other IEDs. The Laptop Computer shall have the following minimum specification:
  1) 15.4 inch WXGA high resolution display
  2) Dell Latitude series

3) The latest Intel processor at the time of delivery
4) Intel® Graphics Media Accelerator (GMA)
5) One Type II card slot, 2 USB ports
6) 8GB Memory
7) 1TB SSD
8) Super Multi DVDRW/CDRW Burner Drive
9) Intel® Pro-Wireless 802.11 a/b/g LAN
10) Windows 7 OS or Current Windows
11) MS office -Latest
12) Adobe Acrobat Pro
13) Configuration software for the provided IEDs shall be installed with license activated.
14) Loaded with the RTU diagnostic, configuration and maintenance tools specified in section 16602.

B. Ethernet Switch installed in RTU cabinet as specified in Section 16604.

C. Ethernet twisted pair cables, fiber optic cables, Fiber patch panels, fiber jumpers and connectors as specified in Section 16149.

D. Distributed Input-Output Modules (DIO) for DC switchgear: as specified in Section 16605.

E. Human Machine Interface (HMI): as specified in Section 16291A.

F. Multi-purpose Protection Relay for DC switchgear: As specified in Section 16341.

G. Intelligent Electronic Devices for TBS equipment.
1. Configuration setup and troubleshooting from a Windows based PC using front panel RS232/USB connection.
2. 10/100 base TX or 100 base FX Ethernet connection.
3. Support for DNP 3.0, IEC61850 or Modbus TCP protocols.

H. Digital Trace Recorder (DTR) for DC switchgear as specified in Section 16603.

I. Remote Terminal Units (RTU) as specified in section 16602.

2.3 DEVICE CONTROL AND INDICATION REQUIREMENTS (Refer to Table 4.0)

Alarms, indications and control functions available to the SCADA system, HMI panel and the OCC master station are listed in Part 4 tables. The tables detail the SCADA points for the following facilities:

A. TIE BREAKER STATIONS (TBS)

2.4 DEVICE MEASURING AND MONITORING REQUIREMENTS

The SCADA system shall be capable of displaying meter values concerning TBS equipment at the SCADA/AEMS Master Stations, AIM, and at individual HMI panels on demand as described in individual equipment specifications and as listed in Section 4 (Tables) of this specification.

PART 3 - EXECUTION

3.1 GENERAL REQUIREMENTS

A. CONTRACTOR shall retain the services of the SCADA RTU manufacturer or their authorized representative to be the system integrator, supervise and/or perform check-out and start-up of all system components. As part of these services, the contractor shall include for those equipment items not manufactured by the RTU manufacturer, the services of an authorized manufacturers' representative to check the equipment installation and place the equipment in operation. The manufacturers' representative shall be thoroughly knowledgeable about the installation, operation and maintenance of the equipment.

B. Tie Breaker Station RTUs will be furnished by the Contractor. The CONTRACTOR must install these RTU's as required by the Contract Documents. The programming and integration of the RTU's will be done by the manufacturer of RTU or the representative.

C. RTU interface circuitry shall be installed in conformance with the typical RTU control and indication circuits shown on the Contract Drawings and connected to the RTU as indicated on the approved RTU Scan Sheets submitted.

D. The CONTRACTOR shall provide and install Multi-mode fiber optic cables specified by WMATA IT to link each DC switchgear MPR, DIO, DTR, IED,SCADA RTU and equipment with fiber ports to the facility's Network Switches as specified in Section 16604.

E. The WMATA IT will install the WMATA furnished network switches on the RTU equipment rack, the contractor shall provide control power the network switches.

F. The CONTRACTOR shall provide and install fiber patch panel and connectors for the DC switchgear, SCADA RTU and the Network Switch. The CONTRACTOR shall also provide and install pre-fabricated jumper fiber cables between patch panels and end devices.

G. The CONTRACTOR shall provide and install Human Machine Interface (HMI) as specified in the technical specification 16291A in each Tie Breaker Station. The programming and integration of the HMI's will be done by the Contractor.

H. Microprocessor based DC relays (MPR), Distributed Input output modules (DIO), DC Trace Recorders (DTR), Track Feeder shielded cable monitors (CSM) installed by the manufacturer of the DC switchgear shall be integrated to the TBS SCADA system by the contractor.

I. The CONTRACTOR shall provide software and licenses for IED provided. Software shall be installed on the Laptop provided by the contractor.

J. The CONTRACTOR shall provide separate, dedicated communication cable trays for the routing of the Fiber optical cable, CAT6 cable, RS-485 cables and other communication cables used for SCADA purpose as specified in Section 16149.

K. The CONTRACTOR is responsible for all wiring installation requirements associated with RTUs, network switches and other equipment as shown on contract drawings.

L. The CONTRACTOR is responsible for providing and installing copper wire between existing DTS panels and the new RTU; however, this wiring will be terminated by WMATA during the RTU system integration.

M. The CONTRACTOR shall provide all cabling from the UPS to the SCADA RTU designated termination points.

N. Hard-wired indication and control circuits including analogs shall be routed from the equipment to the SCADA RTU and terminated onto a Terminal block provided within the SCADA RTU.

O. The CONTRACTOR shall coordinate connections to the SCADA RTU with RTU manufacturer.

P. Intrusion System:

1. The contractor remains responsible for providing and installing copper wire between existing Intrusion System and the new RTU; however, this wiring will be terminated by WMATA later as needed.

Q. Fire Alarm System

1. The contractor remains responsible for providing and installing copper wire between existing Fire Alarm System and the new RTU; however, this wiring will be terminated by WMATA later as needed.

3.2 POINT ASSIGNMENT CHART FORMAT

A. RTU Point Assignment Chart (PAC) is the listing of the input (status), output (control), and spare data points for each type of facility. The standard WMATA RTU PAC shall be used for all RTU provided to ensure compatibility with SCADA servers. All DNP3, IEC61850 and Modbus control, status and other point addresses must be the same as the existing system addresses for compatibility. Any modifications or change to the PAC must be evaluated and approved before implementation. The contractor PAC which has the same format as the WMATA PAC template, but which also contain additional columns showing RTU termination points must be submitted and used for all integration tests.

B. The RTU PAC shall include as a minimum all points included in the SCADA assignment points listed in table 4.0 in this Specifications and shall include any additions, corrections or revisions necessary to provide complete control and indication coverage of all support facilities within the respective RTU control areas, based on the latest information available.

D. The Contractor shall coordinate with the TBS Electrical Sub Contractors for additional Control and Status points to be Monitored and Controlled.

3.3 INTEGRATION WITH OCC SCADA SYSTEM

A. RTU provided under this contract shall be tested for compatibility with the WMATA system servers. Compatibility tests shall be conducted at the WMATA SCADA engineering LAB where the provided RTU shall be connected to WMATA AIM and SCADA servers.

B. CONTRACTOR shall provide all labor, materials, software, configuration, equipment, engineering and incidentals required to perform system compatibility tests.

C. The RTU shall be simulated for the complete ultimate size point counts. All requirements for exchanging data with AIM servers and SCADA servers shall be simulated.

D. Continuous operation test 48 (forty eight) hour period with simulated exchange with interconnected system AIM and SCADA server shall be performed.

3.4 SCADA SYSTEM START-UP AND FIELD TEST

A. CONTRACTOR shall provide all labor, materials, equipment and incidentals as shown, specified and required to furnish and install all equipment and coordinate all activities necessary to perform check-out and start-up of the equipment.

B. CONTRACTOR shall retain the services of the SCADA RTU manufacturer or their authorized representative to be the system integrator, supervise and/or perform check-out and start-up of all system components. As part of these services, the contractor shall include for those equipment items not manufactured by the RTU manufacturer, the services of an authorized manufacturers' representative to check the equipment installation and place the equipment in operation.
The manufacturers' representative shall be thoroughly knowledgeable about the installation, operation and maintenance of the equipment.

C. CONTRACTOR, under the supervision of the SCADA System integrator and other manufacturers' representative shall perform the following:

a. Check and approve the installation of all SCADA System components and all cable and wiring connections between the various system components prior to placing the various processes and equipment into operation.

b. Conduct a complete system checkout and adjustment, including calibration of all instruments, checking operation functions, and testing of final control actions. When there are future operational functions included in this work, they should be included in the system checkout. All problems encountered shall be documented and promptly corrected to prevent any delays in start-up of the various unit processes. The Contracting Officer Representative may witness any or all of this checkout and testing.

c. Upon completion, complete documentation for this checkout and testing shall be submitted.

d. CONTRACTOR shall provide test equipment necessary to perform the testing during system checkout and start-up. CONTRACTOR shall transfer the Laptop, software and the High Current test set to WMATA the after all final testing and commissioning.

e. CONTRACTOR and SCADA System integrator shall be responsible for initial operation of monitoring and control system and shall make any required changes, adjustment or replacements for operation, monitoring and control of the various processes and equipment necessary to perform the functions intended.

f. CONTRACTOR shall furnish to the Contracting Officer Representative certified calibration reports for field instruments and devices specified in Section 16606 and other sections as soon as calibration is completed.

g. CONTRACTOR shall furnish Contracting Officer Representative an installation inspection report certifying that all equipment has been installed correctly and is operating properly. The report shall be signed by authorized representatives of both CONTRACTOR and the System integrator.

h. CONTRACTOR shall provide all software and licenses required to operate, troubleshoot, maintain and repair all systems provided under this contract.

i. Following the SCADA System checkout and initial operation, CONTRACTOR, under the supervision of the SCADA System integrator, shall perform a complete system test to verify that all equipment and programmed software is operating properly as a fully integrated system, and that the intended monitoring and control functions are fully implemented and operational. The test procedure shall be approved by the Contracting Officer Representative at least 30 days before the test is started. The test shall be witnessed by the Contracting Officer Representative. Any defects or problems found during the test shall be corrected by CONTRACTOR and then retested to demonstrate proper operation.

3.5 OPERATIONAL AVAILABILITY DEMONSTRATION

A. Operational Availability Demonstration (OAD) shall begin following completion of the integrated system field test as specified above and shall continue until a time frame has been achieved wherein the system (both hardware and software) availability meets or exceeds 99.7 percent for 60 consecutive days and no system failures have occurred which result in starting the OAD over again. During the OAD the system shall be available to OCC for use in normal operation of the facility.

B. The conditions listed below shall constitute system failures which are considered critical to the operability and maintainability of the system. The OAD shall be terminated if one or more of these conditions occur. Following correction of the problem, a new 60 consecutive day OAD shall begin.

a. Failure to repair a hardware or software problem within 120 consecutive hours from the time of notification of a system failure.

b. Recurrent hardware or software problems: if the same type of problem occurs three times or more or different problems occur to the same hardware or process.Software problem causing a processor to halt execution or malfunction.

C. The following conditions shall constitute a system failure:

a. Loss of communications between devices on the communications network.

b. Failure of one or more input/output components.

c. Failures of any type affecting input/output points simultaneously.

d. Failure of power supply. Where redundant power supplies are provided, failure of one power supply shall not constitute a system failure provided the backup power supply operates properly and maintains supply power. Failure of the backup supply to operate properly and maintain supply power shall constitute a system failure.

D. Time to repair shall be the period between the time that CONTRACTOR is notified of a system failure and the time that the system has been restored to proper operation in terms of hours with an allowance for the following dead times which shall not be counted as part of the time to repair period.

a. Actual travel time for service personnel to get to the site up to six hours per incident from the time CONTRACTOR is notified of a system failure.

b. Time for receipt of spare parts to the site once requested up to 24 hours per incident. No work shall be done on the system while waiting for delivery of spare parts.

E. Completion and documentation of a 60 consecutive day period without any restarts of the OAD and with a System availability in excess of 99.7 percent will constitute acceptance of the SCADA System by WMATA.

F. All parts and maintenance materials required to repair the system prior to completion of the OAD shall be supplied by CONTRACTOR at no additional cost to WMATA. If parts are obtained from the required facility spare parts inventory, they shall be replaced to provide a full complement of parts as specified.

G. A SCADA System Malfunction/Repair Reporting Form shall be completed by the WMATA maintenance personnel and ENGINEER to document system failures, to record CONTRACTOR notification, arrival and repair times and CONTRACTOR repair actions. Format of the form shall be developed and agreed upon prior to the start of the OAD.

PART 4.0 – TABLES

Table 4.1 TBS SCADA ASSIGNMENT POINTS

WMATA reserves the right to add or remove points as necessary to provide a comprehensive remote monitoring and control system. WMATA standard Point assignment charts shall be used by the contractor for the protocol mapping of the IEDs and for points to be simulated and tested during the SCADA system integration.

Typical TBS				**Control**			**Indication**				
Equipment	**Item**	**Point description**	**Signal Type**	**Local HMI**	**AIM**	**AEMS**	**Local HMI**	**AIM**	**AEMS**	**WEB Access**	**IED type**
								OCC		**WEB**	
DC S/G Feeder Breaker	1	D.C SWGR Feeder Breaker Open Control	Ethernet	x	x						DIO
(Typical)	2	D.C SWGR Feeder Breaker Close Control	Ethernet	x	x						DIO
	3	D.C SWGR Feeder Breaker Open Indication	Ethernet				x	x	x	x	DIO
	4	D.C SWGR Feeder Breaker Close Indication	Ethernet				x	x	x	x	DIO
	5	D.C SWGR Feeder Breaker DIO Communication Failure	Ethernet				x	x	x	x	DIO
	6	D.C SWGR Feeder Breaker Rack Out	Ethernet				x	x	x	x	DIO
	7	D.C SWGR Feeder Breaker Test Position	Ethernet				x		x	x	DIO
	8	D.C SWGR Feeder Breaker Local Position	Ethernet				x		x	x	DIO
	9	D.C SWGR Feeder Breaker Relay 201C	Ethernet				x		x	x	DIO

Typical TBS				Control			Indication				
Equipment	Item	Point description	Signal Type	Local HMI	AIM	AEMS	Local HMI	AIM	AEMS	WEB Access	IED type
	10	D.C SWGR Feeder Breaker Relay 201T	Ethernet				x		x	x	DIO
	11	D.C SWGR Feeder Breaker Lockout(86) (where available)	Ethernet				x		x	x	DIO There is only one Lockout relay on the entire DC Swg, Already mentioned on Swg, Already mentioned on the cathode brk line# 8
	12	D.C SWGR Feeder Breaker Loss of Control Power	Ethernet				x	x	x	x	DIO
	14	D.C SWGR Feeder Breaker Rack In	Ethernet				x		x	x	DIO
	15	D.C SWGR Feeder Breaker MPR Failure	Ethernet				x		x	x	DIO
	16	NDC Control Module Trip Circuit Supervision Failure	Ethernet				x		x	x	DIO
	17	NDC Controller Failure	Ethernet				x		x	x	DIO
	18	NDC Controller Overload Operation	Ethernet				x		x	x	DIO
	19	D.C SWGR Feeder Breaker No.41 DIO Local	Ethernet				x		x	x	DIO
DC S/G Feeder	1	D.C SWGR Feeder Breaker MPR Communication Failure	Ethernet				x	x	x	x	Multifunction Relay

Typical TBS				Control			Indication				
Equipment	**Item**	**Point description**	**Signal Type**	**Local HMI**	**AIM**	**AEMS**	**Local HMI**	**AIM**	**AEMS**	**WEB Access**	**IED type**
Breaker											
(Typical)	2	D.C SWGR Feeder Breaker Instantaneous Over Current	Ethernet				x		x	x	Multifunction Relay
	3	D.C SWGR Feeder Breaker Inverse time Over Current	Ethernet				x		x	x	Multifunction Relay
	4	D.C SWGR Feeder Breaker Extreme Inverse Over current	Ethernet				x		x	x	Multifunction Relay
	5	D.C SWGR Feeder Breaker Low Level fault	Ethernet				x		x	x	Multifunction Relay
	6	D.C SWGR Feeder Breaker Current Rate Of Rise	Ethernet				x		x	x	Multifunction Relay
	7	D.C SWGR Feeder Breaker Straight Time Over Current	Ethernet				x		x	x	Multifunction Relay
	8	D.C SWGR Feeder Breaker Long Time Over Current Fault	Ethernet				x		x	x	Multifunction Relay
	9	D.C SWGR Feeder Breaker Load Measuring/Reclosing Timeout	Ethernet				x		x	x	Multifunction Relay
	10	D.C SWGR Feeder Breaker Contact Rail Potential	Ethernet				x		x	x	Multifunction Relay
	11	D.C SWGR Feeder Breaker Bus Potential	Ethernet				x		x	x	Multifunction Relay

Typical TBS				Control			Indication				
Equipment	**Item**	**Point description**	**Signal Type**	**Local HMI**	**AIM**	**AEMS**	**Local HMI**	**AIM**	**AEMS**	**WEB Access**	**IED type**
	12	D.C SWGR Feeder Breaker Feeder Current	Ethernet				x		x	x	Multifunction Relay
UPS	1	UPS Communication Failure	RS485				x		x	x	UPS Communication Board
	2	Battery Charger NOR./IND	Hardwired				x	~~x~~	x	x	UPS to RTU Status panel
	3	Battery Charger ABN./IND	Hardwired				x	~~x~~	x	x	UPS to RTU Status panel
	4	Inv. Transfer SW Position NOR./IND	Hardwired				x	~~x~~	x	x	UPS to RTU Status panel
	5	Inv. Transfer SW Position ABN./IND	Hardwired				x	~~x~~	x	x	UPS to RTU Status panel
	6	Inverter Output NOR./IND	Hardwired				x	~~x~~	x	x	UPS to RTU Status panel
	7	Inverter Output ABN./IND	Hardwired				x	~~x~~	x	x	UPS to RTU Status panel
	8	Input AC Voltage L-L, L-N for phase A	RS485				x		x	x	UPS to RTU RS485
	9	Input AC Voltage L-L, L-N for phase B	RS485				x		x	x	
	10	Input AC Voltage L-L, L-N for phase C	RS485				x		x	x	

Typical TBS				Control			Indication				
Equipment	Item	Point description	Signal Type	Local HMI	AIM	AEMS	Local HMI	AIM	AEMS	WEB Access	IED type
	11	Input AC Current phase A	RS485				x		x	x	
	12	Input AC Current phase B	RS485				x		x	x	
	13	Input AC Current phase C	RS485				x		x	x	
	14	Input Frequency	RS485				x		x	x	
	15	DC bus Voltage	RS485				x		x	x	
	16	Output AC Voltage L-L, L-N for phase A	RS485				x		x	x	
	17	Output AC Voltage L-L, L-N for phase B	RS485				x		x	x	
	18	Output AC Voltage L-L, L-N for phase C	RS485				x		x	x	
	19	Output AC Current phase A	RS485				x		x	x	
	20	Output AC Current phase B	RS485				x		x	x	
	21	Output AC Current phase C	RS485				x		x	x	
	22	Output Frequency	RS485				x		x	x	
	23	Bypass AC Voltage L-L, L-N for phase A	RS485				x		x	x	
	24	Bypass AC Voltage L-L, L-N for phase B	RS485				x		x	x	
	25	Bypass AC Voltage L-L, L-N for phase C	RS485				x		x	x	

Typical TBS				Control			Indication				
Equipment	**Item**	**Point description**	**Signal Type**	**Local HMI**	**AIM**	**AEMS**	**Local HMI**	**AIM**	**AEMS**	**WEB Access**	**IED type**
	26	UPS Data and Events	Ethernet							X	UPS Network Management Interface
Battery Monitor (BM)	1	Battery Communication Failure	Ethernet				x		x	x	
	2	Battery Float Voltage	Ethernet				x	x	x	x	
	3	Individual Cell Resistance	Ethernet							x	
	4	Individual Cell Voltage	Ethernet							x	
	5	Individual Intercell Resistance	Ethernet							x	
	6	Electrolyte Level (Optional)	Ethernet							x	
	7	String current (Charge/Discharge/Float)	Ethernet							x	
	8	Battery Failure alarm	Ethernet				x	x		x	
	9	Ripple Current (Optional)	Ethernet							x	
	10	Ambient Temperatures	Ethernet							x	
	11	Ground Fault Currents (Optional)	Ethernet							x	
	12	Battery Low Voltage Alarm	Ethernet						x	x	
	13	Common Alarms	Ethernet						x	x	

Typical TBS				Control			Indication				
Equipment	**Item**	**Point description**	**Signal Type**	**Local HMI**	**AIM**	**AEMS**	**Local HMI**	**AIM**	**AEMS**	**WEB Access**	**IED type**
ETS Trip Cabinet	1	ETS Trip Circuit Normal TRk1 Inbound	hardwired				x	x	x	x	
	2	ETS Trip Circuit Trip TRk1 Inbound	hardwired				x	x	x	x	
	3	ETS Trip Circuit Normal TRk2 Inbound	hardwired				x	x	x	x	
	4	ETS Trip Circuit Trip TRk2 Inbound	hardwired				x	x	x	x	
	5	ETS Trip Circuit Normal TRk1 Outbound	hardwired				x	x	x	x	
	6	ETS Trip Circuit Trip TRk1 Outbound	hardwired				x	x	x	x	
	7	ETS Trip Circuit Normal TRk2 Outbound	hardwired				x	x	x	x	
	8	ETS Trip Circuit Trip TRk2 Outbound	hardwired				x	x	x	x	
	9	ETS Trip Circuit Normal TRk3 (Where available)	hardwired				x	x	x	x	
	10	ETS Trip Circuit Trip TRk3 (Where available)	hardwired				x	x	x	x	

Typical TBS				Control			Indication				
Equipment	**Item**	**Point description**	**Signal Type**	**Local HMI**	**AIM**	**AEMS**	**Local HMI**	**AIM**	**AEMS**	**WEB Access**	**IED type**
Cable Shield Monitor	1	Cable Shield Monitor Communication Failure	Ethernet				x		x	x	VG Controls
	2	Cable Shield Monitor Healthy/Fail	Ethernet				x		x	x	VG Controls
	3	Cable Shield Overvoltage	Ethernet				x		x	x	VG Controls
	4	Cable Shield Leakage Current	Ethernet				x		x	x	VG Controls
	5	Cable Shield Low Resistance to Ground	Ethernet				x		x	x	VG Controls
	6	Broken connection from cable Shield to SCM	Ethernet				x		x	x	VG Controls
	7	SCM sensor Overtemperature	Ethernet				x		x	x	VG Controls
	8	Cable Shield Common Alarm	Ethernet				x	x	x	x	VG Controls
DTR's	1	DTR Communication Failure	Ethernet				x		x		Analog Signal
	2	DC Bus Voltage	Ethernet				x		x		Analog Signal

Typical TBS				Control			Indication				
Equipment	**Item**	**Point description**	**Signal Type**	**Local HMI**	**AIM**	**AEMS**	**Local HMI**	**AIM**	**AEMS**	**WEB Access**	**IED type**
	3	D.C SWGR Feeder Breaker No. 41 Current Measurement	Ethernet				x		x		Analog Signal
	4	D.C SWGR Feeder Breaker No. 42 Current Measurement	Ethernet				x		x		Analog Signal
	5	D.C SWGR Feeder Breaker No. 43 Current Measurement	Ethernet				x		x		Analog Signal
	6	D.C SWGR Feeder Breaker No. 44 Current Measurement	Ethernet				x		x		Analog Signal
	7	D.C SWGR Feeder Breaker No. 45 Current Measurement	Ethernet				x		x		Analog Signal
	8	D.C SWGR Feeder Breaker No. 46 Current Measurement	Ethernet				x		x		Analog Signal
	9	D.C SWGR Feeder Breaker No. 47 Current Measurement	Ethernet				x		x		Analog Signal
Battery Room	1	Battery Room Exhaust Fan Normal	Hard Wired				x	x	x	x	To RTU
	2	Battery Room Exhaust Fan Abnormal	Hard Wired				x	x	x	x	To RTU
	3	Room Temperature (Analog Signal)	Hard Wired				x		x		To RTU
Ancillary	1	Fire Alarm	Hard				x	x	x	x	To RTU

Typical TBS				Control			Indication				
Equipment	**Item**	**Point description**	**Signal Type**	**Local HMI**	**AIM**	**AEMS**	**Local HMI**	**AIM**	**AEMS**	**WEB Access**	**IED type**
			Wired								
	2	Unauthorized Entrance Summary	Hard Wired				x	x	x	x	To RTU
	3	TBS Room Temperature	Hard Wired				x	x	x	x	To RTU
	4	RTU in Local	Hard Wired				x	x	x	x	To RTU

END OF SECTION

SECTION 16052

BASIC MATERIALS AND METHODS FOR TRACTION POWER

PART 1 - GENERAL

1.1 SUMMARY

A. The scope includes furnishing and installing basic materials.

B. Related Sections:

1. Section 16060 GROUNDING AND BONDING
2. Section 16128 WIRE AND CABLE FOR TRACTION POWER
3. Section 16149 WIRE, CABLE, CABLE TRAY AND TERMINATION PANEL FOR SCADA SYSTEMS
4. Section 16265 BATTERY AND BATTERY MONITORING SYSTEMS
5. Section 16266 BATTERY CHARGER
6. Section 16341 METAL ENCLOSED DC SWITCHGEAR FOR TIE BREAKER STATIONS

1.2 REFERENCES

A. Codes, Regulations, Reference Standards and Specifications:

1. Codes and regulations of jurisdictional authorities
2. NEC
3. UL: 6, 50, 67, 94, 198D, 224, 360, 486, 489, 496, 508, 514, 651, 870, 1029, 1572
4. ASTM: A36, A47, A123, A153, A325, A386, A500, A507, A523, A525, A532, A536, B138, B187, B633, D149, D150, D257, D412, D495, D570, D638, D648, D696, D790, D792, D1000, D1056, D1518, D1682, D1784, D2240, D2583, E84, F593, F594, G21, G235
5. ANSI: C80.1, C80.5, Z55.1, A14.1, B18.21.1, C119.1
6. NEMA: VE1, AB1, PB1,CC1, ST-20, FG-1, 250
7. FS: TT-S-227, FF-S-760, FF-S-325,
8. ACI: 318
9. MS: MIL-I-23053/15

1.3 SUBMITTALS

A. Submit the following for review in accordance with the instructions elsewhere in this Specification and with the additional requirements as specified for each:

1. Shop Drawings: Shop drawings for cable trays and mounting details, panelboards, fiberglass panels, glastic material and through floor barrier/fire stop.

2. Product Data: Manufacturer's product data for all materials.

3. Samples: one of each size nameplate, tags, wire labels, glastic material and danger markers.

1.4 QUALITY ASSURANCE

A. Qualifications: Select manufacturers who are regularly engaged in production of specified materials. Select installation contractors who are regularly engaged in the installation of specified materials.

B. For Codes, Regulations, Reference Standards and Specifications, refer to Article 1.02 above.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Mark each item in accordance with applicable reference standard.

B. Ship each unit securely packaged and labeled for safe handling in shipment and to avoid damage.

C. Store products in secure and dry storage facility.

PART 1 - PRODUCTS

2.1 MATERIALS

A. Floor Sealant:

1. Floor sealant: Water-epoxy concrete floor protective coating providing good resistance to wear, abrasion, soiling and chemical attack.

a. Product: Tennant ECO-LTS (405) coating system mixed with Tennant 413SF solvent-free bonding additive (for first coat only) as manufactured by Tennant Company, Minneapolis, or equal.

b. Tennant 409 Pre-Kote cleaner or equal, for floor preparation and better adhesion of the coating.

B. Insulated Floor Topping:

1. Description: Insulated floor topping consisting of epoxy resin with filler where indicated. Gray color.

2. Epoxy resistivity: Minimum 1012 ohm-cm.

3. Epoxy manufacturers: Hallemite Grey Amazite by Hallemite, 25 Holden Street, Providence, R.I., 02908, or FX-70-6EE by Fox Industries, 3100 Falls Cliff Road, Baltimore, MD, 21211, or equal.

4. Filler: Manufacturer's standard for this service.

2.2 EQUIPMENT

A. Conduit, Cable Tray, Boxes, Cabinets and Fittings.

1. General Requirements:

a. Size: As shown, minimum conduit size 3/4 inch.

b. Materials:

1) Steel sheet: ASTM A507.

2) Zinc-coated steel sheet: ASTM A653, coating G235.

3) Fiberglass Reinforced Polyester (FRE): NEMA FG-1

c. Zinc coating:

1) Hot Dip Galvanizing: ASTM A123 and ASTM A386

2) Electro-galvanizing: ASTM B633

2. Galvanized Steel Rigid Conduit and Fittings: UL 6 and ANSI C80.1, zinc coating tested in accordance with reference test in appendix.

3. Liquid-tight Flexible Conduit and Fittings: (for use with galvanized steel rigid conduit)

a. Applicable requirements of UL 360.

b. Flexible galvanized steel core with extruded liquid-tight neoprene or PVC jacket overall.

c. Sizes up to 1-1/4 inch provided with continuous copper bonding conductor, spiral wound between convolutions.

d. Sizes 1-1/2 inch and above provided with separate grounding conductor.

4. Rigid fiberglass reinforced epoxy conduits and fittings:

a. Rigid fiberglass reinforced epoxy conduit, UL 1684, IPS (Iron Pipe Size) based conduit.

b. Conduit shall be manufactured by using filament winding process with minimum fiberglass content of 65 percent by weight and no fillers.

c. IPS based conduit shall have nominal wall thickness of 0.09 inch for five-inch nominal conduit size.

d. Conduits, elbows and fittings manufactured from the same material and using the same manufacturing process.

e. Conduit sections formed with integral bell-and-spigot type couplings shall use adhesive epoxy compound to make the joints watertight. Rubber sealing gasket at bell end is prohibited.

f. Adhesive epoxy compound as recommended by conduit manufacturer.

g. Conduits, elbows and fittings are specified for use throughout a temperature range of -40F to 230F, and they are to be protected from exposure to sunlight by pigmentation uniformly dispersed through the resin material.

h. Conduits, elbows and fittings shall be suitable for encasement in concrete below grade and conform to UL 1684, and listed and labeled by UL meeting the requirements of NEC Article 347 for Rigid Nonmetallic Conduit and its use.

5. Conduit Expansion Fittings: Weatherproof, fabricated from material compatible with conduit with which fittings are to be used. Metallic fittings equipped with bonding jumper cable to provide electrical continuity.

6. Conduit Connector Fittings:

a. UL 514, material and finish similar to that of conduit with which they are to be used.

b. Indoor Locations: For enclosure, cabinets, boxes and gutters: Nylon-insulated blushing and locknut,

c. Outdoor Locations: Watertight nylon-insulated bushing and locknut for termination of galvanized rigid steel conduit. Watertight PVC threaded adapter with 0-ring and locknut or bushings for termination of PVC conduit.

7. Conduit seal:

a. To provide watertight seal between concrete and conduit where it penetrates wall, floor or ceiling.

b. Size as shown or necessary.

c. Materials: Body and pressure clamp of malleable or cast iron with a neoprene sealing grommet and PVC-coated or galvanized-steel pressure rings, oversized sleeve of PVC or galvanized.

d. Seal between conduit and concrete to withstand pressure from 50-foot head of water without leakage.

8. Cable and Seal Fittings:

a. To provide watertight seal between cable and conduit for use with single-conductor or multiple-conductor cable as necessary.

b. Size as necessary, drilled to accommodate cable.

c. Pressure discs of PVC-coated steel and sealing ring of neoprene.

d. Seal between cable and conduit to withstand water pressure of 50 psi without leakage.

e. O-Z type CSBI, CSBE or equal as shown on drawings.

f. Seal all unused conduits for traction power and auxiliary power using blank seals.

9. Seal Compound:

a. FS TT-S-227, two-component, fast-setting, polymeric sealing compound to provide watertight seal between cable and conduit.

b. Pour-type for horizontal and gun-grade for vertical or overhead application.

c. When cured, sealant to have rubber-like flexibility allowing minimum movement of conduit and cable in temperature range of minus 10F to plus 150F without loss of watertight seal.

d. Pot life: 15 minutes.

e. Minimum ambient temperature for application: 35F.

f. Initial cure: 15 minutes.

g. Final cure: Seven days.

h. Hardness, Durometer A: 20-35.

i. Seal between conduit and single-conductor or multiple-conductor cable to withstand water pressure of 50 psi without leakage.

j. Fox Industries, Type FX-571G or equal.

10. Conduit, Cable Tray and Cable Supports:

a. Retaining straps and fasteners: FS FF-S-760, with the following additional requirements:

1) Type, style and size: As necessary.

2) Material and finish: Steel or malleable iron, hot-dip galvanized after fabrication, fiberglass reinforced polyester.

3) For separating conduit from masonry surface: Galvanized malleable iron spacer assembled with Style A strap.

4) For vertical run of metallic sheath cable: Basket weave cable support.

5) For fastening conduit or cable to channel inserts: Galvanized steel fasteners.

b. Trapeze type hangers: Consisting of two or more hanger rods, horizontal member, U-bolt clamp and other attachment necessary for securing hanger rods and conduit, with the following additional requirements:

1) Material and finish: Steel, hot-dip galvanized after fabrication or Fiberglass Reinforced Polyester conforming to the requirements specified for fiberglass channel struts.

2) Hanger rod: Not smaller than 5/8-inch diameter, threaded for sufficient distance at each end to permit at least 1-1/2 inches of adjustment.

3) Horizontal member: Channel, 1-5/8 inches square by 12 gauge or heavier. Weld two or more channels together for greater strength if necessary.

4) Design: Capable of supporting load equal to sum of weights of conduit, cable and hanger plus 200 pounds. At design load, stress at root of thread on hanger rod 9,500 psi maximum; stress in horizontal member 12,500 psi maximum.

c. Steel Channel Struts:

1) Size and shape as shown, 12-gauge or heavier hot-dip galvanized, with 7/8 inch wide continuous slot, 9/16 inch base slot, two inches on center or solid base with field drilled holes as required with minimum pull out load rating of 1,000 pounds per linear foot.

2) Fittings and accessories compatible with associated steel channel struts and having same material and finish.

d. Stainless Steel Channel Struts:

1) Size and shape as shown, 12-gauge or heavier stainless steel, type 304, with 7/8 inch wide continuous slot, 9/16 inch base slot, two inches on center or solid base with field drilled holes as required with minimum pull out load rating of 1,000 pounds per linear foot.

2) Fittings and accessories compatible with associated channel struts and having same material and finish.

e. Fiberglass Channel Struts:

1) Fiberglass reinforced polyester, self-extinguishing, with 7/8" wide continuous slot, 13/32" pre-drilled holes in base on 1-5/8" centers, or solid base with field drilled holes as required with the following additional requirements

Physical Properties	**Value**	**Method**
Tensile Strength	30,000 PSI	ASTM D638
Flexural Strength	30,000 PSI	ASTM D790
Barcol Hardness	50	ASTM D2583
Dielectric Constant	200 VPM	ASTM D150
Coefficient of Thermal Expansion	5 x 10^{-6} in/in□F	ASTM D696
Specific Gravity	1.7	ASTM D792
Flammability Rating	15	ASTM E84
Moisture Absorption	1% (24 hrs. at 72□F)	ASTM D570

2) Fittings and accessories compatible with associated fiberglass channel struts and having same material or approved similar material.

f. Cinch anchors: One-piece wedge type, galvanized with threaded stud.

g. Cable support brackets: Size and type as shown, 12-gauge or heavier, hot-dip galvanized.

h. Cable insulators: Saddle type, high glazed porcelain, designed for use with the brackets provided.

11. Boxes

a. Outlet boxes:

1) UL 514, capable of accommodating conduit as shown.

2) Material and finish:

a) Steel, cast iron, ductile iron or malleable iron.

b) Hot-dip galvanized or electro-galvanized after fabrication.

b. Junction and pull boxes:

1) Internal volume up to 100 cubic inches, UL 514; internal volume above 100 cubic inches, UL 50.

2) Flush-mounted or surface-mounted as shown.

3) Size: Suitable to accommodate conduit, raceways, ducts, number of cables and splices shown.

4) Material:

a) Stainless Steel, Type 316.

b) Hot-dipped galvanized or electro galvanized after fabrication.

12. Cable Trays

a. General:

1) Dimensions: Minimum four inches inside depth; nine inches rung spacing unless otherwise shown.

2) Maximum load rating: 50 pounds per linear foot with safety factor of 2.0 at 12-foot support span for steel trays. 200 pounds per linear foot with safety factor of 1.5 at 12 foot support span for fiberglass reinforced polyester trays. Support additional concentrated load of 200 pounds at any point without permanent deflection.

3) Bend Radius:

a) For incoming service cable: 36 inches or as approved by the utility.

b) For all other cable: 24 inches or as shown.

b. Fiberglass Cable Tray

1) NEMA FG-1, fiberglass ladder type.

2) Allowed for carrying all dc positive and negative cable except as otherwise noted. Fiberglass material shall be used for all fittings and accessories associated with the installation of fiberglass trays.

3) Fiberglass Reinforced Polyester in accordance with the following:

Physical Properties	**Value**	**Method**
Tensile Strength	40,000 PSI	ASTM D638
Flexural Strength	45,000 PSI	ASTM D790
Barcol Hardness	95	ASTM D2583
Dielectric Strength	200 VPM	ASTM D149
Specific Gravity	1.7	ASTM D792
Coefficient of Thermal Expansion (Longitudinal)	5x10^{-6} in./in./°F	ASTM D696
ASTM D696	1% (24hrs. at 72°F)	ASTM D570
Flammability Classification	V-O	UL 94
Flammability Rating	15	ASTM E84

13. Expansion Bolt Anchors: FS FF-S-325C Group II, Stainless Steel-316, type and class as approved, galvanized.

14. Wire ways and auxiliary gutters:

a. Galvanized steel with formed flanges on both body and cover, screw on covers, in accordance with UL870, complete with all necessary fittings, couplings and end pieces.

b. Size as shown.

c. Electro-galvanized and finished with light gray enamel, ANSI Z55.1, Color 61.

B. Circuit Breakers & Panelboards:

1. General Requirements:

a. Interchangeability: Components of the same type, size, rating, functional characteristics and make are to be interchangeable.

b. Finish for enclosures for panelboards.

1) Clean and degrease metallic surfaces.

2) Prime with zinc primer.

3) Finish with one coat of light gray enamel, ANSI Z55.1, Color 61; two mils minimum DFT.

2. Circuit Breaker: NEMA AB1, UL489, molded-case, bolt-on, quick-make/quick- break, mechanically trip-free, switching mechanism, with thermal trip for inverse time delay overcurrent protection and magnetic trip for instantaneous short-circuit protection. Frame size 225 amperes and above equipped with interchangeable thermal trip and adjustable magnetic trip unit. Designed to carry continuous rating in ambient temperature of 40C with the following parameters as shown:

a. Number of poles.

b. Rated voltage, ac or dc

c. Rated interrupting current.

d. Trip setting.

e. Frame size.

3. Enclosed Circuit Breaker:

a. NEMA AB1.

b. Circuit breaker: As shown and specified. Overcurrent trip device coordinated to provide selective tripping under overload conditions.

c. Enclosure:

1) Galvanized steel, surface-mounted, unless otherwise shown.

d. Type:

1) Above-ground indoor locations and electrical rooms: NEMA 1.

2) Tunnel areas and underground locations, except electrical rooms: NEMA 12.

3) Outdoor locations: NEMA 3R.

4. Panelboard:

a. NEMA PB1, UL 67. Breakers' KAIC: 480V-14KAIC; 208V - 10KAIC

b. Enclosure:

1) UL 50.

2) Galvanized steel, surface mounted unless otherwise shown.

3) NEMA 250, Type 1

4) Gutter size

Main Bus Rating Amperes	Minimum Top and Bottom Gutter Size in Inches	Minimum Side Gutter in Inches
100 and below	4	4
225	6	4

5) Interior components mounted on back plate of reinforced steel for rigid support and accurate alignment.

6) One piece sheet steel front panels with hinged door and lock so constructed that when panelboard door is locked front cannot be removed.

7) Provide latch and handle in accordance with UL 50; screw fastenings will not be accepted in lieu of latch.

8) Provision for enclosure grounding.

c. Bus bars:

1) ASTM B187.

2) 98 percent conductivity copper.

3) Contact surface silver-plated or tin-plated.

4) Rating of neutral and ground bus: Equal to that of phase bus.

5) Neutral bus mounted on insulating block.

6) Neutral and ground bus equipped with integral mechanical connectors.

d. Circuit Directory:

1) Neatly typed to identify the load fed by each circuit by number.

2) Mounted on a metal frame with clear plastic cover inside cabinet door.

e. DC Panelboard: 125 volt dc, 2-wire. Main and branch circuits with 2-pole breakers, quantity and ratings as shown. AIC-10,000 amps minimum.

C. Nameplates, Tags and Wire Labels:

1. Nameplates:

a. Three-ply, laminated phenolic plates, engraved through black face to white core, attached by stainless steel rivets or screws.

b. Lettering: Vertical gothic using round or square cutter. V-shape groove is prohibited.

c. Size: One-inch high with 1/2-inch high lettering.

2. Conduit and Cable Tags: Stainless steel, round, punched with cable or conduit number as shown.

3. Wire labels: Sleeve-type, heat shrinkable, flame retardant Raychem TMS product line, Type XPE or equal and conforming to UL224. Wire identification same as corresponding terminal block identification unless otherwise shown. The labels on 1000 KCMIL cable shall be clear, heat shrinkable with 1/2" height yellow lettering stamped on inside. The labels shall have reference of substation or tie-breaker station breaker Supervisory Control ID number and cable sequence in the branch of the feeder (e.g. BRK. 32-A) at both ends. In all as-built drawings and the DC Switchgear equipment terminal wiring connections shall be identified with labels indicating from where is the wire originating and to where is it terminating.

D. Danger Markers:

1. Danger markers for conduit and cable installed in track areas:

a. Danger plate for use on timber ties supporting conduit and cable.

1) Three-ply, laminated phenolic plates, engraved through red face to white core, attached by stainless steel lag screws.

2) Lettering: Vertical Gothic using round or square cutter. V-shape groove is prohibited.

3) Size: Four-inch high with one-inch high lettering as below and applicable.

DANGER 750 VOLTS

4) Ultra-Violet Protection: coated with polyurethane paint 1.5 mils minimum dry film thickness on all surfaces.

b. Danger label for use on conduit:

1) 2-1/2-inch wide pressure sensitive vinyl with red background and white lettering 1-1/4 inch high, Gothic Capital Style as follows and applicable.

"DANGER 750 VOLTS"

"DANGER 480 VOLTS"

2) Lettering printed with weather resistant ink and shall be durable and scuff resistant.

3) Marker provided with permanent type back adhesive for long term outdoor use.

2.3 ACCESSORIES

A. Wire Connection Accessories:

1. Connectors, terminal lugs and fittings.

a. In accordance with UL486, and NEMA CC1.

b. For 10 AWG and smaller conductors: Compression type, high conductivity copper, tin-plated ring tongues, with nylon self-extinguishing insulating grip with temperature rating equal to that of conductor insulation. Thomas and Betts STA-KON type or equal.

c. For 8 AWG to 4/0 AWG conductor cable: Tin-plated copper compression connectors and terminal lugs with nylon insulating sleeve for insulation grip.

d. For 250 KCMIL and larger conductor cable: Long barrel double-compression tin-plated copper connectors and terminal lugs with two-hole pad.

e. For multiple conductor cable: Watertight aluminum fittings with stainless steel pressure ring and set screws or compression cone for grounding of aluminum sheath of MC cable.

f. Hardware: High strength silicon bronze, corrosion resistant, non-magnetic, and electrolytic action free when in contact with copper.

g. Ground connector:

1) O-Z, Type KG or equal.

2) Two-piece, designed for connecting grounding conductor to bus bar.

3) Copper-alloy bolt and silicon-bronze bolt, nut and lock washer with interlocking clamp.

h. Contact rail terminal lugs: Compression type, 98-percent-pure copper, hot-dip tin-coated to 0.3 mils minimum thickness. Tongues not less than two inches square by 1/2-inch thick and drilled for 5/8-inch diameter fastener. Compatible with 1000 KCMIL, extra flexible cable.

2. Bundling Straps:

a. Self-locking steel barb on one end, with tapered strap of self-extinguishing nylon, temperature rating minus 65F to 250F.

b. For outdoor use: Ultraviolet-resistant.

3. Insulating Tape:

a. Plastic tape: Vinyl plastic tape with rubber-based pressure-sensitive adhesive, pliable at zero degrees F with the following minimum properties when tested in accordance with ASTM D1000:

1) Thickness: 8.5 mils.

2) Breaking strength: 20 pounds per inch width.

3) Elongation: 200 percent.

4) Dielectric breakdown: 10,000 volts.

5) Insulation resistance, indirect method of electrolytic corrosion: 1,000,000 megohms.

b. Rubber tape: Silicone rubber tape with silicone pressure-sensitive adhesive, with the following minimum properties when tested in accordance with ASTM D1000:

1) Thickness: 12 mils.

2) Breaking strength: 13 pounds per inch width.

3) Elongation: 525 percent.

4) Dielectric breakdown: 13,000 volts.

5) Insulation resistance, indirect method of electrolytic corrosion: 1,000,000 megohms.

c. Arc-proof tape: Flexible and conformable organic fabric tape, coated one side with flame-retardant flexible elastomer, self-extinguishing, non-combustible, with the following minimum properties:

1) Thickness, ASTM D1000: 30 mils.

2) Tensile strength, ASTM D1000: 1500 pounds per square inch @ 23C.

3) Elongation, ASTM D1000: 150 percent @ 23C.

4) Thermal conductivity, ASTM D1518: 0.078 BTU per hour per square foot per degree F.

5) Electrical arc resistance: one half-lap layer capable of withstanding a high current fault arc temperature of 13,000K for 75 cycles.

d. Glass tape: Woven glass fabric tape with pressure-sensitive thermosetting adhesive, with the following minimum properties when tested in accordance with ASTM D1000:

1) Nominal width: 3/4 inch.

2) Thickness: Seven mils.

3) Breaking strength: 170 pounds per inch width.

4) Elongation: Five percent.

5) Dielectric breakdown: 2,500 volts.

6) Insulation resistance, indirect method of electrolytic corrosion: 5,000 megohms.

4. Epoxy Resin: Suitable for insulating and moisture sealing cable splices, with the following minimum properties:

a. Dielectric strength, ASTM D149: 400 volts per mil.
b. Volume resistance, ASTM D257: 2.8 x 10
30C.

c. Water absorption, ASTM D570:

1) 0.193 percent in 24 hours at 23C.

ohm per centimeter cube at

2) 0.62 percent in 24 hours at 53C.

d. Tensile strength, ASTM D638: 8,000 psi.

e. Elongation, ASTM D638: 2.4 percent.

f. Coefficient of expansion, ASTM D696: 6.8×10^{-5}

inch per inch per degree C.

5. Contact rail cable connector assemblies:

a. Not used.

6. Terminal blocks:

a. Barriered, screw type equipped with washer head binding screws, white marking strips for terminal identifications and hinged covers; unless otherwise shown or specified.

b. Rated 600 volts, 30 amperes per point and designed to accommodate wire sizes 19 AWG through 10 AWG inclusive.

B. Exothermic mold kit, consisting of mold and handle and Exothermic Weld Cartridge:

1. Not used.

C. Heat-shrinkable tubing: UL-approved, flame retardant, corrosion resistant thick wall tubing with factory-applied sealant for field insulation on inline splices and taps or wraparound type sleeve for retrofit installation on existing splices and taps to provide a watertight seal and insulating encapsulation, with the following additional properties:

1. Material: Cross-linked polyolefin.

2. Shrink ratio: 3 to 1 (min.)

3. Physical properties:

Ultimate tensile strength	2350 psi	ASTM D412
Hardness, Shore D	42	ASTM 2240
Water absorption Method 6.1	0.05%	ASTM D570
Specific gravity	1.28	ASTM D792

4. Electrical properties:

a. Dielectric strength 450 volts ASTMD149 per mil

b. Volume resistivity 1 x 10^{14} ASTMD 257 ohm cm

5. Thermal properties:

a. Continuous operating temp. -55C to +135C

b. Air oven aging (7 days @ 175C):

1) Tensile strength: 2680 psi

2) Elongation: 375 %

3) Low temp. flexibility (4 hours @ -55C): No cracking when flexed

4) Heat shock (4 hours @ 225C): No cracking, flowing or dripping

6. Chemical properties:

a. Corrositivity Non-corrosive MIL-I-23053/15

b. Fungus resistance Non-nutrient ASTM G21

D. Nuts, Bolts, U-Bolts and Miscellaneous Hardware.

1. Material

   a. All nuts, bolts, u-bolts and washers for outdoor locations including tunnels shall be Type 316 stainless steel in accordance with ASTM F593 and F594.

   b. All nuts, bolts, and flat washers for indoor locations in TBS and TPS shall be galvanized steel in accordance with ASTM A325.

   c. The dimensional data and type hardware for all nuts, bolts and miscellaneous parts shall be shown and specified; where not shown as recommended by the manufacturer.

2. Galvanizing

   a. All parts to be galvanized shall be galvanized after manufacture. Unless otherwise specified, parts to be galvanized shall be coated in accordance with the requirements of ASTM A123. Bolts and miscellaneous hardware shown or specified to be galvanized shall be coated in accordance with ASTM A153 or alternate method in accordance with ASTM B633

E. Structural Steel Shapes:

1. Shapes, plates and bars: ASTM A36.

2. Structural tube: ASTM A500, Grade A, Galvanizing: Hot-dip galvanized after fabrication in accordance with ASTM A123, zinc coating weight two ounces per square foot, minimum.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install generally as shown and in accordance with approved shop drawings, the NEC and jurisdictional agencies.

B. Conduit, Cable Tray, Boxes, Cabinets and Fittings:

1. General:

   a. Use size, type, general routing, and location of conduit, raceways, boxes and cabinets as shown and specified.

   b. Install metallic raceway, fittings, boxes and cabinets free from contact with reinforcing steel.

   c. Where aluminum is placed in contact with dissimilar metal or with concrete, separate contact surfaces by means of gasket, non-absorptive tape or coating to prevent corrosion.

   d. Unless specified or shown otherwise, make metallic conduit, raceways, and cable trays, electrically and mechanically continuous, and grounded in accordance with NEC and as shown.

2. Conduit:

   a. Run exposed conduit parallel to building lines.

   b. Install exposed conduit to avoid interference with other work.

      1) Where shown and as necessary, install cable seal in accordance with the manufacturer's recommendation.

      2) Use sealing compound where approved and in accordance with manufacturer's recommendations, with the following additional requirements:

         a) Before applying sealing compound, prime conduit and cable surface using primer recommended by the manufacturer.

         b) Pour or inject compound to prevent voids inside seal and to keep cable centered in conduit.

      3) In empty conduit installed for future use, install blank cable seal inside conduit to prevent seepage of water.

      4) Ensure conduits are free of water before conduit seals are installed.

   c. Apply lead-free conductive anti-seize compound to threaded conduit joints.

   d. For outdoor locations use threaded conduit hub to attach conduit to equipment enclosure. Use watertight conduit fitting for attachment of conduit to enclosure having punched or formed knockout.

   e. For indoor locations use locknut and nylon-insulated bushing to attach conduit to enclosure.

   f. Install suitable caps or plugs in empty conduit for future extension.

   g. Thread and ream ends of field-cut conduit to remove rough edges. Use bushing at conduit entrance to boxes, cabinets, and equipment enclosures.

   h. Bends:

      1) Unless otherwise shown or specified, install conduit bends in accordance with reference codes.

      2) Bend conduit so that field made bend is free from cuts, dents and other surface damage and does not reduce cross-sectional area of conduit.

   i. Support horizontal conduit 1-1/2 inches and smaller with one-hole pipe straps or individual pipe hangers.

   j. Support horizontal conduit larger than 1-1/2 inches with individual pipe hangers.

k. Spring steel fasteners, clips or clamps specifically designed for supporting exposed single conduits may be used in lieu of pipe straps or pipe hangers. Use 1/4-inch minimum diameter galvanized steel rods for hanger rods with spring steel fasteners, clips and clamps.

l. Secure conduit supported on multi-hangers (trapeze) or channel inserts by fasteners suitable for such purpose.

m. Where conduit is attached to masonry surface, use malleable iron spacers with Style A pipe straps.

n. Support and secure vertical conduit spanning open areas at intervals not exceeding 10 feet.

o. Install conduit so as to drain moisture to nearest outlet or pull box.

p. Use only metallic conduit in exposed locations in tunnels and buildings.

q. Ensure waterproof conduit connection where conduit is installed in outdoor locations.

r. Install expansion fittings in exposed conduit runs longer than 300 feet.

s. Use metallic conduit routed between control cable trays and equipment enclosures.

3. Channel Inserts and Spot Inserts:

a. Mount outlet boxes.

b. Keep number of knock-outs to minimum.

c. Clean boxes thoroughly after installation and correct damage to boxes and to finish.

d. Install covers on boxes mounted on walls and ceilings.

e. Install junction and pull boxes so that covers are readily accessible.

4. Cabinets:

a. Fasten cabinets using expansion bolts, toggle bolts or mounting ears.

b. Touch-up damaged painted finish.

5. Cable Trays:

a. For incoming service cable from power company, coordinate with the power company, and install cable tray with covers as approved by the power company.

b. Support cable tray straight sections, elbows, tees and crosses at the locations specified in NEMA FG-1 for fiberglass tray. Provide supports on

10 foot centers for horizontal positive and negative cable tray and not more than 12 feet on center for all other cable trays.

6. Fasteners:

a. Fasten equipment and devices to concrete surfaces with lag screw shields, cinch anchors, expansion bolt anchors or lead jacketed tamp-in inserts. Use bolt sizes providing a safety factor of 2.5.

b. Fasten equipment and devices to concrete masonry units with toggle bolts.

c. Fasten equipment, devices and supports to structural steel with beam clamps, welded studs or drilled and tapped holes no greater than 1/4 inch diameter.

7. Filling of openings:

a. Where conduit and raceway (including cable tray and bus duct) pass through fire-rated walls, ceilings or floors, provide approved firestops to prevent passage of fire and fumes and to maintain integrity of fire-rated structure.

b. Close unused openings or spaces in floors, walls and ceilings. Plug or cap unused conduit and sleeves.

c. Seal unused traction power conduits in duct bank at both ends using OZ Gedney CSBE seals or equal.

8. Cleaning of raceways:

a. Rod and swab raceways and ducts through which cables are to be installed. Use a mandrel with an outside diameter 3/8-inch less than the inside diameter of the duct and remove all obstructions. Install a non-metallic pull line fish wire, as approved by the Engineer in each raceway or duct immediately after rodding and swabbing and, unless cables are pulled immediately.

b. The Contractor shall be responsible for the dewatering and removal of all dirt, rocks, track ballasts and trash from trenches, pipe, manholes, pull chambers, cable trough, surface trench, and conduit and duct bank prior to and during the installation of cable, at no additional cost to the Authority.

9. Cable Troughs (Track Right-of-Way):

a. Remove the trough covers, install wire and cables and reinstall the trough covers.

b. The Contractor is specifically warned of the following conditions and potential problems with the track right-of-way cable troughs:

1) The covers for these troughs are not of uniform length and locations of drill holes, i.e., each cover section must be replaced on the trough section from where it was removed.

10. Apply anti-corrosion joint compound to connectors, terminal lugs and bolting pads before installation. Install lock washer under each bolt head and nut.

11. Install terminal fittings on multiple-conductor cable in accordance with manufacturer's recommendation. Completely seal cable from moisture.

12. Attach contact rail cable connector assembly compression connectors to the cable with manufacturer's recommended tooling. Install a lock washer under the head of each bolt and under each nut when bolting tongues together. Tighten bolted connections to a uniform torque of 450 inch-pounds.

13. Prior to assembly of contact rail cable terminal lugs to composite contact rail, coat mating services with oxide-inhibiting paste, NO-OX-ID, Dearborn Chemical, or equal. Coat all interfaces of the compression fasteners. Fasten terminal lugs to the composite compact rail using methods and equipment recommended by the rail manufacturer.

14. The splicing of power and control cables is not permitted in manholes, duct banks and cable troughs. However, if permitted by the Engineer, make water tight splices as approved.

C. Panelboards:

1. Install panelboards at locations shown.

2. Mound panelboards with front straight and plumb.

3. Connect branch circuit wires as shown. Connect neutral wire of branch circuit to neutral bar in Panelboard.

4. Make power cable connections to circuit breakers, neutral and ground bus bars in Panelboard by means of integral mechanical connectors. If such items are not furnished with integral mechanical connectors, make connections using compression connectors.

5. Ground panelboards.

6. Apply matching touch-up paint where necessary.

7. Provide directory for each Panelboard.

D. Insulated Floor Topping:

1. Job Conditions:

a. Maintain substrate temperature within limits recommended by the flooring materials manufacturer.

b. Provide adequate ventilation during installation and curing.

2. Inspection:

a. Examine the existing insulated floor topping and based upon its condition recommend to the Contracting Officer Representative whether the topping shall be replaced or repaired. Confirm viability of repairing insulated floor topping by conducting electrical isolation test prior to repair and provide result to Contracting Officer Representative.

b. Examine substrate and conditions under which flooring materials are to be prepared and installed. Do not proceed with the installation until all unsatisfactory conditions have been corrected.

3. Surface Preparation:

a. Inspect all surfaces to determine that entire area to receive insulating floor topping is structurally sound. Remove loose sections down to the substrate.

b. Remove grease, oil, asphalt, mastics, and other contaminants that may prevent adhesion, by scrubbing with degreasers, detergents, or solvents. Grinding, scarifying, or sandblasting are other acceptable methods.

c. Repair cracks, holes, eroded and damaged areas with patching materials recommended by the insulating flooring manufacturer.

d. Prepare concrete surface by acid etching, grinding, sandblasting, scarifying, or other approved method.

e. Saw cut at all termination points.

f. Prior to applying base coats and top coats, apply marking tape at all termination points and adjacent surfaces not to be coated.

g. Remove tape immediately after broadcasting and after top coating.

4. Materials Protection: Mix and prepare materials in accordance with manufacturer's written instructions.

5. Application: Mix and apply each component of the insulating flooring system in accordance with the manufacturer's written instructions and as indicated to provide an uninterrupted, uniformly thick, seamless, and monolithic surface.

6. Contraction Joints: When floor insulating topping material crosses contraction joints in the floor slab, a contraction joint shall be provided in the topping. Provide a v shaped groove, 1/2 inch wide at the base of the groove, but not less than the width of the contraction joint, and insure the groove is 1/2 inch wider at the top than at the bottom. A bond breaker shall be provided to top of the concrete. An epoxy shall be used to seal damp surfaces before application of the primer and polysulfide. The groove shall then be filled with two component, self-leveling, gray polysulfide. Epoxy primer and polysulfide material shall be as recommended by the floor topping manufacturer. Surface preparation, and mixing and installation of materials shall be in accordance with manufacturer's instructions. Sheets of Haysite, not less than 1/16 inch thick, and 1/4 inch narrower than the groove at the top, shall be placed on top of the polysulfide and flush with the top of the insulated floor topping.

7. Cleaning: After completion of insulating flooring installation, clean free of residue those surfaces not required to receive insulating flooring materials.

8. Protection: Close to all traffic for 24 hours minimum for completed insulated floor topping installation. Protect it for 3 days from acid, alkali, or solvent which may spill on the flooring.

9. Insulated floor topping requiring repairs shall be thoroughly cleaned of dust, rust and other debris and prepared to provide a bonding surface to receive ¼" thick coat of insulating epoxy. The newly installed epoxy layer shall be tapered along the edges providing a smooth transition to the uncoated surface.

E. Nameplates, Tags and Wire Labels:

1. Nameplates: Attach nameplates to all panelboards, remove control and monitoring cabinet.

2. Cable Tags: Attach cable tags to each cable at all pull boxes, manholes and terminations.

3. Wire labels: Attach wire labels at all control, annunciation and supervisory wiring at each terminal point. Attach label to a clean, dry section of wire as close as possible to the terminal point.In all as-built drawings and the DC Switchgear equipment terminal wiring connections shall be identified with labels indicating from where is the wire originating and to where is it terminating.

F. Danger Marker:

1. Conduit carrying DC power cables: DANGER 750 VOLTS.

2. Conduit carrying AC power and control cables: DANGER 480 VOLTS.

G. Arc-Proofing:

1. Cover all cables installed in manholes and pits with arc-proof tape, applied in a single layer, half-lapped with the coated side next to the cable and held in place with random wrap of glass cloth electrical insulating tape.

H. Floor Sealant:

1. Apply to finished floor surfaces in all traction power substations and tie breaker stations excluding areas with insulating floor topping.

2. Prepare floor by removing compacted dirt.

3. Treat with 409 Pre-Kote cleaner, mixed in ration one part 409 to nine parts water. Apply mix solution to the floor liberally (100 square feet per gallon) with a spray. Allow soaking for 10 minutes but do not allow it to dry. Scrub floor clean and vacuum using a wet vacuum. Scrub and rinse with clear water and repeat the scribe/rinse/vacuum process to ensure removal of all residues. The texture of floor should feel like sand paper before applying sealant.

4. Let the floor dry completely.

5. Mix Tennant ECO-LTS Parts A and B and Bond Additive (for the first coat) as recommended.

6. Applicator or airless sprayer. Ensure ambient temperature is 65F or higher during application. Apply two additional coats of the mix with four hours drying time in between.

7. Allow to cure for 16 hours at 75F before opening up the floor to traffic.

3.2 FIELD QUALITY CONTROL

A. Submit test procedure for approval and perform approved tests. Do not perform tests without approved test procedure. Schedule tests through the Engineer with minimum of 14 days prior notice. Furnish the necessary equipment and perform the following tests:

1. Test metallic conduit and boxes for electrical continuity.

2. Panelboards: Perform insulation resistance tests of each bust section phase-to-phase and phase-to-ground for one minute using 1,000 volt megger. Insulation resistance not less than manufacturer's recommended value, two megohms minimum. Test enclosure for continuity to substation ground bus. Test circuit connections in accordance with wiring diagrams.

3. Molded case circuit breakers: Perform pole-to-pole and pole-to-ground insulation resistance tests with a 1,000 volt megger. Insulation resistance: 50 megohms minimum.

4. Prior to installation, test two contact rail cable connector assembly compression connections, prepared under the direction of foremen who will supervise the installation, as follows:

a. Measure the electrical resistance between distal end of the cable and the connector tongue. Resistance shall not be greater than that of an equivalent length of uncut cable.

b. Subject the test connections to a sustained tension of 5000 psi for three hours. At the end of three hours, verify that there has been no slipping of the cable in the connector, deforming or loosening of the connection or increase in the electrical resistance beyond that specified.

c. Should any sample fail to meet the specified test requirements, the qualification of the foreman and the equipment shall be disapproved.

5. Test contact rail, DC switchgear and negative switchboard 1,000 KCMIL cable terminal lugs as specified for contact rail cable connector assembly compression connectors.

6. Testing of Exothermic Connections of Composite Contact Rail and Steel Running Rail:

a. All exothermic connections shall be tested for mechanical strength using a two-pound hammer. A minimum of three sharp blows fifteen inches in stroke shall be directed to the weld nugget. The weld shall sustain the blows without cracking weld metal or at the interface with the steel contact rail. Defective welds shall be removed and the rail and cable thoroughly cleaned before re-welding.

b. Electrical Resistance: Using a megohmmeter, measure and record the insulated flooring electrical resistance to ground at four points designated by the Engineer. Resistance not less than 100 megohms for a 12-inch by 12-inch floor area.

B. Submit certified test reports within 10 days of completion of tests.

END OF SECTION

SECTION 16060
GROUNDING AND BONDING

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes requirements for providing complete grounding and bonding system.

1.2 RELATED SECTIONS

A. Section 16128, WIRE AND CABLE FOR TRACTION POWER

1.3 REFERENCES

A. Comply with codes and regulations of the Jurisdictional Authorities.

B. National Electrical Code (NEC)

C. UL 467, Grounding and Bonding Equipment.

D. American Standards of Testing and Materials (ASTM) B187-00, Standard Specification for Copper Bar, Bus Bar, Rod and Shapes.

E. ITS: Directory of ITS Listed Products.

1.4 QUALITY ASSURANCE

A. Each item, except for exothermic-welded electrical connections, listed in accordance with referenced UL or ITS directory.

1.5 DELIVERY, STORAGE, AND HANDLING:

A. Mark each item in accordance with applicable reference standard.

B. Ship each unit securely packaged and labeled for safe handling and to avoid damage.

C. Store equipment in secure and dry storage facility.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Grounding and Bonding Equipment

1. General Requirements:

a. UL 467.

2. Grounding conductor:

a. Grounding electrode conductors:

1) Insulated or bare conductor, as shown, in accordance with the following:

a) Insulated conductor: As specified in Section 16128, WIRE AND CABLE FOR TRACTION POWER, for single-conductor cable.

b) Bare conductor: Section 16128, WIRE AND CABLE FOR TRACTION POWER.

2) Size:

a) For use in ground grid and for connecting of ground grid to ground bus: 4/0 AWG.

b) For connection of ground bus in train-control, communications, electrical, dispatcher, Bell system, and mechanical rooms to main ground bus in AC-switchboard rooms: 2/0 AWG.

c) For other grounding electrode conductors: In accordance with NEC Table 250-66.

b. Equipment grounding conductor:

1) Sized in accordance with NEC Article 250-122 unless otherwise shown.

2) Insulated equipment grounding conductor: Single-conductor cable as specified in Section 16128, WIRE AND CABLE FOR TRACTION POWER.

3) Bare equipment grounding conductor integral with multiple-conductor cable: Section 16128, WIRE AND CABLE FOR TRACTION POWER.

3. Bus bar: ASTM B187-00, 98 percent conductivity copper bus bar, size 2 inches wide by 1/4 inch thick, length as necessary.

4. Terminal lugs:

a. For 4/0 AWG and smaller conductors: Copper compression terminal lugs.

b. For 250 MCM and larger: Long-barrel, copper, double-compression terminal lugs.

5. Ground connector:

a. O-Z, Type KG or approved equal.

b. Two-piece, designed for connecting grounding conductor to bus bar.

c. Copper-alloy body and silicon-bronze bolt, nut, and lock washer with interlocking clamp.

6. Jumpers: Copper braided or leaf-type flexible jumper, size as necessary.

7. Bus-bar insulators: Fiberglass reinforced-polyester insulator with 1/2-inch diameter threaded holes at both ends for bus-bar installation.

8. Exothermic welded electrical connections:

a. Exothermic process using powdered metals contained in a mold to form a molecular bond between materials to be connected without application of an external source of heat or power in accordance with ANSI/IEEE 80-2000.

b. Molds, weld metal and associated accessories designed for making electrical connections between copper and copper, copper and steel, copper and cast iron and copper and ductile iron as required.

c. Welding system designed for making connections suitable for the application as follows:

1) Connections made outdoors for grounding using the standard process and not containing phosphorous or any caustic, toxic, or explosive materials.

2) Connections made indoors or in confined spaces for grounding using a low-smoke, low-emission process.

3) Connections made specifically for cathodic protection applications using the standard process.

d. Molds made of graphite with permanent marking indicating name of manufacturer, model, conductor size, and type and size of welding mixture compatible with the welding process. Mold connection type suitable for making connections between various configurations of items as shown or specified.

e. Weld metal consisting of copper oxide and aluminum contained in a moisture-resistant container along with other necessary materials required for the specific application as determined by the manufacturer. Container for applications other than low-smoke, low-emission process shall also include suitable starting material.

f. Container for weld metal identified with part number, type of metals shall be connected and application such as standard outdoor, low emission, or cathodic application.

PART 3 - EXECUTION

3.1 GROUNDING:

A. Ground Connections

1. Use terminal lug to connect grounding conductor to equipment enclosure. Use ground connector to connect grounding conductor to ground bus. Secure connector or terminal lug to the conductor so as to engage all strands equally. Install terminal lug using tools and pressure recommended by the manufacturer. Indent mark terminal lug with the number of die used for installation.

2. Splices in grounding conductor are prohibited.

3. For making ground connections located indoors and in confined spaces located outdoors such as manholes, use exothermic welds with low-smoke, low-emission process.

B. Equipment Grounding Conductor: Provide insulated equipment grounding conductor for following services and as shown:

1. Feeders.

2. Branch circuits.

C. Grounding of Separately Derived AC System

1. Ground in accordance with NEC.

2. Ground secondary neutral and enclosure of transformers to nearest ground bus or sub-bus using insulated grounding electrode conductor.

3. For transformer located outside of building, install additional grounding connector between transformer secondary neutral/enclosure and ground bus or grid using insulated grounding electrode conductor.

D. Grounding for Personnel Safety

1. In substation, electrical and mechanical rooms, tie-breaker stations, chiller plants, fan shaft and pumping stations, bond exposed metallic structure, motor frame, ac-equipment enclosure, ductwork and metallic piping to local ground bus, using minimum of 6AWG insulated grounding conductor as follows:

   a. Ground multiple items of exposed metallic structure to local ground bus using a separate grounding conductor for each item or by using series-connected grounding conductors to connect two or more items.

   b. Ground each AC equipment enclosure to local ground bus using a separate grounding conductor.

   c. Connection of grounding conductor for AC equipment enclosure in series with grounding conductor for exposed metal structure is prohibited.

2. Exothermically weld or gas torch braze grounding and bonding connection to exposed metallic structure, metallic cable trough, and junction box.

3.2 FIELD QUALITY CONTROL

A. Ground resistance not to exceed the following:

1. Ground grid/bus in DC tie-breaker stations: Five ohms.

B. Test metallic conduits and raceways, metallic enclosures for equipment, metallic cable troughs, junction boxes, and lighting fixtures for continuity to grounding system.

C. Conduct tests in presence of Contracting Officer Representative.

D. Inspect and test exothermic welds as follows:

1. Inspect finished exothermic welds for visual characteristics that are consistent with a properly made connection in accordance with the manufacturer's instructions and recommendations. Remove welds that do not meet minimum visual requirements as acknowledged by the Contracting Officer Representative, and reweld after cleaning the area to be welded.

2. Test mechanical strength of exothermic weld by applying three sharp blows to the weld with a 2-pound hammer using 15-inch strokes. Acceptable welds shall sustain the blows without cracking the weld metal or the bond between the two connecting materials. Remove defective welds and reweld after cleaning the area to be welded.

END OF SECTION

SECTION 16128

WIRE AND CABLE FOR TRACTION POWER

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes furnishing, installing, and testing wire and cable for traction power.

1.2 RELATED SECTIONS

A. Section 16052, BASIC MATERIALS AND METHODS FOR TRACTION POWER

B. Section 16060, GROUNDING AND BONDING

C. Section 16149, WIRE, CABLE, CABLE TRAY, AND TERMINATION PANEL FOR SCADA SYSTEMS

D. Section 16265, BATTERY AND BATTERY MONITORING SYSTEMS

E. Section 16266, BATTERY CHARGER

F. Section 16341, METAL ENCLOSED DC SWITCHGEAR FOR TIE BREAKER STATIONS

1.3 REFERENCES

A. Codes and regulations of the Jurisdictional Authorities.

B. NFPA-130 (Latest Edition), NFPA-70 (NEC)

C. ICEA: S-95-658 (NEMA WC70), S-93-639 (NEMA WC74)

D. IEEE: C2, 1202

E. ASTM: B3, B8, D471, B173, E662.

F. UL: 44, 224, 1277, 1581, 1569, 1685, 2556

1.4 SUBMITTALS

A. Submit the following for approval in accordance with Special Provisions:

1. Product literature for each type of wire and cable in accordance with this Section

2. Samples: Specified smoke-density test sample will become property of the Authority.

3. Certification:

a. Certified flame retardancy test reports and data for tests performed not more than 36 months prior to submittal for materials, which are identical to those of the cable furnished.

b. Submit smoke-density test reports and data from tests performed not more than 36 months prior to the submittal for materials, which are identical to those of the furnished cable.

c. Certified test reports demonstrating that cable complies with specified requirements and those of referenced ASTM, ICEA, and UL Standards.

d. Certificates from manufacturers verifying that products conform to specified requirements. Include certificate with submittal of Shop Drawings and with each cable shipment.

1.5 QUALITY ASSURANCE

A. Qualifications: Select a manufacturer who is regularly engaged in production of similar wire and cable, particularly to Railway or Transit industry in USA.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Mark each single-conductor cable and each multiple-conductor cable to show UL type, listing/certifications, size, voltage, manufacturer, and number of conductors or phases in accordance with NEC requirements.

B. Ship each unit securely packaged and labeled for safe handling and shipment.

C. Store products in a dry and secure facility.

PART 2 - PRODUCTS

2.1 MATERIALS

A. The following general requirements for single-conductor and multiple-conductor cable apply to specific cables described under Articles 2.01B through 2.01F:

1. Type and size: Type 1, low-smoke, zero halogen. Rated 90 degrees C, suitable for dry and wet locations.

2. Conductors:

a. ASTM B3 or ASTM B8 annealed copper.

b. Size 10 AWG and smaller: Solid or Class B or Class C stranded.

c. Size 8 AWG and larger: Class B stranded, unless otherwise specified.

d. Other constructions as specified.

3. Standards: Except as modified, wire and cable complying with ICEA S-95-658 (NEMA WC70) and ICEA S-93-639 (NEMA WC74).

4. Insulation material (See Article 2.01A. 5 for Jacket material) for single-conductor cable and individual conductors of multiple-conductor cable and as overall insulation covering on multiple-conductor cable:

   a. Cross-linked polyethylene (XLPE) or EPR as specified.

   b. EPR insulation shall be LSZH, low toxicity, ICEA Type II in accordance with ICEA S-95-658 (NEMA WC70).

5. All single and multiple-conductor cables shall be provided with jacket. Jacket material shall be cross-linked polyolefin complying with the following physical requirements:

   a. Tensile strength, minimum pounds per square inch: 1,700.

   b. Elongation at rupture, minimum percent: 150.

   c. Aging requirement: After 168 hours in air oven test at 121 degrees C, plus or minus 1 degree C:

      1) Tensile strength, minimum percentage of unaged value: 100.

      2) Elongation at rupture, minimum percentage of unaged value: 80.

   d. Oil immersion: 18 hours at 121 degrees C, plus or minus 1 degree C, ASTM D471, Table 1, No. 2 oil:

      1) Tensile strength, minimum percentage of unaged value: 60.

      2) Elongation at rupture, minimum percentage of unaged value: 70.

   e. Jacket materials free of PVC and PVC-based compounds.

   f. Flame retardancy: Single-conductor and multiple-conductor cable demonstrating flame retardancy in accordance with NFPA-130, IEEE-1202 and UL-1685 (FT4 Method). Not required for medium voltage cable.

   g. Single-conductor cable and individual conductors of multiple-conductor cable passing vertical flame test VW1 or FT1. Cable size for testing: 14 AWG.

   h. Single-conductor cable, Size 1/0 AWG and larger, passing vertical tray flame test, using ribbon gas burner in accordance with IEEE-1202 and UL-1685 (FT4/ST1 Method). Cable size for testing: 1/0 AWG.

   i. Multiple-conductor cable passing vertical tray flame test, using ribbon gas burner with IEEE-1202 & UL-1685 (FT4/ST1 Method). Cable size for testing: 7/C or 9/C with 12 AWG or 14 AWG conductors.

6. Applied Voltage Testing:

   a. Single-conductor cable and individual conductors of multiple-conductor cable shall be given applied AC voltage dielectric strength test, i.e., 6-

hour water immersion test.

b. For single conductors of multiple-conductor cable, conduct tests prior to assembly as multiple-conductor cable

c. Test procedures in accordance with requirements of ICEA S-95-658 (NEMA WC70) and S-93-639 (NEMA WC74).

7. Smoke Generation: Single-and-multiple-conductor cable jacket materials of cables rated 2 kV and below demonstrating low-smoke generation when tested in accordance with ASTM E662 by independent, nationally recognized testing agency. Test in accordance with NFPA 130.

a. Conduct tests on specimens of overall jacket material for multiple-conductor cable and on jacket material for single-conductor cable.

b. Prepare slab specimens for each material 0.100-inch, plus or minus 0.005 inch thick, identical to those of finished cables and meeting minimum physical requirements specified.

c. Prior to testing, submit 6-inch square portion of each specimen. Tag sample with manufacture's jacket or insulation identification code or number.

d. Test values not to exceed the following:

1) Flaming mode:

a) Uncorrected maximum specific optical density during first 4 minutes of test: 150.

b) Uncorrected maximum specific optical density for entire 20-minute test: 300.

2) Non-flaming mode:

a) Uncorrected maximum specific optical density during first four minutes of test: 150.

b) Uncorrected maximum specific optical density for entire 20-minute test: 350.

B. 15-kV and 35-kV Single-Conductor Cable:

1. Rated voltage: 15-kV 133 percent insulation level for 13.8 kV rated feeders and circuits; 35 kV 100 percent insulation levels for 34.5 kV rated feeders and circuits.

2. Conductor: As specified and with an extruded semi-conducting strand screen.

3. Insulation: Ethylene-propylene rubber, with an extruded semi-conducting insulation screen.

4. Shield: Copper tape, minimum thickness 2.5 mils with a minimum 25 percent

overlap.

5. Jacket: Overall nonmetallic jacket of cross-linked polyolefin.

6. Medium Voltage Cable Terminations:

a. Except as otherwise specified, heat shrinkable tubing kit type, with grounding accessory kits in accordance with the characteristics of the medium voltage cable shall be furnished.

1) Shrinkable tubing kits to be pre-stretched shrinkable tubing and shall contain all necessary components to reinstate cable insulation, metallic shielding/grounding system, and overall jacket.

2) Provide terminations at both ends of any length of medium voltage cable provided under this Contract.

C. 2000-Volt Aluminum Sheathed Single-Conductor TBS Negative Reference Cable:

1. Rated voltage: 2000.

2. Conductor:

a. 6 AWG, Class B stranded

b. Construction: Complying with one of the following:

1) Insulated with ethylene-propylene-rubber, with nonmetallic jacket of T-33-655 thermoset type II cross-linked polyolefin.

3. Metallic Sheath:

a. Continuous welded and corrugated Aluminum sheath in accordance with UL1569.

4. Jacket: Overall nonmetallic jacket of T-33-655 thermoset type II cross-linked polyolefin.

5. UL labeling: Type MC, suitable for wet and dry locations.

6. Additional requirements:

a. Insulation power factor: Two percent maximum.

b. Bond jacked to insulation to prevent moisture pockets. Minimum peel strength of the jacket from insulation: 4 pounds per inch for cross-linked polyolefin.

D. 2000-Volt Single-Conductor Cable:

1. Rated voltage: 2000

2. Conductor:

a. 6 AWG or other size; surge arrestor to ground cable or shop receptacles

b. Construction: Complying with one of the following:

1) Insulated with ethylene-propylene-rubber, with nonmetallic jacket of T-33-655 thermoset type II cross-linked polyolefin.

3. UL listed as Type RHW-2

4. Additional requirements:

a. Bond jacked to insulation to prevent moisture pockets. Minimum peel strength of the jacket from insulation: 4 pounds per inch for cross-linked polyolefin.

E. 600-Volt, Single-Conductor Cable:

1. Rated voltage: 600.

2. Construction: Complying with one of the following:

a. Insulated with ethylene-propylene-rubber, with nonmetallic jacket of T-33-655 thermoset type II cross-linked polyolefin.

b. Insulated with composite compound of ethylene-propylene-rubber and Class XL outer layer.

c. UL Class EPCV, without outer jacket.

d. Insulated with filled cross-linked polyethylene without outer jacket.

3. UL-listed as Type RHW-2 or XHHW-2.

4. Color coding: In accordance with NEC.

F. 600-Volt, Multiple-Conductor Power and Control Tray Cable:

1. Individual conductors:

a. Rated voltage: 600.

b. Number of conductors: As shown.

c. Construction: Complying with one of the following:

1) Insulated with ethylene-propylene-rubber, with nonmetallic jacket of T-33-655 thermoset type II cross-linked polyolefin.

2) Insulated with composite compound of ethylene-propylene-rubber and Class XL outer layer.

3) UL Class EPCV, without outer jacket.

4) Insulated with filled cross-linked polyethylene without outer jacket.

d. Phase and neutral conductors: Individually insulated.

e. Neutral conductors: Same size as phase conductors.

f. Insulated ground conductors: Sized in accordance with the NEC, unless otherwise shown.

g. UL listed as Type RHW-2 or XHHW-2.

2. Conductors assembled with non-wicking, flame-retardant filler shall form cable of circular cross section.

3. Cable UL listed as follows:

a. Power and Control Tray Cable: Type TC, suitable for wet and dry locations.

4. Color coding:

a. Power cables: In accordance requirements of the NEC.

b. Control cables: In accordance with requirements of ICEA standards.

G. 600-Volt, Aluminum sheathed multiple-conductor control cable for ETS and other wiring (without conduits):

1. Individual conductors:

a. Rated voltage: 600.

b. Number of conductors: As shown.

c. Construction:

1) Insulated with ethylene-propylene-rubber, with nonmetallic jacket of T-33-655 thermoset type II cross-linked polyolefin

d. Conductors: Individually insulated

e. Neutral conductors: Same size as phase conductors.

f. Insulated ground conductors: Sized in accordance with the NEC, unless otherwise shown.

g. UL-listed as Type RHW-2.

h. Bond jacket to insulation to prevent moisture penetration. Minimum peel strength of the jacket from insulation: 4 pounds per inch for cross-linked polyolefin.

2. Conductors assembled with non-wicking, flame-retardant filler shall form cable of circular cross section.

3. Metallic Sheath:

a. Continuous welded and corrugated Aluminum sheath in accordance with

UL1569.

4. Multiple-conductor cable provided with overall nonmetallic jacket of T-33-655 thermoset type II cross-linked polyolefin.

5. Cable UL listed as follows:

   a. Metal Clad Cable: Type ALS, 90 degree C suitable for wet and dry locations.

   b. Additional Markings: for “CT Use”.

6. Color coding:

   a. Power cables: In accordance requirements of the NEC.

   b. Control cables: Color coded with numbering in accordance with ICEA.

H. Instrumentation Cable: 2/C, twisted pairs:

1. Individual conductors:

   a. Rated voltage: 600.

   b. Number of conductors: As shown, Class B stranded.

   c. Construction: Complying with one of the following:

      1) Insulated with ethylene-propylene-rubber, with nonmetallic jacket of T-33-655 thermoset type II cross-linked polyolefin.

      2) Insulated with composite compound of ethylene-propylene-rubber and Class XL outer layer.

2. Conductors twisted and covered with a tinned copper braided shield 85 percent minimum coverage.

I. Bare Conductor: ASTM B3, annealed copper conductor; 8 AWG and larger, Class B stranded.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install all wiring continuous, without splices, between terminations, except as otherwise noted.

B. Install single-conductor cable in conduit or cable tray as shown. Install UL Type TC multiple-conductor cable in cable trays. Install UL Type MC multiple-conductor cable and ground cable on channel inserts, cable trays, or racks, using straps and fasteners as specified in Section 16052, BASIC MATERIALS AND METHODS FOR TRACTION POWER. Install UL Type MC multiple-conductor cable in conduit where shown or required. On walls or ceilings, fasten cable directly to channel inserts, or use expansion bolt anchors to attach to concrete and toggle bolts to attach to concrete masonry walls.

C. Use nylon straps to bundle and secure wire and cable located in panelboards, cabinets, switchboards, switchgear, and control panels.

D. Minimum bending radius 12 times outer diameter of cable. Where shown, use shorter bending radius as permitted by NEC and cable manufacturer.

E. To facilitate pulling cable, use UL-listed lubricant recommended by cable manufacturer.

F. Use polyethylene or other suitable nonmetallic rope for pulling cable. Attach to cable by means of either woven basket grips or pulling eyes attached directly to the conductors.

G. In damp and dusty indoor locations, manholes and outdoor locations, seal cable at conduit termination using duct-sealing compound.

H. Support cable installed in manholes at each invert location with cable brackets, racks and insulators specified in Section 16052, BASIC MATERIALS AND METHODS FOR TRACTION POWER. Provide brackets of suitable length with one insulator for each cable.

I. Where shown or necessary, install cable seal fitting specified in Section 16052, BASIC MATERIALS AND METHODS FOR TRACTION POWER. to prevent entry of water into electrical facilities. Where approved, use seal compound specified in Section 16052, BASIC MATERIALS AND METHODS FOR TRACTION POWER. .

J. Terminate medium voltage cable, using the specified termination kits, in accordance with the manufacturer's recommendations.

K. The splicing of cables is not permitted in duct banks, cable troughs or cable trenches. However, if permitted by the Contracting Officer Representative, make watertight splices as approved.

L. Identify cable terminations, feeders, power and control circuits using the following:

1. Cable Tags: Stainless steel tags punched with conduit or cable number as shown.

2. Wire Labels: Sleeve-type, heat shrinkable, flame retardant Raychem TMS product line, Type XPE or approved equal and conforming to UL 224. Wire identification shall be the same as corresponding terminal block identification unless otherwise shown. The labels on cable shall be clear, heat shrinkable with 1/2-inch height yellow lettering stamped on inside. The labels shall have reference of substation or tie breaker station breaker supervisory control ID number and cable sequence in the branch of the feeder (e.g. BRK. 32-A) at both ends. In all as-built drawings and the DC Switchgear equipment terminal wiring connections shall be identified with labels indicating from where is the wire originating and to where is it terminating.

3. Attach tags to cable with slip-free, plastic lacing or nylon bundling straps. Use designation shown.

3.2 FIELD QUALITY CONTROL

A. Furnish equipment required to perform tests. Prior to insulation and high potential tests, disconnect instruments and equipment, which might be damaged during such tests. Conduct tests in presence

of the
Contracting Officer Representative. Schedule all tests through the Contracting Officer Representative.

B. Submit test procedure for approval and perform approved tests. Do not perform tests without approved test procedure. Schedule all tests through the Contracting Officer Representative. Tests include but not limited to the following:

1. 600-volt multiple-conductor cable:

   a. Test continuity of cable conductors using ohmmeter.

   b. Proof-test insulation resistance to ground and between insulated conductors for minimum of 1 minute using 1000-volt megger. Insulation resistance: 1 megohm minimum, corrected to 15.6 degrees C. Testing procedures shall be as follows:

      1) Disconnect all wires of the cable under test at both ends and tape the far end of the wire under test with insulating tape of 600-volt class. Connect the bare end of the wire under test to the positive terminal of 1000-volt megger.

      2) Connect the negative terminal of 1000-volt megger to the nearest available ground terminal.

      3) Measure the insulation resistance of the wire under test by cranking the megger.

   c. When cable shows insulation resistance of less than 1 megohm, perform high potential test at 80 percent of factory dc test voltage or as recommended by cable manufacturer. A gradual decrease of leakage current with time indicates an acceptable cable installation.

2. 600-volt single-conductor cable:

   a. Test continuity of conductors using ohmmeter.

   b. Disconnect cable under test at both ends. Proof-test insulation resistance between each cable and the conduit in which the cable runs. While conducting the test, all other cables installed in the same conduit with the cable under test shall be connected to ground at one end. Insulation resistance shall be measured with a 1000-volt megger for minimum of 1 minute between the cable under test and the ground. Insulation resistance: One megohm minimum corrected to 15.6 degrees C.

   c. When cable shows insulation resistance of less than 1 megohm, perform high potential test at 80 percent of factory DC test voltage or as recommended by cable manufacturer. A gradual decrease of leakage current with time indicates an acceptable cable installation.

3. 2000-volt single-conductor cable:

   a. Test continuity of conductors using ohmmeter.

   b. Proof-test insulation resistance to ground of the cable under test for a minimum of 1 minute using a 2500-volt, three-terminal megger.

Insulation resistance: 500 megohms, minimum, corrected to 15.6 degrees C. Testing shall be done prior to termination of the cables at the two ends. Terminal lugs shall be installed prior to cable testing. Testing procedures shall be as follows:

1) Proof-test the system insulation resistance to ground of the cable under test using step-voltage testing method.

2) Insulation resistance: 500 megohms, corrected to 15.6 degrees B. Testing shall be done after all cables have been installed and lugged.

3) Isolate all cables at trackside and in the switchgear.

4) Secure each cable under test and connect the positive test lead of the megger to one end of the cable under test. Connect the megger ground lead to the station ground busbar.

5) Apply a 1000-volt DC test voltage to the cable for 1 minute and record the end test reading on the data sheet.

6) If the megger reading is greater than or equal to 500 megohms, proceed with testing the next cable in the test plan. If the test value is lower than 500 megohms, proceed with the step-voltage test as described below.

7) Step-voltage test:

   a) Examine and clean cable termination for presence of moisture or contamination.

   b) Make a second megger test at 1000 volts DC for one minute and record end test reading on data sheet. If reading is less than 500 megohms, proceed with step c) below, otherwise record new test reading on data sheet with comments depicting corrective action and proceed with testing next cable in the test plan.

   c) Increase the megger test voltage in increments of 500 volts starting at 1500 volts DC up to 2500 volts dc and perform 1 minute insulation resistance measurement tests. Record end test readings on data sheet for each incremental test.

   d) Compare insulation test readings at all levels of test voltage. A decrease of insulation resistance from the 1000 volts DC test voltage to the 2500 volts DC test voltage indicates the cable insulation has incipient weakness and the cable shall be replaced at no cost to the Authority.

8) Repeat the above procedures for all the positive and negative traction power cables.

4. 15-kV and 35-kV single-conductor cable:

   a. Test continuity of conductors using ohmmeter.

   b. Proof-test insulation resistance between conductor and the metallic shield. While conducting the test, the metal shield shall be tied to ground. Insulation resistance shall be measured with a 2500-volt megger for minimum of 1 minute. Insulation resistance: 500 megohm minimum corrected to 15.6 degrees C.

   c. Conduct Hipot test on each cable.

   d. Submit certified test reports within 10 days after completion of test.

END OF SECTION

SECTION 16130
RACEWAYS, BOXES, AND CABINETS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes requirements for providing conduit, raceways, cable trays, boxes, and cabinets to form raceway and support system for power, communications, and control cables.

1.2 RELATED SECTIONS

A. Section 16060, GROUNDING AND BONDING

1.3 REFERENCES

A. Comply with codes and regulations of the Jurisdictional Authorities.

B. National Electrical Code (NEC).

C. National Electrical Manufacturers Association (NEMA): 250, Enclosures for Electrical Equipment (1000 Volts Maximum); VE 1, Metallic Cable Tray Systems; TC-2, Electrical Polyvinyl Chloride (PVC) Tubing and Conduit.

D. American National Standards Institute (ANSI): C80.1, Rigid Steel Conduit - Zinc Coated; C80.5, Aluminum Rigid Conduit - (ARC); and Z55.1, Gray Finishes for Industrial Apparatus and Equipment.

E. UL: 5, Surface Metal Raceways and Fittings; 6, Rigid Metal Conduit; 50, Enclosures for Electrical Equipment; 94, Test for Flammability of Plastic Materials for Parts in Devices and Appliances; 360, Liquid Tight Flexible Steel Conduit; 514A, Metallic Outlet Boxes; 514B, Fittings for Conduit and Outlet Boxes; 514C, Nonmetallic Outlet Boxes, Flush-Device Boxes and Covers; 651, Schedule 40 and 80 Rigid PVC Conduit; 884, Under floor Raceways and Fittings; and 1684, Reinforced Thermosetting Resin Conduit (RTRC) and Fittings.

F. Federal Specifications (FS): FF-S-325C, FF-S-760, TT-S-227.

G. ASTM International (ASTM): A47/A47M, Standard Specification for Ferrite Malleable Iron Castings; A123/A123M, Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products; A185, Standard Specification for Steel Welded Wire Fabric, Plain, for Concrete Reinforcement; A276, Standard Specification for Stainless Steel Bars and Shapes; A507, Standard Specification for Drawing Alloy Steel, Sheet and Strip, Hot-Rolled and Cold-Rolled; A532/A532M, Standard Specification for Abrasion-Resistant Cast Irons; A536, Standard Specification for Ductile Iron Castings; A615/A615M, Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement; A653/A653M, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process; B138, Standard Specification for Manganese Bronze Rod, Bar and Shapes; B455, Standard Specification for Copper-Zinc-Lead Alloy (Leaded-Brass) Extruded Shapes; B584, Standard Specification for Copper Alloy Sand Castings for General Applications; B633, Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel;

C109/C109M, Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens); C173, Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method; C231, Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method; D149, Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies; D495, Standard Test Method for High-Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation; D570, Standard Test Method for Water Absorption of Plastics; D638, Standard Test Method for Tensile Properties of Plastics; D648, Standard Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position; and D790, Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials.

H. American Association of State Highway and Transportation Officials (AASHTO): Standard Specifications for Highway Bridges (SSHB).

I. ITS: Directory of ITS listed products.

J. The following items to be listed or labeled per referenced UL or ITS directory:

1. Conduit and fittings.
2. Surface raceways and fittings.
3. Under floor raceways and fittings.
4. Boxes.
5. Cabinets.

1.4 SUBMITTALS:

A. Submit the following for approval in accordance with Special Provisions and with the additional requirements as specified for each:

1. Shop Drawings.
2. Certification.

1.5 QUALITY ASSURANCE:

A. Qualifications: Select a manufacturer who is engaged in production of similar raceways, boxes, and cabinets.

1.6 PRODUCT DELIVERY, STORAGE, AND HANDLING:

A. Mark each item in accordance with applicable reference standard.

B. Ship each unit securely packaged and labeled for safe handling in shipment and to avoid damage or distortion.

C. Store products in secure and dry storage facility.

PART 2 - PRODUCTS

2.1 MATERIALS:

A. General Requirements for Conduit, Raceways, Cable Trays, Boxes, Cabinets and Fittings:

1. Size: As shown, minimum conduit size 3/4 inch.

2. Materials:

a. Steel sheet: ASTM A507.

b. Zinc-coated steel sheet: ASTM A653/A653M.

c. Cast iron: ASTM A532/532M.

d. Ductile iron: ASTM A536.

e. Malleable iron: ASTM A47/A47M.

f. Bronze extrusion: ASTM B455, Alloy C38500.

g. Bronze casting: ASTM B584, Alloy C83600.

h. Rigid fiberglass reinforced epoxy: UL 1684.

i. Stainless steel: ASTM A276, Type 304.

3. Zinc coating:

a. Hot-dip galvanizing: ASTM A123/A123M.

b. Electro galvanizing: ASTM B633.

B. Galvanized-Steel Rigid Conduit and Fittings: UL 6 and ANSI C80.1, zinc coating tested in accordance with reference test in appendix.

C. Plastic Conduit and Fittings:

1. PVC, UL 651, NEMA TC-2, Schedule 40 and 80 heavy-wall, for use with 90C conductors.

2. Solvent cement: Manufacturer's standard.

D. Aluminum Rigid Conduit and Fittings:

1. ANSI C80.5 and UL 6.

E. Liquid-Tight Flexible Conduit and Fittings:

1. Applicable requirements of UL 360.

2. Flexible galvanized-steel core with extruded liquid-tight neoprene or PVC jacket overall.

3. Sizes up to 1-1/4 inches provided with continuous copper bonding conductor, spiral wound between convolutions.

4. Sizes 1-1/2 inches and above provided with separate grounding conductor.

F. Conduit Expansion Fittings and Expansion and Deflection Fittings:

1. Materials:

a. For galvanized-steel rigid conduit:

1) Expansion fittings: Steel or malleable iron, hot-dip galvanized.

2) Expansion/deflection fittings: Bronze or ductile iron end couplings, neoprene sleeve and stainless steel clamping bands.

b. For PVC conduit: Rigid metal expansion/deflection fitting with galvanized rigid steel to PVC conduit adapters at each end.

2. Conduit expansion fitting: Weatherproof.

3. Conduit expansion and deflection fitting: Watertight.

4. Metallic fittings equipped with bonding jumper cable to provide electrical continuity.

G. Conduit Connector Fittings:

1. UL 514B, material and finish similar to that of conduit with which they are to be used.

2. For enclosures, cabinets, boxes and gutters in electrical rooms and aboveground, indoor locations: Threaded, nylon-insulated bushing and locknuts.

3. For enclosure, cabinets, boxes, and gutters with hub in outdoor, tunnel and underground locations, except electrical rooms: Threaded watertight hub fitting with gasket.

4. For enclosure having punched or formed knockout for conduit entry in outdoor and underground locations, except electrical rooms: Threaded watertight fitting with gasket, nylon-insulated throat and sealing locknut.

H. Conduit and Cable-Seal Fittings:

1. Conduit seal:

a. To provide watertight seal between concrete and conduit where it penetrates wall, floor or ceiling.

b. Size as shown or necessary.

c. Materials: Body and pressure clamp of malleable or cast iron with a neoprene sealing grommet and PVC-coated or galvanized-steel pressure rings, oversized sleeve of FRE or galvanized steel.

d. Seal between conduit and concrete to withstand pressure from 50-foot head of water without leakage.

2. Cable seal:

a. To provide watertight seal between cable and conduit for use with single-conductor or multiple-conductor cable as necessary.

b. Size as necessary, drilled to accommodate cable.

c. Pressure discs of PVC-coated steel and sealing ring of neoprene.

d. Seal between cable and conduit to withstand water pressure of 50 psi without leakage.

3. Seal compound:

a. FS TT-S-227, two-component, fast-setting, polymeric sealing compound to provide watertight seal between concrete and conduit, between cable and conduit.

b. Pour-type for horizontal and gun-grade for vertical or overhead application.

c. When cured, sealant to have rubber-like flexibility allowing minimum movement of conduit and cable in temperature range of minus 40 degrees F to plus 150 degrees F without loss of watertight seal.

d. Pot life: 15 minutes.

e. Minimum ambient temperature for application: 35 degrees F.

f. Initial cure: 15 minutes.

g. Final cure: 7 days.

h. Hardness, Durometer A: 20 to 35.

i. Seal between conduit and concrete to withstand pressure from 50-foot head of water without leakage.

j. Seal between conduit and single-conductor or multiple-conductor cable to withstand water pressure of 70 psi without leakage.

k. Fox Industries, Type FX-571G or approved equal.

I. Conduit and Cable Supports:

1. Retaining straps and fasteners: FS FF-S-760, with the following additional requirements:

a. Type, style, and size: As necessary.

b. Material and finish: Stainless steel, Type 304, or approved equal.

c. For separating conduit from masonry surface: Hot-dip galvanized malleable-iron spacer assembled with Style A strap.

d. For vertical run of metallic-sheath cable: Basket-weave cable support.

e. For fastening conduit or cable to channel inserts: Stainless steel, Type 304, or approved equal.

2. Multiple pipe hangers (trapeze-type): Consisting of two or more hanger rods, horizontal member, U-bolt clamp and other attachment necessary for securing hanger rods and conduit, with the following additional requirements:

a. Material and finish: Stainless steel, Type 304, or approved equal.

b. Hanger rod: Not smaller than 3/8-inch diameter, threaded for sufficient distance at each end to permit at least 1-1/2 inches of adjustment.

c. Horizontal member: Channel, 1-1/2 inches square or 1-5/8 inches square by 12 gauge or heavier. Weld two or more channels together for greater strength if necessary.

d. Design: Capable of supporting load equal to sum of weights of conduit, cable and hanger plus 200 pounds. At design load, stress at root of thread on hanger rod 9,500-psi maximum; stress in horizontal member 12,500-psi maximum.

3. Channel inserts:

a. Size and shape as shown, 12 gauge or heavier stainless steel, Type 304, or approved equal, with 7/8-inch wide slot.

b. For surface mounting: Channel inserts with 9/16-inch base slot, 8 inches on center with minimum pullout-load rating of 1,000 pounds per linear foot.

4. Spot inserts: Rated 800 pounds with safety factor of five, fabricated from steel galvanized after fabrication, covered to prevent entrance of concrete during installation.

J. Surface Raceways and Fittings: UL 5, fabricated from galvanized steel.

K. Under-floor Raceways and Fittings:

1. UL 884.

2. Size: As shown.

3. Fabricated from steel 14 gauge or heavier steel sheet.

4. Finish: Corrosion-resistant coating listed per referenced UL or ITS directory.

L. Boxes and Cabinets:

1. Outlet boxes:

a. UL 514A, capable of accommodating conduit as shown.

b. Material and finish:

1) Steel, malleable iron, cast iron or ductile iron.

2) Hot-dip galvanized or electro galvanized after fabrication.

c. For aboveground indoor locations and electrical rooms: Punched or formed knockouts.

d. For outdoor and underground locations, except electrical rooms:

1) Threaded-conduit entrance hub.

2) Threaded watertight fitting with gasket, nylon-insulated throat and sealing locknuts for enclosures having punched or formed knockouts for conduit entry.

e. For wall receptacles and switches, single or double devices: Outlet boxes 4-11/16-inch square by 1-1/2 inches deep.

f. For floor receptacles: Watertight cast-iron outlet boxes, 4-inch diameter, of suitable depth and complete with the following:

1) Adjustment screws for final leveling.

2) Bronze floor plate with flush-mounted screw plugs, without exposed fastener, M32 finish.

3) Screw plug attached to outlet-box assembly by chain or other means, M32 finish.

4) Bronze floor plate flange, 5 inches in diameter, extending beyond box 1/2 inch above finished floor, M32 finish.

5) One special screw-plug removal tool with every ten receptacles.

g. For recessed wall-mounted receptacles: Watertight cast-iron outlet box, 3-inch diameter, of suitable depth and complete with the following:

1) Bronze faceplate with flush-mounted screw plug, without exposed fasteners, M32 finish.

2) Screw plug attached to outlet-box assembly by chain or other approved means, M32 finish.

3) Bronze faceplate flange, 5 inches in diameter, extending beyond box, M32 finish.

4) One special screw-plug removal tool with every ten receptacles.

2. Junction and pull boxes:

a. Internal volume up to 100 cubic inches, metallic boxes: UL 514A, nonmetallic boxes: UL514C; internal volume above 100 cubic inches, UL 50.

b. Flush-mounted or surface-mounted as shown.

c. Size: Suitable to accommodate conduit, raceways, ducts, number of cables and splices shown.

d. Material and finish:

1) Metallic boxes:

a) Steel, malleable iron, cast iron, or ductile iron.

b) Hot-dip galvanized or electro galvanized after fabrication.

c) Stainless steel in tunnel areas.

2) Non-metallic boxes:

a) Precast concrete: Compressive strength 3,500 psi; air entrainment 6 percent minimum, ASTM C173 or C231; Section 03300, CAST-IN-PLACE CONCRETE, and Section 03400, PRECAST CONCRETE, and in accordance with the following:

i) Box: Concrete formed with closed bottom and sides and recess at top of box or at edge of cover to provide mating surfaces to prevent lateral movement of flush-mounted cover. Knockouts provided to accommodate conduits as shown.

ii) Cover:

a] Material same as for box. Use of metallic cover and cover frame prohibited.

b] Metro Type "B" logo with 3-1/8 inch by 4-inch envelope and service designation recessed in center of cover.

c] Non-protruding provisions provided for lifting.

iii) Reinforcement:

a] Sidewalk and landscape locations: Welded wire fabric, ASTM A185-97.

b] Areas subject to vehicular traffic: Deformed steel bars, ASTM A615/A615M-00.

iv) Loading:

a] Sidewalk and landscape locations: AASHTO's SSHB H15-44.

b] Areas subject to vehicular traffic: AASHTO's SSHB H20-44.

c] Hardware: Stainless steel.

d] Size: As shown or next available larger size.

b) Composite material: Sand and gravel bound together with a polymer and reinforced with continuous woven glass strands and in accordance with the following:

Physical Properties	Values	Method
Compressive strength	11,000 psi	ASTM C109
Tensile strength	1,700 psi	ASTM D638
Flexural strength	7,500 psi	ASTM D790
Water Absorption (24 hours)	0.5 percent	ASTM D570

i) Box: Gray-color material formed with closed bottom and sides and flange with recess at top of box to accommodate flush-mounted cover.

ii) Cover:

a] Material same as for box.

b] Skid-resistant top surface with minimum 0.5 coefficient of friction

c] Metro Type "B" logo with 3-1/8-inch by 4-inch envelope and service designation recessed in center of cover.

d] Secured to box with bolts.

e] Non-protruding provisions provided for lifting.

iii) Loading:

a] Sidewalk and landscape locations:

AASHTO's SSHB H15-44.

b] Areas subject to vehicular traffic: AASHTO's SSHB H20-44.

iv) Hardware: Stainless steel.

v) Size: As shown or next available larger size.

c) Molded fiberglass-reinforced polyester 1/8-inch thickness, minimum, and in accordance with the following requirements:

Physical Properties	Values	Method
Flexural strength	17,000 psi	ASTM D790
Deflection temperature	400 degrees F	ASTM D648
Water absorption (24 hours)	0.5 percent	ASTM D570
Tensile strength	6,500 psi	ASTM D638
Specific gravity	1.8	ASTM D794
Flammability	94-5V	UL 94
Dielectric strength	400 volts per mil	ASTM D149
Arc resistance	180 seconds	ASTM D495

i) Ultraviolet protection: Fiberglass material containing ultraviolet-inhibitor, or coated with polyurethane paint, 1.5 mils minimum dry-film thickness on both inside and outside surfaces.

ii) Color: Fiberglass material, gray inside and outside.

d) Molded polyvinyl chloride 1/8-inch thickness, minimum.

e. For aboveground indoor locations and electrical rooms: Punched or formed knockouts.

f. For outdoor and underground locations, except electrical rooms:

1) Threaded conduit entrance hub.

2) Threaded watertight fitting with gasket, nylon-insulated throat and sealing locknuts for boxes having punched or formed knockouts for conduit entry.

3. Cabinets:

a. UL 50, fabricated from galvanized steel.

b. Surface-mounted, unless otherwise shown.

c. Back plate of reinforced steel for mounting interior components and to ensure rigid support and accurate alignment.

d. Provision for cabinet grounding.

e. Provide latch and handle in accordance with UL 50; screw fastenings will not be accepted in lieu of latch.

f. Finish: Metallic surface thoroughly cleaned, degreased, primed with zinc primer and coated after fabrication with light-gray enamel, ANSI Z55.1, Color 61; minimum dry-film thickness, two mils.

M. Cable Trays:

1. NEMA VE1, ventilated-steel ladder-type.

2. Dimensions: Three-inch inside depth; 9-inch rung spacing unless otherwise shown.

3. Maximum load rating: 50 pounds per linear foot with safety factor of 1.5 at 12-foot support span.

4. Bend radius:

a. For incoming service cable: As required by power company.
b. For all other cable: 24 inches or as necessary and approved.

5. Finish: Cable trays, fittings, and accessories hot-dip galvanized or electro galvanized after fabrication.

N. Expansion Bolt Anchors: FS FF-S-325C Group II, stainless steel, Type 304, or approved equal.

O. Data Transmission System (DTS) Cabinet (Where required):

1. Wall-mounted, single-door, NEMA 250 Type 12, with panel, Hoffman Engineering Company, as shown or approved equal.

2. Enclosure: Formed of minimum 14-gauge steel, seams continuously welded and ground, without openings or knockouts, with threaded-conduit entrance hubs, lugs for mounting enclosure and collar studs for mounting panel. Rolled lip formed on all sides of door opening. Enclosure and door reinforced when size

exceeds 30 inches square. Size as shown.

3. Door: Formed of minimum 14-gauge steel, with rolled lip along top and sides to mate with enclosure. Fitted with removable print pocket. Closed-cell neoprene gasket attached with oil-resistant adhesive and steel retaining clips.

4. Hardware: Corrosion-resistant steel continuous piano hinge with removable pin. Hasp and staple for padlocking.

5. Panel: Formed of 12-gauge steel.

6. Finish: Galvanized enclosure, door, panel and latch mechanism. Prepared for painting by manufacturer's standard method in accordance with the following:

   a. Outside: Phosphatized, primed and finished with two coats of light-gray enamel or epoxy coating, ANSI Z55.1, Color 61; minimum dry-film thickness, 2 mils.

   b. Inside including panel: Two coats of white enamel or epoxy coating.

7. Breather drain: One 1/2-inch diameter, Crouse-Hinds Catalog No. ECD11, or approved equal.

8. Grounding stud: Manganese bronze, ASTM B138-96, Alloy No. 675 hard, 3/8-inch high; Evedur GSI, American Brass Company or approved equal.

9. Terminations: Assembly rail and modular terminals, Weidmuller Terminations, Incorporated or approved equal.

   a. Terminal: Modular test terminal, Melamine plastic, screw-clamp connections, with socket screws; Type SAKC4, Catalog No. 3406.2 or approved equal, with the following additional requirements:

      1) Amperes: 25.

      2) Volts: 300.

      3) Wire-gauge range: 22AWG to 12AWG.

      4) Thickness: 0.256 inch.

      5) Listed per referenced UL or ITS directory.

      6) Standard accessories; compatible with terminal, with the following additional requirements:

         a) End section: Type AP, No. 1179.2 or approved equal.

         b) End bracket: Type EWK1, No. 2061.6 or approved equal.

         c) Test plug: Type PS, No. 1804.0 or approved equal.

         d) Cross-connection combination: QB25, No. 91455.D or approved equal.

e) Disconnect plug for SAKC4 terminal: Type TST, No. 3399.0 or approved equal.

b. Assembly rail: Type TS32 steel standard section compatible with terminals, with fixing slots, Catalog No. 1228.0 and standard rail-mounting screws or approved equal.

c. Marking tags: Dekafix 6.5-FS or approved equal, consecutive vertical, Number 4682.6 or Number 5766.6 as approved. Consecutive numbering conforming to that of DTS box.

d. Group marking carrier with paper marking strip and transparent cover.

1) Type SCHT5, Catalog No. 2924.6 or approved equal.

2) Type ESO5, Catalog No. 2937.0 or approved equal.

3) SST5, Catalog No. 2940.0 or approved equal.

P. Fiberglass Conduit and Fittings:

1. Rigid fiberglass reinforced epoxy conduit, UL 1684, IPS (Iron Pipe Size) based conduit.

2. Conduit shall be manufactured by using filament-winding process with minimum fiberglass content of 65 percent by weight and no fillers.

3. IPS based conduit with nominal wall thickness of 0.09 inches for 5-inch nominal conduit size.

4. Conduits, elbows and fittings manufactured from the same material and using the same manufacturing process.

5. Conduit sections formed with integral bell and spigot type couplings. Rubber sealing gasket at bell end is prohibited.

6. Conduits, elbows and fittings provided with protection from exposure to sunlight by pigmentation uniformly dispersed through resin material.

7. Adhesive as recommended by conduit manufacturer.

8. Conduits, elbows, and fittings are specified for use throughout a temperature range of minus 40 degrees F to plus 230 degrees F, and they shall be protected from exposure to sunlight by pigmentation uniformly dispersed through the resin material.

9. Conduits, elbows and fittings shall be suitable for encasement in concrete below grade and conform to UL 1684, and listed and labeled by UL meeting the requirements of NEC Article 347 for Rigid Nonmetallic Conduit and its use.

10. Each piece of the straight length conduit and each piece of the elbow and other bend made from and for use with such conduit shall be labeled with the following information, mark clearly legible and durable every 10 feet or as recommended by the manufacturer.

a. Reinforced Thermosetting Resin Conduit (RTRC); Fiberglass Reinforced Epoxy Conduit (FREC); or equivalent, as applicable.

b. Normal Size: (IPS)

c. Manufacturer’s name and trademark.

d. Temperature range for conduit application.

e. Above Ground (AG), Below Ground (BG), or equivalent wording, as applicable.

PART 3 - EXECUTION

3.1 INSTALLATION

A. General

1. Use size, type, general routing, location of conduit, raceways, boxes, and cabinets as shown and specified.

2. Install metallic raceway, fittings, boxes, and cabinets free from contact with reinforcing steel.

3. Where aluminum is placed in contact with dissimilar metal or with concrete, separate contact surfaces by means of gasket, non-absorptive tape, or coating to prevent corrosion.

4. Make metallic conduit, raceways, ducts, and cable trays, electrically and mechanically continuous and ground them in accordance with Section 16060, GROUNDING AND BONDING.

5. Install FRE conduit where conduit runs are embedded in concrete and where conduit is shown as direct burial.

B. Conduit

1. Run exposed conduit parallel to building lines.

2. Install exposed conduit to avoid interference with other work.

3. Traction-power substations, tie-breaker stations, AC switchboard, electrical, train control, communications, and mechanical rooms: Where shown or where necessary to prevent seepage of subsoil or water into such areas, seal where conduits in contact with concrete and seal cable inside conduit using cable seal or sealing compound in accordance with the following requirements:

a. Where shown and as necessary, install cable seal and conduit seal in accordance with the manufacturer's recommendations.

b. Use sealing compound where approved and in accordance with manufacturer's recommendations, with the following additional requirements:

1) Before applying sealing compound, prime concrete, conduit and cable surface using primer recommended by manufacturer.

2) Pour or inject compound to prevent voids inside seal and to keep cable centered in conduit.

3) Use FRE sleeve for conduit seal installed on traction-power, train-control and communication conduit.

c. For 34.5 kV incoming-service cable with concentric neutral, install cable seal in traction-power substations, AC switchboard rooms, and 34.5 kV utility company manholes adjacent to WMATA facilities in accordance with the following requirements:

1) All work shall be done in coordination with a Utility company representative.

2) Install O-Z CSBI cable seal at each end of the conduit for the service entrance cables (one at the last Utility company manhole and one at the WMATA facility entrance). Use torque recommended by manufacturer for this type of cable seal, do not over-torque.

d. For 13.8 kV incoming-service cable, install cable seal in traction-power substation, AC switchboard rooms, and Utility company manholes adjacent to WMATA facilities. Coordinate the work with Utility company representative.

e. In empty conduit installed for future use, install blank cable seal inside conduit to prevent seepage of water.

f. All conduits free of water before conduit seals are installed.

4. Apply lead-free, conductive, anti-seize compound to threaded-conduit joints.

5. In outdoor and underground locations, except electrical rooms, use threaded-conduit hub to attach conduit to equipment enclosure. Use watertight conduit fitting with gasket, nylon-insulated throat and sealing locknuts for attachment of conduit to enclosure having punched or formed knockout.

6. In aboveground indoor locations and electrical rooms, use locknut and nylon-insulated bushing to attach conduit to enclosure.

7. Install suitable caps or plugs in empty conduit for future extension. Leave approved nylon or polyester pull line in each conduit.

8. Thread and ream ends of field-cut conduit to remove rough edges. Use bushing at conduit entrance to boxes, cabinets, and equipment enclosures.

9. Bends:

a. Unless otherwise shown or specified, install conduit bends in accordance with reference codes.

b. Install bends in buried conduit in accordance with the following:

Size of Conduit (inches)	Minimum Radius of Factory-Bend	Minimum Radius of Field-Bend (inches)
3	18	24
4	24	30
5	48	48
6	48	48

d. Total bends in each conduit run for traction-power cable: 225 degrees maximum.

e. Bend conduit so that field-made bend is free from cuts, dents, and other surface damage.

10. Support conduit during construction to prevent distortion and to ensure independent support.

11. Support horizontal conduit with one-hole pipe straps or individual pipe hangers.

12. Secure conduit supported on multiple-hangers (trapeze) or channel inserts by fasteners suitable for such purpose.

13. Where conduit is attached to masonry surface, use malleable-iron spacers with Style A pipe straps

14. Support and secure vertical conduit spanning open areas at intervals not exceeding 10 feet.

15. Support conduit above suspended ceiling using applicable specified methods.

16. Install conduit so as to drain moisture to nearest outlet or pull box.

17. Use minimum of 18-inch long, liquid-tight, flexible-conduit connection for equipment enclosure subject to vibration.

18. Do not use wire for support of conduit and cable.

19. Install expansion fitting in exposed conduit runs longer than 300 feet and where shown. Install expansion/deflection fittings where embedded conduits cross structural expansion joints. Where embedded conduits cross a structural

contraction joint, paint the external surface of conduit with linseed oil or other compatible bond breaker for 2 feet on each side of contraction joint.

20. Buried FRE conduit: Install in accordance with the following requirements in addition to those specified elsewhere:

    a. Arrange conduit to cross each expansion joint at right angle to joint.

    b. Prevent concrete and other materials from obstructing the conduit. Pack outlets, pull boxes and junction boxes and cap conduit ends prior to pouring concrete.

    c. Use Tight Lock Joint method to join conduit sections for providing water tightness and pull out strength.

    d. Provide compatible conduit supports and spacers to maintain position of conduit during placement of concrete.

    e. Install buried non-metallic conduit for cable over 600 volts in accordance with reference code.

    f. Waterproof conduit connections.

    g. Rod and swab conduit after installation so as to remove water, cement and other foreign matter; cap conduit ends. If obstructions cannot be removed or if condition exists which may result in damage to cable, replace conduit.

    h. Leave approved nylon or polyester pull-line in each conduit.

21. Use metallic conduit or above ground FRE conduit in exposed locations.

22. Conduit installed in outdoor location: Waterproof conduit connection.

C. Channel Inserts and Spot Inserts:

1. Surface-mount channel inserts as shown.

D. Surface Raceways:

1. Install as shown.

E. Under floor Raceways: **- NOT USED**

1. Install under floor raceways as specified in Section 03100. Align and level raceways accurately. Hold raceways in place during placing of concrete.

F. Outlet, Junction, and Pull Boxes:

1. Mount outlet boxes as shown.

2. Arrange front of box or attached plaster cover flush with finished wall or ceiling.

3. Keep number of knock-outs to minimum.

4. Clean boxes thoroughly after installation and correct damage to boxes and to finish.

5. Install covers on boxes mounted on walls and ceilings.

6. Measure height of wall-mounted outlet box from finished floor to horizontal centerline of cover plate.

7. Fasten floor boxes securely in place.

8. Install junction and pull boxes so that covers are readily accessible.

9. Do not install boxes above suspended ceilings except where ceilings are removable or definite provision is made for access to boxes.

10. Use stainless steel (Type 304) mounting channels, retaining straps and fasteners, pipe hangers for conduits and cables; expansion bolt anchors, junction boxes, outlet boxes, cover plates for receptacles, enclosures for load centers in tunnel environment which includes vent and fan shafts and under platform areas.

11. Use non-metallic boxes as follows:

    a. Buried with cover flush-mounted with finish grade: Precast concrete or composite material junction and pull boxes within AASHTO load designations as specified.

    b. For indoor and outdoor locations not subject to pedestrian or vehicular traffic: Molded fiberglass-reinforced polyester junction and pull boxes.

    c. For outdoor locations but not for burial: Molded polyvinyl chloride junction and pull boxes.

G. Cabinets:

1. Fasten cabinet securely using expansion bolts, toggle bolts, or mounting ears.

2. Touch-up damaged painted finish.

H. Cable Trays:

1. Install cable trays neatly, adequately supported, and as shown.

2. For incoming-service cable from Utility company, install cable tray as approved by the Utility company.

I. Use expansion-bolt anchors to secure equipment to concrete surfaces.

J. Attachments to Prestressed-Concrete Girders:

1. Attach pipes, conduits, boxes, or similar items to pre-stressed girders by welding to embedded plates or bolting to embedded fittings. Drilling into pre-stressed girders is prohibited, except for track fasteners and appurtenances as shown.

3.2 FILLING OF OPENINGS:

A. Where conduit and raceway pass through fire-rated walls, ceilings or floors, provide seals to prevent passage of fire and fumes and to maintain integrity of fire-rated.

B. Where openings are provided for passage of conduit and raceways in walls, ceilings, or floors, use fire-resistant fibrous-glass safing or similar material to seal unused openings to prevent passage of fire and fumes.

C. Close unused openings or spaces in floors, walls, and ceilings. Plug or cap unused conduit and sleeves.

3.3 IDENTIFICATION:

A. At end of each run, use stainless steel or aluminum tags, minimum 1-1/2 inch diameter, with stamped markings, minimum 1/4-inch high lettering, and tag holders attached to conduit using a stainless steel band with worm screw clamping device to establish identification of conduits and raceways in accordance with designations shown. Where conduits are terminated flush with concrete structure, install three-ply laminated phenolic plate, engraved through black face to white core and attached adjacent to conduits' entrance by means of non-metallic screws. Engrave conduits' designations within circles arranged in pattern similar to that of conduits.

B. Identify by red painted color code and by marking EMERGENCY SYSTEM on all boxes and enclosures for emergency circuits to identify them as part of an emergency system in accordance with the NEC.

3.4 FIELD QUALITY CONTROL:

A. Arrange with the Contracting Officer Representative for inspection and approval of embedded conduit and boxes prior to concrete placement.

B. Arrange with the Contracting Officer Representative for inspection by electrical Utility company representative of incoming-service conduit prior to placing concrete.

C. Test metallic conduit and boxes for electrical continuity. Conduct tests in presence of Contracting Officer Representative.

D. Test not less than 0.5 percent of total installed channel inserts and spot inserts as directed for compliance with specified pullout-load rating. Replace and retest inserts which fail. Conduct tests in presence of Contracting Officer Representative.

E. Arrange with the Contracting Officer Representative for inspection and approval of direct-buried conduits for future train control circuits prior to backfilling.

END OF SECTION

SECTION 16145

WIRING AND CONTROL DEVICES

PART 1 - General

1.1 Summary

A. This Section includes requirements for providing switches, cover plates, receptacles, and plugs.

1.2 RELATED SECTIONS

A. Section 16060, GROUNDING AND BONDING

B. Section 16130, RACEWAYS, BOXES, AND CABINETS.

1.3 REFERENCES

A. Comply with codes and regulations of the Jurisdictional Authorities.

B. National Electrical Code (NEC).

C. National Electrical Manufacturers Association (NEMA):WD1, General Color Requirements for Wiring Devices*;* KS1, Enclosed and Miscellaneous Distribution Equipment Switches (600 Volts Maximum); ICS 2, Industrial Control and Systems: Controllers, Contactors, and Overload Relays, Rated Not More Than 2000 Volts AC or 750 Volts DC; ICS 12, Profiles of Networked Industrial Devices--Part 1: General Rules; NEMA 250, Enclosures for Electrical Equipment (1000 Volts Maximum).

D. American National Standards Institute (ANSI): Z55.1, Gray Finishes for Industrial Apparatus and Equipment.

E. UL: 98, Enclosed and Dead-Front Switches; 198D, Class K Fuses; 198E, Class R Fuses; 508, Industrial Control Equipment; 773, Plug-In Locking-Type Photo controls for Use With Area Lighting; 1008, Transfer Switch Equipment.

F. ASTM International (ASTM): A47/A47M, Standard Specification for Ferritic Malleable Iron Castings; A276, Standard Specification for Stainless Steel Bars and Shapes; and A507, Standard Specification for Drawing Alloy Steel, Sheet and Strip, Hot-Rolled and Cold-Rolled.

G. ITS: Directory of ITS Listed Products

1.4 SUBMITTALS

A. Submit the following for approval in accordance with Special Provisions:

1. Product literature for all furnished products

1.5 QUALITY ASSURANCE

A. Source Quality Control:

1. Following items listed per referenced UL or ITS directory:

a. Snap switches.

b. Disconnect switches.

c. Receptacles and plugs.

B. Qualifications: Select a manufacturer who is regularly engaged in the production of automatic transfer switches.

1.6 PRODUCT DELIVERY, STORAGE, AND HANDLING:

A. Mark each item in accordance with applicable reference standard.

B. Ship each unit securely packaged and labeled for safe handling and to avoid damage

C. Store products in secure and dry storage facility.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Snap Switches:

1. NEMA WD1

2. Rating:

a. Twenty amperes at 120-277 volts AC.

b. Horsepower-rated when used as disconnecting device for motor circuit.

3. Body and base: Fully enclosed, brown, fire-resistant, non-absorptive thermosetting urea or nylon.

4. Contacts: Silver alloy.

5. Mounting yoke: Corrosion-resistant metal with plaster ears.

6. Poles: Single-pole, double-pole, three-way, or four-way as shown.

B. Disconnect (Safety) Switches:

1. UL 98, NEMA KS1, heavy-duty, fusible, or non-fusible as shown.

2. Voltage rating: 240 volts AC, 480 volts AC, or 250 volts DC as shown and as necessary.

3. Number of poles and current rating: As shown and as necessary.

4. Fuses:

a. UL 198D.

b. For fused disconnect switch associated with motor load: UL Class RK5 with time delay or as shown.

c. For fused disconnect switch associated with other loads: UL Class RK1 or as shown.

d. Current rating: As shown.

5. Enclosure: (NEMA 250)

a. Type:

1) For aboveground indoor locations and electrical rooms: Type 1.

2) For tunnel and underground locations, except electrical rooms: Type 4.

3) For outdoor locations: Type 3R.

b. Materials:

1) Steel sheet: ASTM A507.

2) Malleable iron: ASTM A47/A47M.

c. Finish: Metallic surface cleaned, degreased, primed with zinc primer and finished with light-gray enamel, ANSI Z55.1, Color 61; minimum dry-film thickness, two mils.

6. Quick-make/quick-break switching mechanism with operating handle external to enclosure with positions labeled ON/OFF and capable of being padlocked in OFF position, defeat able interlock to prevent opening of enclosure door when switch is closed.

C. Receptacles and Plugs:

1. NEMA WD1

2. Rating: 20 amperes at 125 or 250 volts as shown.

3. Base and body: Brown, fire-resistant, non-absorptive, thermosetting urea or nylon.

4. Receptacles:

a. Outlet: Single or duplex as shown.

b. Mounting yoke: Corrosion-resistant metal with plaster ears.

c. Configuration:

Rating	NEMA Configuration
Two-pole, three-wire, 20 amps, 125 volts	5-20 R
Two-pole, three-wire, 20 amps, 250 volts	6-20 R

d. For use in restroom, water service room, locker room, wash rooms, elevator machine room, pit and hoistway, and outdoor locations: Equipped with solid-state, ground-fault circuit interrupter with 5-milliamp trip level.

5. Plugs:

a. Configuration and design: As follows unless otherwise shown:

Rating		NEMA Configuration
Two-pole, three-wire, 20 amps, 125 volts	Urea or neoprene with cord grip	5-20 P
Two-pole, three-wire, 20 amps, 250 volts	Armored cap with cord grip	6-20 P

D. Cover Plates:

1. Wall plates:

a. NEMA WD1, suitable for specified receptacles and switches, size suitable for recess-mounted or surface-mounted associated outlet box, stainless steel, ASTM A276, Type 304, or approved equal.

b. For above ground indoor service areas and electrical rooms: Steel, stainless steel or aluminum plate, as standard with the manufacturer.

c. For receptacles in outdoor and underground locations, except electrical rooms: Stainless steel, ASTM A276, Type 304, wall plate with gasketed spring-loaded hinged cover.

2. Floor plates: Section 16130, RACEWAYS, BOXES, AND CABINETS.

PART 3 - EXECUTION

3.1 INSTALLATION:

A. Install switches, limit switches, occupancy sensors, receptacles, automatic transfer switches, lighting contactor, photoelectric controls, and time switches as shown and in accordance with referenced codes and standards in Article 1.03 herein and manufacturer's instructions.

B. Install cover plate on switch and receptacle.

C. Install cover plate with gasketed spring-loaded cover, on each receptacle in outdoor and underground locations except electrical rooms.

D. Ground disconnect switches, receptacles, and snap switches enclosures in accordance with Section 16060, GROUNDING AND BONDING.

E. Make power cable connections to snap switches and plugs by means of integral mechanical connectors. If such items are not furnished with integral mechanical connectors, make connections using compression connectors in accordance with Section 16125, WIRE CONNECTION ACCESSORIES.

F. Make power cable connections to snap switches and receptacles using their side screw wiring connection terminals.

G. Apply matching touch-up paint as necessary.

3.2 FIELD QUALITY CONTROL:

A. Furnish necessary test equipment and perform the following in the presence of the Contracting Officer Representative, in accordance with approved procedures:

1. Test receptacles for connection in accordance with wiring diagram.

2. Test equipment enclosure for continuity to grounding system.

3. Check tightness of cable connections of snap switches, receptacles, and disconnect switches.

4. Test operations of circuits and controls of switches and receptacles.

B. Submit certified test reports for compliance with field quality control requirements.

END OF SECTION

SECTION 16149
WIRE, CABLE, CABLE TRAY AND TERMINATION PANEL FOR TBS SCADA SYSTEMS

PART 1 – GENERAL

1.1 SUMMARY

A. This document describes the standards, products and execution requirements relating to furnishing and installing Telecommunications, Supervisory Control and Data Acquisition (SCADA) systems cabling at Tie Breaker Stations.

B. These standards, used in conjunction with published current ANSI/EIA/TIA standards represent a structured communications wiring system which will accommodate technological developments over the next several years. As technology changes this document will be amended to provide the most current and effective information available. Any aspects of communications wiring or design which are not sufficiently addressed in this document shall be brought to the attention of the manager of SCADA and System Integration in the department of Chief Engineer and Infrastructure.

1. Backbone and other cabling comprised of copper and fiber cabling, and support systems are covered under this document.

2. All cables and related terminations, support and grounding hardware shall be furnished, installed, wired, tested, labeled, and documented by the contractor/installer as detailed in this document unless otherwise noted.

3. Product specifications, general design considerations, and installation guidelines are provided in this document. Typical installation details, cable routing will be provided as an attachment to this document. If bid documents are in conflict, this specification shall take precedence. The contractor/installer shall meet or exceed all requirements for the cable system described in this document.

1.2 REFERENCES

A. All work and materials shall conform in every detail to the rules and requirements of the National Fire Protection Association, the local Electrical Code and present manufacturing standards.

B. All materials shall be UL Listed and shall be marked as such. If UL has no published standards for a particular item, then other national independent testing standards shall apply and such items shall bear those labels. Where UL has an applicable system listing and label, the entire system shall be so labeled.

C. The cabling system described in this document is derived from the recommendations made in recognized telecommunications industry standards. The following documents are incorporated by reference:

1. ANSI/TIA-568-C.0, Generic Communications Cabling for Customer Premises, February 2009
2. ANSI/TIA-568-C.1, Commercial Building Telecommunications Cabling Standard Part 1: General Requirements

3. ANSI/TIA-568-C.2, Commercial Building Telecommunications Cabling Standard Part 2: Balanced Twisted-Pair Cabling Components
4. ANSI/TIA-568-C.3, Commercial Building Telecommunications Cabling Standard Part 3: Optical Fiber Cabling Components
5. ANSI/TIA-569-C, Commercial Building Standard for Telecommunications Pathways and Spaces
6. TIA-527, Measurement of Optical Power Loss of Installed Single-mode Fiber Cable Plant, OFSTP-7
7. TIA-526-14-A, Optical Power Loss Measurements of Installed Multimode Fiber Cable Plant OFSTP-14A
8. TIA-598-C, Optical Fiber Cable color Coding, January, 2005
9. ANSI/TIA – 570-B, Residential Telecommunications Infrastructure Standard, April 2004
10. ANSI/TIA – 606 - B, Administration Standard for Commercial Telecommunications Infrastructure April 2012
11. ANSI/TIA- 607-B - Commercial Building Bonding and Grounding (Earthing) Requirements for Telecommunications, August 2011
12. TIA– 758-A, Customer-Owned Outside Plant Telecommunications Infrastructure Standard, August 2004
13. National Fire Protection Agency (NFPA – 70)
14. National Fire Protection Agency (NFPA-130) Standard for Fixed Guideway Transit and Passenger Rail Systems, 2007
15. BICSI - TDMM, Building Industries Consulting Services International, Telecommunications Distribution Methods Manual (TDMM) – 13th Edition, 2014
16. National Fire Protection Agency (NFPA – 70),
17. National Electrical Code: (NEC) 2014.
18. National Fire Protection Agency (NFPA-130) Standard for Fixed Guideway Transit and Passenger Rail Systems, 2010
19. WMATA Information Technology/ Network & Communications Services (IT/NCS) specification section: Infrastructure design & wiring standards

1.3 APPROVED PRODUCTS

Superior Essex and Legrand/Ortronics have been listed here as a WMATA preferred solution; however any other manufacture's solution meeting or exceeding the listed criteria may be submitted for review and approval. Any solution submitted must also be capable of providing a manufacturer's warranty equal to, or greater than the preferred Superior Essex-Legrand/Ortronics nCompass solution. See **Appendix A, Approved Material List. This is not an all-inclusive list and represents our most commonly used products.**

1.4 WORK INCLUDED

A. The work included under this design standard consists of furnishing all labor, equipment, materials, and supplies and performing all operations necessary to complete the installation of this structured cabling system in compliance with the specifications and drawings. The contractor/installer will provide and install all of the required material to form a complete system whether specifically addressed in the technical specifications or not.

B. The work shall include, but not be limited to the following:

1. Furnish and install a complete telecommunications wiring infrastructure

2. Furnish, install, and terminate all Cables provided under this contract

3. Furnish and install all patch panels, patch cords and jumper cables

4. Furnish and install all required cabling cabinets (termination panels) and/or racks as required and as indicated

5. Furnish all the necessary materials needed to form a complete, fully functional system.

6. Adhere and comply with all requirements of Legrand/Ortronics Certification program.

1.5 SUBMITTALS

A. Submit the following for approval in accordance with Subcontract Documents and additional requirements as specified for each:

1. Shop Drawings: Submit shop drawings for each type of cable.

2. Submit appropriate cut sheets and samples for all products, hardware and cabling.

3. Samples: Specified smoke-density test sample will become property of the Owner.

4. Certification:

a. Certified flame retardancy test reports and data for tests performed not more than 12 months prior to submittal, for actual cable supplied or for cable which is identical to those of cable furnished.

b. Submit smoke-density test reports and data from tests performed not more than 12 months prior to the submittal for materials which are identical to those of the furnished cable.

c. Certified test reports demonstrating that cable complies with specified requirements and those of referenced applicable Standards.

d. Certificates from manufacturers and UL verifying that products conform to specified requirements; Include certificate with submittal of shop drawings with each cable shipment.

5. Test procedures

6. The contractor/installer shall receive approval from WMATA on all substitutions of material. No substituted materials shall be installed except by written approval from the Chief engineer office.

1.6 QUALITY ASSURANCE

A. The Legrand/Ortronics CIP / CIP-ESP telecommunications contractor/installer shall be a company specializing in communication cabling installation. The contractor must be in good standing with a minimum of 30% of the technicians on site and at least one manager current with the required training.

B. **Labeling**: Labeling system shall clearly identify all components of the system, cabinets, patch panels, cables and if applicable, racks. The labeling system shall designate the cables origin and destination with a unique identifier for the cable within the system. Jumper fiber cables shall be labeled at both patch panel and equipment ends. Backbone cables shall have an identifying number that is labeled at each end. Labels shall be the same color on each end. Cable identifier must be linked to all pathways which it runs.

Racks and patch panels shall be labeled to identify the location within the cable system infrastructure. All labeling information shall be recorded on the as-built drawings and test documentation.

All label printing will be machine generated by a label maker or software (such as Ortronics Label MO software) using indelible ink ribbons or cartridges. Self-laminating labels will be used on cable jackets, appropriately sized to the OD of the cable and placed within view at the termination point on each end. Patch panel and wiring block labels shall be installed on or in the device.

C. Cable Installation Quality Control Process

1. QA Phase 1 - Cable Installation Practices.
   Inspections will ensure the following conform to TIA/EIA, NFPA 70, WMATA Design & Wiring Standards and all Local codes
   a. Cable bend radius
   b. Conduit sizing/ bend radius
   c. Cable tray fill
   d. Cable support in ceiling (Hangers/J hooks/ladder racks)
   e. Cable slack at the work area and the Telecommunication Room (TR)
   f. TR Configuration (Proper cable placement based on scope of work)

2. QA Phase 2 - Cable Termination Practices
   Inspections will ensure the following conform to TIA/EIA, WMATA Design & Wiring Standards, and all Local codes
   a. Correct jack pin out configuration
   b. Correct TR termination: Pin out, Hardware and placement
   c. Correct fiber backbone and jumper termination (Per SCADA and Remote Monitoring Network & Termination Diagrams)

3. QA Phase 3 Final Testing and Inspection.
   a. All cables and terminations shall be tested for defects in installation and to verify cabling system performance under installed conditions according to the requirement of ANSI/TIA/EIA.
   b. All pairs of each installed cable shall be verified prior to system acceptance. Any defect in the cabling system installation including but not limited to cable, connectors, patch panels and connector blocks shall be repaired or replaced in order to ensure 100% useable conductors in all cables installed.
   c. Copper Testing: All twisted pair copper cable links shall be tested for continuity, pair reversals, shorts, opens and performances as specified in Section 3.02.B of this specification.
   d. Fiber Testing: All fiber testing shall be performed on all fibers in the completed end to end system as specified in Section 3.02.C of this specification.
   e. All cables shall be tested in accordance with this document, the ANSI/TIA/EIA standard and best industry practice.

4. **Final sign off:** WMATA Information Technology/Network & Communication Services (IT/NCS) will sign documents provided by the contractor/installer approving the installation

process and materials demonstrated in this project.

1.7 NATIONAL FIRE PROTECTION ASSOCIATION (NFPA) REQUIREMENTS

A. All internal wire and cable installed in tunnels and passenger stations shall meet the requirements of Chapter 5 and 6 of the 2003 Edition of NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems.

B. All external wire and cable installed in stations and passenger stations shall meet the requirements of Chapter 6 of the 2003 Edition of NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems.

C. In the event that compliance with NFPA 130 will produce non-compliance with the requirements of this Specification, the NFPA shall take precedence.

1.8 DELIVERY, STORAGE, AND HANDLING

A. WMATA will not be responsible for the acceptance or delivery of any materials.

B. Cable shall be stored according to manufacturer's recommendations as a minimum. In addition, cable must be stored in a location protected from vandalism and weather. If cable is stored outside, it must be covered with opaque plastic or canvas with provision for ventilation to prevent condensation and for protection from weather. If air temperature at cable storage location will be below 40 degrees F., the cable shall be moved to a heated (50 degrees F. minimum) location. If necessary, cable shall be stored off site at the contractor's expense.

C. If the contractor/installer wishes to have a trailer on site for storage of materials, arrangements shall be made with the Owner.

1.9 DRAWINGS

A. It shall be understood that the electrical details and drawings provided with the specification package are diagrammatic. They are included to show the intent of the specifications and to aid the contractor/installer in bidding the job. The contractor/installer shall make allowance in the bid proposal to cover whatever work is required to comply with the intent of the plans and specifications.

B. The contractor/installer shall verify all dimensions at the site and be responsible for their accuracy.

C. Prior to submission of any bid package, the contractor/installer shall call to the attention of WMATA Engineer of any materials or apparatus the contractor/installer believes to be inadequate and to any necessary items of work omitted.

PART 2 - Products

2.1 EQUIVALENT PRODUCTS

A. All products, including but not limited to patch panels, racks, blocks, and, for the purpose of this document, shall be manufactured by Legrand/Ortronics. All copper and optical fiber cable products shall be manufactured by Superior Essex. There will be no substitutions allowed. Refer to Appendix A for the list of approved products.

B. WMATA’s recommended product for ETS RS-485 cable shall be manufactured by Blake Cable, LLC. However, any other manufacture’s solution meeting or exceeding the listed criteria may be submitted for review and approval. Any solution submitted must also be capable of providing a manufacturer's warranty equal to, or greater than the preferred Blake Cable, LLC solution.

2.2 MATERIALS

A. 20 AWG 2 PAIRS SHIELDED 300V RS-485 CABLE FOR MISCELLANEOUS INSTALLATIONS WITH IN TBS

Two pair twisted pair cables for serial interconnection cables internal use between Intelligent Electronic Devices (lED's)I Multipurpose Relay's (MPR's) /Device Servers I Media Convertors and SCADA RTU within TBS as needed shall meet RS-485 requirements in Section 2.02. B. of this specification.

B. FIBER CABLES, CONNECTORS AND PANELS

1. FIBER DISTRIBUTION CABLE

All horizontal fiber data cables shall be terminated on patch panels, mounted in their respective equipment enclosures as specified in each equipment specifications, and shown on the drawings.

2. Indoor/Outdoor Optical Fiber Plenum (OFNP) with Laser Optimized 50/125µm Multimode Optical Fibers

a. Multimode Optical Fibers type OM3 50/125µm shall be used within facilities.

b. Each Multimode Fiber shall be:

1) Graded-index Multi-mode optical fiber wave-guide with TeraFlex Bend Resistant Laser Optimized 50/125nm-core/cladding.

2) Approved products as specified in section 1.03 of this specification.

3) Shall comply with the latest revision of ANSI/EIA/TIA-492AAAB.

4) Shall comply with the latest revision of ANSI/ICEA S-104-696.

5) Attenuation shall be measured in accordance with ANSI/EIA/TIA- 455-78.

6) Information transmission capacity shall be measured in accordance with the latest revision of ANSI/EIA/TIA-455-204 or – 455-220.

7) Maximum attenuation dB/Km @ 850/1300 nm: Per manufacturer's specifications

c. Physical Characteristics:

1) Shall be available in either tight buffered or loose tube construction for use in both outdoor and indoor applications without the use of a transition at the building entrance.

2) Shall be suitable for use in risers, plenums and horizontal applications.

3) Shall have a dry water blocking system for cable core and buffer tubes.

4) Shall be available with a fiber strand count range from 6 to 24.

5) Shall have and be marked with an UL-OFNP and OFN FT6 Flame Rating.

6) Shall comply with the requirements of the latest revision of ANSI/ICEA S-104-696

7) Strength members shall be dielectric

8) Suitable for underground or above ground conduits.

9) Cable shall be color coded in accordance with the latest revision of ANSI/TIA-598 with an overall black jacket.

10) Suitable for operation between -40°C to +70°C

11) Shall be UV resistant

12) Shall be available in either aluminum interlock or steel construction armor.

3. Indoor/Outdoor Optical Fiber Low Smoke Zero Halogen (LSZH) Loose Tube With Laser Optimized OM3 50/125 Optical Fibers - use in NFPA-130 required environments

a. Each Multimode Fiber shall be:

1) Graded-index Multi-mode optical fiber wave-guide with TeraFlex Bend Resistant Laser Optimized 50/125nm-core/cladding.

2) Be as described in section 1.4, Approved Products

3) Shall comply with the latest revision of ANSI/ICEA S-104-696- 2013.

4) Attenuation shall be measured in accordance with the latest revision of ANSI/TIA-455-78.

5) Information transmission capacity shall be measured in accordance with the latest revision of ANSI/TIA-455-220.

6) Maximum attenuation dB/Km @ 850/1300 nm: Per manufacturer's specifications

b. Physical Characteristics:

1) Shall be suitable for use in NFPA-130 tunnel, subway passages and passage station environments both outdoor and indoor applications without the use of a transition at the building entrance.

2) Shall be suitable for use in low smoke zero halogen applications.

3) Shall have a dry, fully water blocked core and buffer tubes water blocked with PFM.

4) Shall be available with a fiber strand count range from 6 to 288.

5) Shall have and be marked with an UL-1666 and OFNG-LS (OFCG-LS for armored) Flame Rating.

6) Shall comply with the requirements of the latest revision of ANSI/ICEA S-104-696.

7) Strength members shall be dielectric and may be aramid yarn.

8) Suitable for underground or above ground conduits.

9) Loose Tube fibers shall be color coded in accordance with TIA- 598-C with an overall black jacket.

10) Suitable for operation between -40°C to +70°C

11) Shall be flame and sunlight resistant

12) Shall be available in Corrugated Steel Armor construction as needed.

4. Indoor/Outdoor Optical Fiber Plenum (OFNP) With Enhanced (Low Water Peak) Single-mode Optical Fibers

a. Single-Mode Optical Fibers shall be used to link TBS to communications rooms.

b. Each Single-mode Fiber shall be:

1) IVa dispersion - unshifted single mode optical fibers with TeraFlex Bend Resistant G657.A1 complying with the latest revision of ANSI/ICEA S-104-696.

2) Approved Products as specified in section 1.03 of this specification.

c. The zero dispersion wavelengths shall be between 1300 nm and 1320 nm. The ANS/TIA-455-168 maximum value of the dispersion slope shall be no greater than 0.090 ps/km-nm2. Dispersion measurements shall be made in accordance with the latest revision of ANSI/TIA-455-175.

d. Transmission Characteristics:

1) Maximum cabled attenuation dB/km @ 1310/1550 nm: 0.5/0.4

2) The cabled cutoff wavelength shall be ≤1260 nm when measured in accordance with ANSI/EIA/TIA-455-80.

e. Physical Characteristics:

1) Shall be suitable for use in both outdoor and indoor applications without the use of a transition at the building entrance.

2) Shall be suitable for use in risers, plenums and horizontal applications.

3) Shall have a dry water blocking system for cable

G. core and buffer tubes.

4) Shall be available with a fiber strand count of 6 to 24.

5) Shall have and be marked with an OFNP (OFCP for armored) and OFN (OFC for armored) FT-6 Flame Rating.

6) Shall comply with the latest revision of ANSI/ICEA S-104-696.

7) Strength members shall be dielectric.

8) Suitable for underground or above ground conduits.

9) Cable shall be color coded in accordance with the latest revision of ANSI/TIA-598 with an overall black jacket.

10) Shall have a ripcord for overall jacket.

11) Suitable for operation between -40oC to +70o C

12) Shall be UV resistant

13) Shall be available in either aluminum interlock or steel construction armor.

5. Indoor/Outdoor Optical Fiber Plenum (OFNP) Loose Tube With Enhanced (Low Water Peak) Single-mode Optical Fibers - use in NFPA-130 required environments

a. Each Single-mode Fiber shall be:

1) Class IVa dispersion - unshifted single mode optical fibers with TeraFlex Bend Resistant G657.A1 complying with the latest revision of ANSI/ICEA S-104-696.

2) Be as described in section 1.4, Approved Products

3) The zero dispersion wavelengths shall be between 1300 nm and 1320 nm. The ANSI/TIA-455-168 maximum value of the dispersion slope shall be no greater than 0.090 ps/km-nm2. Dispersion measurements shall be made in accordance with the latest revision of ANSI/TIA-455-169 or ANSI/TIA-455-175.

b. Transmission Characteristics:

1) Maximum cabled attenuation dB/km @ 1310/1550 nm: 0.5/0.4

2) The cabled cutoff wavelength shall be ≤1260 nm when measured in accordance with the latest revision of ANSI/TIA- 455-80.

c. Physical Characteristics:

1) Shall be suitable for use in NFPA-130 tunnel, subway passages and passage station environments both outdoor and indoor applications without the use of a transition at the building entrance

2) Shall be suitable for use in low smoke zero halogen applications.

3) Shall have a dry, fully water blocked core and buffer tubes water blocked with PFM.

4) Shall be available with a fiber strand count range from 6 to 288.

5) Shall have and be marked with an UL-1666 and OFNG-LS (OFCG-LS for armored) Flame Rating.

6) Shall comply with the latest revision of ANSI/ICEA S-104-696.

7) Strength members shall be aramid/yarn.

8) Suitable for underground or above ground conduits.

9) Loose Tube fibers shall be color coded in accordance with TIA- 598-C with an overall black jacket.

10) Suitable for operation between -40°C to +70°C

11) Shall be flame and sunlight resistant

12) Shall be available in Corrugated Steel Armor construction as needed.

6. FIBER PATCH CORDS (JUMPERS)

a. The contractor shall provide factory terminated and tested, 50/125µm, multimode, duplex, OM-3 type pre-terminated (SC-ST or SC-LC), shall connect the end devices (IEDs, MPR, Meters, network switch, etc) to their respective equipment patch panels. Each fiber patch cord shall:

1) Contain two (2) optical fibers.

2) Meet the requirements of the ‘Approved product’ list as specified in section 1.03.

3) Include listing of actual loss of patch cord when packaged

7. FIBER OPTIC CONNECTORS

a. Each Fiber Connector shall:

1) Meet WMATA’s standard multimode and single-mode fiber optic connector that is SC style connector.

2) Be available in single-mode and multimode versions.

3) Be in ‘Approved Products’ list as specified in section 1.03 of this specification.

4) Have a typical insertion loss of 0.3 dB for multimode and 0.2 dB for

single-mode

5) Be stable over an operating range of -40°C to +75°C.

8. FIBER OPTIC PATCH PANELS

a. In Tie Breaker Stations:

1) Multimode and single-mode backbone fiber optic cables shall be connected to fiber patch panels in the Network switch enclosure, DC switchgears, and the RTU. Fibers interconnecting the network switch to the equipment shall be connected to the rear of the patch panel connectors, Fiber Jumpers to devices and Network switches shall be connected to the front of the patch panel connector per the WMATA Network termination diagrams drawings.

2) In TBS network switch enclosure install:

a) One (1) Ortronics #OR-FC01U-C fiber patch panel for incoming single mode fibers from communication room with two (2) 6 sc duplex sc 50um 10gig coupling panels, Ortronics #OR-OFP-SCD12AC

b) One (1) Ortronics #OR-FC02U-C fiber patch panel to terminate outgoing multimode fiber to equipment IED, each with six(6) 6 sc duplex sc 50um 10gig coupling panels, Ortronics #OR-OFP-SCD12LC

c) At TBS with limited space, network switches, fiber patch panels will be installed in the RTU as specified by the contract drawings.

3) DC Switchgear Patch Panel:

a) Patch panels shall be installed on the external side wall of the DC switchgear or on the wall next to the DC switchgear.

b) Provide one Ortronics #OR-615SMFC-48P/S fiber patch panel to terminate outgoing multimode fiber to network switch patch panels.

c) The type and minimum number of connector panels (adaptor panels) needed is as defined in the standard SCADA drawings and as required for the full functionality of the system.

4) Optical Fiber patch cords: As specified in section 2.02.F.6

5) Patch Panels in Rectifier / RTU:

a) One (1) Corning's Single-Panel, Wall-Mount Housing (# SPH-01P) that will accept one (1) 6 sc duplex 50um 10gig multimode fiber coupling connector panel for each rectifier and the RTU

C. COMMUNICATION CABLE TRAY

1. Contractor shall install communication cable trays in TBS for fiber cables and 300V rated cables.

2. Cable tray shall be single tiered and shall be installed to allow 12 inches of open space above and to one side of the tray along the entire length. Cable tray shall be installed a minimum of 6 inches from any source of EMI.

3. Actual dimensions of cable tray shall be determined by the volume of cable planned for installation at the time of construction and account for future growth.

4. The cable tray shall not be filled more than 50% of its capacity.

5. Communication cable tray shall be wire mesh cable tray manufactured by Cablofil/Legrand.

D. FIRESTOP

1. A fire stop system is comprised of the item or items penetrating the fire rated structure, the opening in the structure and the materials and assembly of the materials used to seal the penetrated structure. Fire stop systems comprise an effective block for fire, smoke, heat, vapor and pressurized water stream.

   a. All penetrations through fire-rated building structures (walls and floors) shall be sealed with an appropriate fire stop system. This requirement applies to through penetrations (complete penetration) and membrane penetrations (through one side of a hollow fire rated structure). Any penetrating item i.e., riser slots and sleeves, cables, conduit, cable tray, and raceways, etc. shall be properly fire stopped.

      1) Fire stop systems shall be UL Classified to ASTM E814 (UL 1479) and shall be approved by a qualified Engineer.

      2) A drawing showing the proposed fire stop system shall be provided to the Owner's Technical Representative prior to installing the fire stop system(s).

PART 3 - EXECUTION

3.1 GENERAL REQUIREMENTS

A. CABLE INSTALLATION

1. Cable shall be installed in accordance with manufacturer's recommendations and best industry practices.

2. A pull cord (nylon; 1/8" minimum) shall be co-installed with all cable installed in any conduit.

3. Cable raceways shall not be filled greater than the ANSI/TIA/EIA-569-A maximum fill for the particular raceway type or 40%.

4. Cables shall be installed in continuous lengths from origin to destination (no splices) except for transition points, or consolidation points.

5. Where transition points or consolidation points are allowed, they shall be located in accessible locations and housed in an enclosure intended and suitable for the purpose.

6. Install RS485 and Fiber cable in communication cable tray/conduit and segregate from power/control cables.

7. The cable's minimum bend radius and maximum pulling tension shall not be exceeded.

8. Cable shall be installed per section 16052 Basic Materials and Methods for Traction. The cable system and support hardware shall be installed so that it does not obscure any conduit, boxes, or other control devices.

9. Use hook and loop wraps to bundle and secure fiber and twisted pair cable located in panelboards, cabinets, switchboards, switchgear and control panels, ensure that wraps are not over tightened on the cables.

10. Cables shall be identified by a self-adhesive label in accordance with the Chief Engineer Office SCADA and remote monitoring network and termination diagrams. The cable label shall be applied to the cable behind the faceplate on a section of cable that can be accessed by removing the cover plate.

11. Unshielded twisted pair cable shall be installed so that there are no bends smaller than four times the cable outside diameter at any point in the run and at the termination field.

B. OPTICAL FIBER TERMINATION HARDWARE

1. Fiber slack shall be neatly coiled within the fiber patch panel. No slack loops shall be allowed external to the fiber panel.

2. Each cable shall be individually labeled and attached to the respective patch panel by mechanical means. The cables strength member shall be securely attached the cable strain relief bracket in the enclosure.

3. Each fiber bundle shall be stripped upon entering the patch panel and the individual fibers routed in the patch panel.

4. Terminate fiber optic cables only by using the pre-manufactured terminations and plug directly into the patch panels in accordance with the manufacturer's recommendations.

5. All spare strands shall be installed into spare connector.

C. BACKBONE CABLE INSTALLATION

1. Refer to WMATA Information Technology/Network & Communications Services Design & Wiring Standards for all Single mode fiber installations.

D. Identify cable terminations, using the following:

1. The contractor shall develop and submit for approval a labeling system for the cable installation based on the Chief Engineer Office SCADA and remote monitoring network and termination diagrams. Labeling scheme.

2. At a minimum, the labeling system shall clearly identify all components of the system: equipment, cables and panels.

3. The labeling system shall designate the cables origin and destination and a unique identifier for the cable within the system.

4. Racks and patch panels shall be labeled to identify the location within the cable system infrastructure.

5. All labeling information shall be recorded on the as-built drawings and all test documents shall reflect the appropriate labeling scheme.

6. Labeling shall follow the guidelines of ANSI/TIA/EIA-606-A.

7. All label printing will be machine generated by Ortronics LabelMo software using indelible ink ribbons or cartridges or equivalent.

8. Self-laminating labels will be used on cable jackets, appropriately sized to the OD of the cable, and placed within view at the termination point on each end.

9. Patch panel and wiring block labels shall be installed on or in the space provided on the device.

3.2 TESTING AND ACCEPTANCE

A. General

1. All cables and termination hardware shall be 100% tested for defects in installation and to verify cabling system performance under installed conditions according to the requirements of ANSI/TIA/EIA-568-C.

2. All pairs of each installed cable shall be verified prior to system acceptance.

3. Any defect in the cabling system installation including but not limited to cable, connectors, feed through couplers, patch panels, and connector blocks shall be repaired or replaced in order to ensure 100% useable conductors in all cables installed.

4. All cables shall be tested in accordance with this document, the ANSI/TIA/EIA standards, the Ortronics Certification Program Information Manual and best industry practice. If any of these are in conflict, the Contractor/Installer shall bring any discrepancies to the attention of this office for clarification and resolution.

B. Copper Testing

1. All twisted-pair copper cable links shall be tested for continuity, pair reversals, shorts, opens and performance as indicated below. Additional testing is required to verify Category performance.

2. Horizontal cabling shall be tested using a Level III test unit for category 6 performance compliance.

3. The basic tests required are:

a. Wire Map

b. Length

c. Attenuation

d. NEXT (Near end crosstalk)

e. Return Loss

f. ELFEXT Loss

g. Propagation Delay

h. Delay skew

i. PSNEXT (Power sum near-end crosstalk loss)

j. PSELFEXT (Power sum equal level far-end crosstalk loss)

4. Continuity:

a. Each pair of each installed cable shall be tested using a test unit that shows opens, shorts, polarity and pair-reversals, crossed pairs and split pairs.

b. Shielded cables shall be tested with a device that verifies shielded continuity in addition to the above tests.

c. The test shall be recorded as pass/fail as indicated by the test unit in accordance with the manufacturers' recommended procedures, and referenced to the appropriate cable identification number and circuit or pair number.

d. Any faults in the wiring shall be corrected and the cable re-tested before final acceptance.

5. Length:
   a. Each installed cable link shall be tested for installed length using an approved hand held tester from an industry recognized test equipment manufacturer.

   b. The cables shall be tested from patch panel to patch panel and patch panel to workstation as appropriate.

   c. The cable length shall conform to the maximum distances set forth in the ANSI/TIA/EIA-568-C.2 and B.3 standard.

   d. Cable lengths shall be recorded, referencing the cable identification number and circuit or pair number.

   e. For multi-pair cables, the shortest pair length shall be recorded as the length for the cable.

6. Category 6 Performance:

Shall meet the channel requirements outlined below for a 100-meter, 4- Connector channel. Frequency (MHz)	Maximum Insertion Loss (dB)	Minimum NEXT (dB)	Minimum PSNEXT (dB)	Minimum ELFEXT (dB)	Minimum PSELFE XT (dB)	Minimum Return Loss (dB)
1.0	2.1	70.0	67.0	68.3	65.3	24.0
4.0	4.0	68.0	65.5	56.2	53.2	24.0
10.0	6.3	61.6	59.0	48.3	45.3	24.0
20.0	9.0	56.6	54.0	42.2	39.2	24.0
31.25	11.3	53.4	50.7	38.4	35.4	22.1
62.5	16.4	48.4	45.6	32.3	29.3	19.1
100.0	21.2	44.9	42.1	28.3	25.3	17.0
155.0	26.6	41.7	38.8	24.4	21.4	15.1
200.0	31.5	39.8	36.9	22.2	19.2	14.0
250.0	36.0	38.1	35.2	20.3	17.3	13.0

C. Fiber Testing

1. Fiber testing shall be performed on all fibers in the completed end-to-end system.
2. There shall be no splices unless clearly defined in an RFI.
3. Testing shall be conducted in accordance with the latest revision of TIA-526-7, Method B for single-mode fibers.
4. Test shall be conducted in accordance with the latest revision of ANSI/TIA-526- 14 Standard for multimode fibers.
5. System loss measurements shall be provided at 850 and1300 nanometers for multimode fibers and 1310 and1550 nanometers for

single mode fibers.

6. These tests also include continuity checking of each fiber.

7. Backbone multimode fiber cabling shall be tested at both 850 nm and 1300 nm (or 1310 and 1550 nm for single-mode) in both directions.

8. Where links are combined to complete a circuit between devices, the Contractor/Installer shall test each link from end to end to ensure the performance of the system. ONLY LINK TEST IS REQUIRED.

9. The contractor/installer can optionally install patch cords to complete the circuit and then test the entire channel.

10. The test method shall be the same used for the test described above. The values for calculating loss shall be those defined in the latest revision of the ANSI/TIA Standard.

11. Attenuation testing shall be performed with an approved hand held tester from an industry recognized test equipment manufacturer. Fiber cable characterization report shall be generated for each installed fiber and submitted as detailed in the System Documentation section of this specification.

12. A minimum of 0.11dB or higher headroom/margin is required

3.3 SYSTEM DOCUMENTATION

A. Upon completion of the installation, the contractor/installer shall provide three (3) full documentation sets to the Engineer for approval. Documentation shall include the items detailed in the sub-sections below.

B. Manufacturer's original certificate of origin with each fiber's factory attenuation results must be submitted. In the event the "birth certificate" was destroyed or lost the contractor/installer is responsible for contacting the factory of origin for a certified duplicate copy.

C. Documentation shall be submitted within ten (10) working days of the completion of each testing phase (e.g. subsystem, cable type, area, floor, etc.). This is inclusive of all test result and draft as-built drawings.

D. Draft drawings may include annotations done by hand. Machine generated (final) copies of all drawings shall be submitted within 30 working days of the completion of each testing phase.

E. At the request of the Engineer, the contractor/installer shall provide copies of the original test results.

F. The Engineer may request that a 10% random field re-test be conducted on the cable system, at no additional cost, to verify documented findings.

G. Tests shall be a repeat of those defined above. If findings contradict the documentation submitted by the contractor, additional testing can be requested to the extent determined necessary by the Engineer, including a 100% re-test. This re-test shall be at no additional cost to the Owner.

3.4 TEST RESULTS

A. The results shall include a record of test frequencies, cable type, conductor pair and cable I.D., measurement direction, reference setup, and crew member name(s).

B. The test equipment name, manufacturer, model number, serial number, software version and last calibration date will also be provided at the end of the document. Unless the manufacturer specifies a more frequent calibration cycle, an annual calibration cycle is anticipated on all test equipment used for this installation.

C. The test document shall detail the test method used and the specific settings of the equipment during the test as well as the software version being used in the field test equipment.

D. The field test equipment shall meet the requirements of ANSI/TIA/EIA-568-C including applicable TSB's and amendments.

E. The appropriate Level III tester shall be used to verify Category 6 cabling systems.

F. Printouts generated for each cable by the wire (or fiber) test instrument shall be submitted as part of the documentation package.

G. The contractor/installer must furnish this information in electronic form (CD-ROM) or acceptable pre-approved media.

H. When repairs and re-tests are performed, the problem found and corrective action taken shall be noted, and both the failed and passed test data shall be documented.

3.5 AS-BUILT DRAWINGS

A. The drawings are to include cable routes and outlet locations.

B. Numbering, icons, and drawing conventions used shall be consistent throughout all documentation provided.

C. The project manager will provide floor plans in paper and electronic (DWG, AutoCAD rel. 14) formats on which as-built construction information can be added.

D. The Chief Engineer Infrastructure SCADA and remote monitoring Standard drawing, Network & Termination Diagrams shall be used as template.

3.6 WARRANTY AND SERVICES

A. An Extended Product Warranty shall be provided which warrants functionality of all components used in the system for 25 years from the date of registration. The Extended Product Warranty shall warrant the installed horizontal and/or backbone copper, and both the horizontal and the backbone optical fiber portions of the cabling system.

B. The Application Assurance Warranty shall cover the failure of the wiring system to support the applications that are designed for the link/channel specifications of ANSI/TIA/EIA–568-C.1. These applications include, but are not limited to, 10BASE-T, 100BASE-T, 1000BASE-T, and 155 Mb/s ATM.

C. The contractor/installer shall provide a warranty on the physical installation.

PART 4 FINAL ACCEPTANCES AND SYSTEM CERTIFICATION

A. Completion of the installation, in-progress and final inspections, receipt of the test and as-built documentation, and successful performance of the cabling system for a two week period will constitute acceptance of the system.

B. Upon successful completion of the installation and subsequent inspection, the end user shall be provided with a numbered certificate, from Ortronics or Berk-Tek, registering the installation.

PART 5 INSTALLATION AND DESIGN PRACTICES

All installation practices will adhere to the Building Industry Consulting Service International (BISCI) Telecommunications Distribution Methods Manual (TDMM) Eleventh edition, as well as the Information Transport Systems Installation Manual (ITSIM) & Outside Plant Design Reference Manual (OPDRM). These BISCI manuals shall take precedence in any situation regarding design and installation practices.

Appendix A

Item Description	**Manufacturer**	**(MFR.) Part Number**
Fiber Optic Cable and Connectivity		
Indoor/Outdoor Optical Fiber Plenum (OFNP) with Laser Optimized 50/125µm Multimode Optical Fibers	Superior Essex	Coordinate with IT for approved part number
Indoor/Outdoor Optical Fiber Low Smoke Zero Halogen (LSZH) Loose Tube With Laser Optimized OM3 50/125 Optical Fibers - use in NFPA-130 required environments	Superior Essex	Coordinate with IT for approved part number
Indoor/Outdoor Optical Fiber Plenum (OFNP) With Enhanced (Low Water Peak) Single-mode Optical Fibers	Superior Essex	Coordinate with IT for approved part number
Indoor/Outdoor Optical Fiber Plenum (OFNP) Loose Tube With Enhanced (Low Water Peak) Single-mode Optical Fibers - use in NFPA-130 required environments	Superior Essex	Coordinate with IT for approved part number
Fiber Optic Connectors		
SC Multimode Unicam 50 Micron Organizer Pack	Corning	95-050-41-X-Z
SC Singlemode (Pretium) Unicam Organizer Pack (25)	Corning	95-200-42-Z
Fiber Optic Coupler Panels		
12 Port SC Coupler Panel, Single mode	Ortronic	OR-OFP-SCD12AC
12 Port SC Coupler Panel, Multimode, 50 micron	Ortronics	OR-OFP-SCD12LC
Fiber Optic Termination Enclosures		
Three Slot Rack Mount Enclosure; 1RU patching & Splice (2 splice trays)	Ortronics	OR-FC01U-C
Six Slot Rack Mount Enclosure; 2RU patching & splice (6 splice trays)	Ortronics	OR-FC02U-C
Patch Cabinet , Wall Mount 48 port & splice	Ortronics	OR-615SMFC-48P/S
Fiber Patch Cords FPC MM 50 10G 2F SC-LC 3M CERAMIC ZIP (2.0MM) AQUA (Patch Cords)		
LC to SC 50um (OM3), duplex patch cord	Ortronic	
SC to ST 50um (OM3) duplex patchcord	Ortronics	
Cable Tray		
12" Trapeze Bracket	Cablofil	FAS P 450
24" Trapeze Bracket	Cablofil	FAS P 600
90 Deg. Raduis TEE Bend KIT	Cablofil	RADT90KIT 4
1/4" Nut & Bolt	Cablofil	EZ BN 1/4
Square Splice Washer	Cablofil	CE-40

Item Description	**Manufacturer**	**(MFR.) Part Number**
Splice for sweep's	Cablofil	FASLOCKS
EDRN Tool	Cablofil	EDRNTOOL
EDRN Fast Splice	Cablofil	EDRN
Cable Tray 4" x 8" x 10'	Cablofil	CF-105/200
Cablofil Tray cutters	Cablofil	COUPFIL
Elevation Change Hinge	Cablofil	EAC
90 Deg. (Hard) TEE Bend KIT	Cablofil	EZT 90 KIT
Tray drop out kit	Cablofil	DROPOUTKITPG
2" x 12" x 10' Cable Tray	Cablofil	CF54/300EZ
4" x 12" x 10' Cable Tray	Cablofil	CF54/105EZ
4"x8"x10' Cable Tray	Cablofil	Cf-105/200
12" Cable Tray Splice (50 pk)	Cablofil	EDRNEZ
Hold down Bracket	Cablofil	CE-25
Nut and Bolt	Cablofil	EZ BN 5/16
J Bolt (To mount to top of rack)	Cablofil	EZJB-5/16

APPENDIX B: SAMPLE TEST REPORTS

LINKWARE™ PC
CABLE TEST MANAGEMENT SOFTWARE

Cable ID	Summary	Test Limit	Length	Headroom	Date / Time
SWITCHBOARD 1 - COMM RM01	PASS	TIA-568-C Singlemode ISP	114 ft	1.12 dB (Loss Margin)	05/19/2015 04:27 AM
SWITCHBOARD 1 - COMM RM02	PASS	TIA-568-C Singlemode ISP	114 ft	1.50 dB (Loss Margin)	05/19/2015 04:27 AM
SWITCHBOARD 1 - COMM RM03	PASS	TIA-568-C Singlemode ISP	114 ft	1.00 dB (Loss Margin)	05/19/2015 04:30 AM
SWITCHBOARD 1 - COMM RM04	PASS	TIA-568-C Singlemode ISP	114 ft	1.26 dB (Loss Margin)	05/19/2015 04:30 AM
SWITCHBOARD 1 - COMM RM05	PASS	TIA-568-C Singlemode ISP	115 ft	1.12 dB (Loss Margin)	05/19/2015 04:31 AM
SWITCHBOARD 1 - COMM RM06	PASS	TIA-568-C Singlemode ISP	115 ft	1.35 dB (Loss Margin)	05/19/2015 04:31 AM
SWITCHBOARD 1 - COMM RM07	PASS	TIA-568-C Singlemode ISP	114 ft	0.88 dB (Loss Margin)	05/19/2015 04:33 AM
SWITCHBOARD 1 - COMM RM08	PASS	TIA-568-C Singlemode ISP	114 ft	0.86 dB (Loss Margin)	05/19/2015 04:33 AM
SWITCHBOARD 1 - COMM RM09	PASS	TIA-568-C Singlemode ISP	115 ft	0.22 dB (Loss Margin)	05/19/2015 04:35 AM
SWITCHBOARD 1 - COMM RM10	PASS	TIA-568-C Singlemode ISP	115 ft	1.32 dB (Loss Margin)	05/19/2015 04:35 AM
SWITCHBOARD 1 - COMM RM11	PASS	TIA-568-C Singlemode ISP	115 ft	1.16 dB (Loss Margin)	05/19/2015 04:37 AM
SWITCHBOARD 1 - COMM RM12	PASS	TIA-568-C Singlemode ISP	115 ft	1.37 dB (Loss Margin)	05/19/2015 04:37 AM
SWITCHBOARD 1 - LVSWGR-01	PASS	TIA-568-C Multimode	58 ft	0.52 dB (Loss Margin)	05/18/2015 12:23 AM
SWITCHBOARD 1 - LVSWGR-02	PASS	TIA-568-C Multimode	58 ft	0.36 dB (Loss Margin)	05/18/2015 12:23 AM
SWITCHBOARD 1 - LVSWGR-03	PASS	TIA-568-C Multimode	58 ft	0.29 dB (Loss Margin)	05/18/2015 01:02 AM
SWITCHBOARD 1 - LVSWGR-04	PASS	TIA-568-C Multimode	58 ft	0.59 dB (Loss Margin)	05/18/2015 01:02 AM
SWITCHBOARD 1 - LVSWGR-05	PASS	TIA-568-C Multimode	58 ft	0.05 dB (Loss Margin)	05/18/2015 01:04 AM
SWITCHBOARD 1 - LVSWGR-06	PASS	TIA-568-C Multimode	58 ft	0.77 dB (Loss Margin)	05/18/2015 01:04 AM
SWITCHBOARD 1 - MV-F60-01	PASS	TIA-568-C Multimode	65 ft	0.52 dB (Loss Margin)	05/18/2015 01:09 AM
SWITCHBOARD 1 - MV-F60-02	PASS	TIA-568-C Multimode	65 ft	0.58 dB (Loss Margin)	05/18/2015 01:09 AM
SWITCHBOARD 1 - MV-F60-03	PASS	TIA-568-C Multimode	65 ft	0.53 dB (Loss Margin)	05/18/2015 01:11 AM
SWITCHBOARD 1 - MV-F60-04	PASS	TIA-568-C Multimode	65 ft	0.75 dB (Loss Margin)	05/18/2015 01:11 AM
SWITCHBOARD 1 - MV-F60-05	PASS	TIA-568-C Multimode	65 ft	~~0.00 dB (Loss Margin)~~	~~05/18/2015 01:13 AM~~
SWITCHBOARD 1 - MV-F60-06	PASS	TIA-568-C Multimode	65 ft	0.79 dB (Loss Margin)	05/18/2015 01:13 AM
SWITCHBOARD 1 - RTU DROP	PASS	TIA Cat 6 Perm. Link	15 ft	7.6 dB (NEXT)	05/18/2015 02:16 AM
SWITCHBOARD 1 - RTU-01	PASS	TIA-568-C Multimode	34 ft	0.54 dB (Loss Margin)	05/18/2015 12:15 AM
SWITCHBOARD 1 - RTU-02	PASS	TIA-568-C Multimode	34 ft	0.26 dB (Loss Margin)	05/18/2015 12:15 AM
SWITCHBOARD 1 - RTU-03	PASS	TIA-568-C Multimode	34 ft	0.54 dB (Loss Margin)	05/18/2015 12:18 AM
SWITCHBOARD 1 - RTU-04	PASS	TIA-568-C Multimode	34 ft	0.21 dB (Loss Margin)	05/18/2015 12:18 AM
SWITCHBOARD 1 - RTU-05	PASS	TIA-568-C Multimode	35 ft	0.68 dB (Loss Margin)	05/18/2015 12:20 AM
SWITCHBOARD 1 - RTU-06	PASS	TIA-568-C Multimode	35 ft	0.16 dB (Loss Margin)	05/18/2015 12:20 AM
SWITCHBOARD 2 - COMM RM01	PASS	TIA-568-C Singlemode ISP	642 ft	1.34 dB (Loss Margin)	05/19/2015 04:19 AM
SWITCHBOARD 2 - COMM RM02	PASS	TIA-568-C Singlemode ISP	642 ft	1.37 dB (Loss Margin)	05/19/2015 04:19 AM
SWITCHBOARD 2 - COMM RM03	PASS	TIA-568-C Singlemode ISP	641 ft	1.43 dB (Loss Margin)	05/19/2015 03:15 AM
SWITCHBOARD 2 - COMM RM04	PASS	TIA-568-C Singlemode ISP	641 ft	1.11 dB (Loss Margin)	05/19/2015 03:15 AM
SWITCHBOARD 2 - COMM RM05	PASS	TIA-568-C Singlemode ISP	641 ft	1.21 dB (Loss Margin)	05/19/2015 03:12 AM
SWITCHBOARD 2 - COMM RM06	PASS	TIA-568-C Singlemode ISP	641 ft	1.13 dB (Loss Margin)	05/19/2015 03:12 AM
SWITCHBOARD 2 - COMM RM07	PASS	TIA-568-C Singlemode ISP	642 ft	0.96 dB (Loss Margin)	05/19/2015 03:09 AM
SWITCHBOARD 2 - COMM RM08	PASS	TIA-568-C Singlemode ISP	642 ft	1.31 dB (Loss Margin)	05/19/2015 03:09 AM
SWITCHBOARD 2 - COMM RM09	PASS	TIA-568-C Singlemode ISP	641 ft	1.48 dB (Loss Margin)	05/19/2015 03:06 AM
SWITCHBOARD 2 - COMM RM10	PASS	TIA-568-C Singlemode ISP	641 ft	1.05 dB (Loss Margin)	05/19/2015 03:06 AM
SWITCHBOARD 2 - COMM RM11	PASS	TIA-568-C Singlemode ISP	641 ft	1.39 dB (Loss Margin)	05/19/2015 03:03 AM
SWITCHBOARD 2 - COMM RM12	PASS	TIA-568-C Singlemode ISP	641 ft	1.21 dB (Loss Margin)	05/19/2015 03:03 AM
SWITCHBOARD 2 - LVSWGR-01	PASS	TIA-568-C Multimode	76 ft	0.57 dB (Loss Margin)	05/17/2015 11:26 PM
SWITCHBOARD 2 - LVSWGR-02	PASS	TIA-568-C Multimode	76 ft	0.51 dB (Loss Margin)	05/17/2015 11:26 PM
SWITCHBOARD 2 - LVSWGR-03	PASS	TIA-568-C Multimode	76 ft	0.52 dB (Loss Margin)	05/17/2015 11:29 PM
SWITCHBOARD 2 - LVSWGR-04	PASS	TIA-568-C Multimode	76 ft	0.59 dB (Loss Margin)	05/17/2015 11:29 PM
SWITCHBOARD 2 - LVSWGR-05	PASS	TIA-568-C Multimode	76 ft	0.50 dB (Loss Margin)	05/17/2015 11:31 PM
SWITCHBOARD 2 - LVSWGR-06	PASS	TIA-568-C Multimode	76 ft	0.42 dB (Loss Margin)	05/17/2015 11:31 PM
SWITCHBOARD 2 - MV-F60-01	PASS	TIA-568-C Multimode	56 ft	0.50 dB (Loss Margin)	05/17/2015 11:34 PM
SWITCHBOARD 2 - MV-F60-02	PASS	TIA-568-C Multimode	56 ft	0.62 dB (Loss Margin)	05/17/2015 11:34 PM
SWITCHBOARD 2 - MV-F60-03	PASS	TIA-568-C Multimode	56 ft	0.59 dB (Loss Margin)	05/18/2015 12:00 AM
SWITCHBOARD 2 - MV-F60-04	PASS	TIA-568-C Multimode	56 ft	0.76 dB (Loss Margin)	05/18/2015 12:00 AM
SWITCHBOARD 2 - MV-F60-05	PASS	TIA-568-C Multimode	56 ft	0.38 dB (Loss Margin)	05/17/2015 11:48 PM
SWITCHBOARD 2 - MV-F60-06	PASS	TIA-568-C Multimode	56 ft	0.76 dB (Loss Margin)	05/17/2015 11:48 PM
SWITCHBOARD 2 - RTU DROP	PASS	TIA Cat 6 Perm. Link	57 ft	3.6 dB (NEXT)	05/18/2015 02:22 AM
SWITCHBOARD 2 - RTU-01	PASS	TIA-568-C Multimode	81 ft	0.60 dB (Loss Margin)	05/17/2015 11:19 PM
SWITCHBOARD 2 - RTU-02	PASS	TIA-568-C Multimode	81 ft	0.57 dB (Loss Margin)	05/17/2015 11:19 PM
SWITCHBOARD 2 - RTU-03	PASS	TIA-568-C Multimode	81 ft	0.62 dB (Loss Margin)	05/17/2015 11:21 PM
SWITCHBOARD 2 - RTU-04	PASS	TIA-568-C Multimode	81 ft	0.54 dB (Loss Margin)	05/17/2015 11:21 PM
SWITCHBOARD 2 - RTU-05	PASS	TIA-568-C Multimode	82 ft	0.16 dB (Loss Margin)	05/17/2015 11:22 PM
SWITCHBOARD 2 - RTU-06	PASS	TIA-568-C Multimode	82 ft	0.25 dB (Loss Margin)	05/17/2015 11:22 PM

ED

FLUKE networks

LINKWARE™ PC
CABLE TEST MANAGEMENT SOFTWARE

Total Length:	11366 ft
Number of Reports:	62
Number of Passing Reports:	62
Number of Failing Reports:	0
Number of Warning Reports:	0
Documentation Only:	0

FLUKE networks.

LINKWARE™ PC
CABLE TEST MANAGEMENT SOFTWARE

Cable ID: SWITCHBOARD 1 - COMM RM01 **Test Summary: PASS**
Date / Time: 05/19/2015 04:27:33 AM n = 1.4690 (1310 nm)
Cable Type: Single-Mode - AB - OS1/2 n = 1.4690 (1550 nm)

Loss (R->M)
PASS
Date / Time: 05/19/2015 04:27:33 AM
Test Limit: TIA-568-C Singlemode ISP
Limits Version: 1.9300
Operator:
DTX-1800 (1173017 v2.7400)
Module: DTX-SFM2(1172023)
Calibration Date: 06/12/2014
DTX-1800R (1173028 v2.7400)
Module: DTX-SFM2(1172028)
Calibration Date: 06/12/2014

Propagation Delay (ns)	170	
Length ft	114	PASS
Limit 16404		
	1310 nm	1550 nm
Result	PASS	PASS
Loss (dB)	0.17	0.41
Limit (dB)	1.53	1.53
Margin (dB)	1.36	1.12
Reference (dBm)	-5.84	-6.31

Number of Adapters: 2
Number of Splices: 0
Patch Type: Single-Mode - AB - OS1/2
Patch Length1 (ft): 3
Patch Length2 (ft): 3
Reference Date: 05/19/2015 04:07:05 AM
1 Jumper

Compliant Network Standards:

1000BASE-LX	100GBASE-ER4	100GBASE-LR4
10GBASE-E	10GBASE-L	10GBASE-LRM
10GBASE-LX4	40GBASE-FR	40GBASE-LR4
Fibre Channel 100-SM-LC-L	Fibre Channel 1200-SM-LC-L	Fibre Channel 1600-SM-LC-L
Fibre Channel 200-SM-LC-L	Fibre Channel 400-SM-LC-L	Fibre Channel 400-SM-LC-M
Fibre Channel 800-SM-LC-I	Fibre Channel 800-SM-LC-L	

LinkWare™ PC Version 9.3

Test Results.flw

FLUKE networks

LINKWARE™ PC
CABLE TEST MANAGEMENT SOFTWARE

Cable ID: SWITCHBOARD 1 - LVSWGR-01
Date / Time: 05/18/2015 12:23:53 AM n = 1.4830 (850 nm)
Cable Type: GIGALite 10XB - XB - OM4+ n = 1.4780 (1300 nm)

Test Summary: PASS
Modal Bandwidth: 4900MHz-km (850 nm)
Modal Bandwidth: 4900MHz-km (1300 nm)

Loss (R->M)
PASS
Date / Time: 05/18/2015 12:23:53 AM
Test Limit: TIA-568-C Multimode
Limits Version: 1.9300
Operator:
DTX-1800 (1173017 v2.7400)
Module: DTX-MFM2(1172040)
Calibration Date: 06/12/2014
DTX-1800R (1173028 v2.7400)
Module: DTX-MFM2(1173007)
Calibration Date: 06/12/2014

Propagation Delay (ns)	88	
Length ft	58	PASS
Limit 6562		
	850 nm	1300 nm
Result	PASS	PASS
Loss (dB)	1.04	0.75
Limit (dB)	1.56	1.53
Margin (dB)	0.52	0.78
Reference (dBm)	-21.72	-22.34

Number of Adapters: 2
Number of Splices: 0
Patch Type: GIGALite 10XB - XB - OM4+
Patch Length1 (ft): 3
Patch Length2 (ft): 3
Reference Date: 05/17/2015 11:11:36 PM
1 Jumper

Compliant Network Standards:

10/100BASE-SX	1000BASE-LX	1000BASE-SX
100BASE-FX	100GBASE-SR10	100GBASE-SR4
10BASE-FL	10GBASE-LRM	10GBASE-LX4
10GBASE-SR	40GBASE-SR4	ATM155
ATM155SWL	ATM52	ATM622 Fiber Optic
ATM622SWL Fiber Optic	FDDI Fiber Optic	Fibre Channel 100-M5-SN-I
Fibre Channel 100-M5E-SN-I	Fibre Channel 1200-M5-SN-I	Fibre Channel 1200-M5E-SN-I
Fibre Channel 133	Fibre Channel 1600-M5-SN-S	Fibre Channel 1600-M5E-SN-I
Fibre Channel 1600-M5F-SN-I	Fibre Channel 200-M5-SN-I	Fibre Channel 200-M5E-SN-I
Fibre Channel 266	Fibre Channel 266SWL	Fibre Channel 400-M5-SN-I
Fibre Channel 400-M5E-SN-I	Fibre Channel 400-M5F-SN-I	Fibre Channel 800-M5-SN-S
Fibre Channel 800-M5E-SN-I	Fibre Channel 800-M5F-SN-I	

LinkWare™ PC Version 9.3

Project: ROSSLYN METRO STATION
Test Results.flw
Site: ROSSLYN METRO STATION

FLUKE networks.

END OF SECTION

SECTION 16265

BATTERY AND BATTERY MONITORING SYSTEMS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes requirements for storage battery, battery monitoring system, battery-disconnect circuit breaker, battery racks, and electrolyte spill containment system as well as training requirements.

B. Requirements for separate chargers and inverters, which are not integrated into a single Battery and Battery Monitoring System, are described in Section 16266, BATTERY CHARGER. If new battery is to be provided, include new Electrolyte Spill Containment System, new battery disconnect, new battery racks, and all new battery appurtenances and components.

1.2 RELATED SECTIONS

A. Section 16060, GROUNDING AND BONDING

B. Section 16128, WIRE AND CABLE FOR TRACTION POWER

C. Section 16149, WIRE, CABLE, CABLE TRAY, AND TERMINATION PANEL FOR SCADA SYSTEMS

D. Section 16602, REMOTE TERMINAL UNIT (RTU) FOR TIE BREAKER STATIONS

E. Section 16604, NETWORK SWITCH FOR TBS SCADA AND AUTOMATION SYSTEMS

1.3 REFERENCES

A. Comply with codes and regulations of Jurisdictional Authorities.

B. National Electrical Code (NEC).

C. National Electrical Manufacturers Association (NEMA): PE1, Uninterruptible Power Systems.

D. American National Standards Institute (ANSI): C39.1, Requirements, Electrical Analog Indicating Instruments; and Z55.1, Gray Finishes for Industrial Apparatus and Equipment.

E. ANSI/NEMA: PB1, Panel boards, and 250, Enclosures for Electrical Equipment (1000 Volts Maximum).

F. ANSI/IEEE: C57.12.90, Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers; 450, IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead- Acid Batteries for Stationary Applications, and 484, IEEE Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications; IEEE 485, Recommended Practice for Sizing Lead

Acid Batteries for Stationary Applications; IEEE 1578, Recommended Practice for Stationary Battery Electrolyte Spill Containment and Management; IEEE 1491 ERTA, IEEE Guide for Selection and use of Battery Monitoring Equipment in Stationary Applications.

G. UL: 50, Enclosures for Electrical Equipment; 67, Panel boards; 94, Tests for Flammability of Plastic Materials for Parts in Devices and Appliances; and 198C, High-Interrupting-Capacity Fuses, Current Limiting Type.

H. ASTM International (ASTM):B187 Standard Specification for Copper Bar, Bus Bar, Rod, and Shapes; and D635 Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position.

I. ANSI/American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE): 52.1, Gravimetric and Dust Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter.

J. ANSI/American Hardboard Association (AHA): 135.4, Basic Hardboard.

K. The equipment manufacturer shall maintain ISO 9001 or ISO 9002 certification

1.4 SUBMITTALS:

A. General: Submit the following for approval in accordance with Special Provisions and with the additional requirements as specified for each:

B. Shop Drawings: In accordance with requirements of Table16265-1 herein.

1. Certification

2. Documentation

3. As-built drawings: All As-built drawings provided shall comply with WMATA.

4. Operations and Maintenance Manuals:

a. Describe and include in manuals procedures for:

1) Battery testing and for optimizing:

a) Float voltages.

b) Equalizing voltages.

c) Equalizing time adjustments.

d) Quarterly maintenance.

e) Bi-annual maintenance.

2) Include in manual the Shop Drawings listed in Table 16265-1. Print Shop Drawings on folded pages in accordance with the General Requirements.

3) Preventive Maintenance Instructions

C. A Test plan and schedule of Testing shall be furnished at least a month before Testing is scheduled for WMATA approval. The cost of performing the test, necessary travel, boarding and lodging for three WMATA Engineers at a local hotel for the duration of testing, shall be included as a separate line item in the proposal for supplying respective Batteries.

1.5 QUALITY ASSURANCE

A. Source Quality Control

1. Design and production tests: Perform and submit, in accordance with the General Requirements, certified test results for the following tests on the Battery.

a. Storage battery: Perform tests (on new battery systems) to determine the following:

1) Ampere-hour rating of battery during 3-hour discharge period.

2) Charge rate starting from fully discharged state based on 105-volt terminal voltage, to 90 percent of fully charged state within 12 hours.

3) Maximum short-circuit current available at battery terminals at full charge.

B. Furnish products of a manufacturer regularly engaged in the manufacture of uninterruptible power systems.

C. Qualifications of Instructor for Operation and Maintenance Training: See Special Provisions.

1.6 PRODUCT DELIVERY, STORAGE AND HANDLING:

A. Ship battery cells assembled and filled to proper level with electrolyte and fully charged. On charge date must be clearly marked on outside of boxes or pallets.

B. Store equipment in secure and dry storage facility.

1.7 WARRANTY FOR STORAGE BATTERY:

A. Manufacturer shall furnish a FULL 5-year warranty with a continued 15-year straight-line, prorated warranty against manufacturing defects and workmanship for a total of 20 years. In addition, the battery manufacturer shall furnish a 10-year warranty against any manufacturing defects in the post and post/seal construction of cells. It is acknowledged that temperature has an effect on battery service life. Manufacturer shall provide written statement of the prorate effect of temperature on warranty during service life.

B. Instructional Equipment (Storage Batteries Instructional Equipment described in later sections)

PART 2 PRODUCTS

2.1 MANUFACTURERS:

The Battery shall be manufactured by the following or approved equal:

1. BAE (Lead-selenium)

2.2 PRODUCTS AND MATERIALS:

A. Storage Battery:

1. Complete with accessories and battery racks.

2. Battery: 60 Cells Battery: Industrial grade capable of full service life in either an industrial UPS duty cycle application or for standby DC power backup in a switchgear or communications application.

a. Acceptable Lead Selenium Batteries are as follows: Lead Selenium-Low Antimony (Less than 1.6 percent antimony content preferred); tubular plate or equal construction with a minimum positive plate thickness of 0.31 inches.

1) Not used.

2) Note: The replacement Batteries Catalog Numbers listed below are given for a projected matchup with the existing batteries in the WMATA System. The Contractor shall provide necessary calculations to prove that the proposed batteries match the UPS and the Switchgear Control Power Requirements. The sizing calculations shall be performed by the Vendor/Contractor in accordance with the applicable Standards listed under Article 1.03, References, and such sizing calculations shall be submitted for WMATA approval before Batteries are ordered by the Contractor.

a) BAE 2V 4 OPzS 200 (8-Hour Rating: 208 Ah) approved equal.

3) Cycling duty: Capable of numerous cycling discharges at full load. Corresponding minimum number of cycles for each discharge duration representing 100 percent of the available cycles: 30 seconds, up to 15,000 events; 30 seconds to 1.5 minutes, up to 8,000 events; 1.5 minutes to 4 minutes, up to 4500 events and 3 hours, 1500 events minimum.

4) The proposed Switchgear Power Control Batteries shall be capable of providing the necessary control power requirements of the applicable switchgear, which will be provided to the Contractor at the time of the Bid.

5) Cell container:

a) Extra strength transparent plastic made of industry accepted SAN material, providing clear view of cell interior.

b) Internal elements shall be constructed to withstand any stresses caused by variation of temperature without affecting standard service life, normal effects of aging caused by temperature notwithstanding.

c) Ample sediment space below cell plate to prevent premature battery failure.

d) Markings indicating the minimum and maximum levels of electrolyte to be maintained. Markings should be provided on two opposite sides of the jar container.

c. Post type: Post should be of a sliding dead top threaded brass or copper insert design with a total of two to eight posts per cell depending on ampere-hour rating of the cell design. Posts shall be of a "raised" design, i.e. one that is fully accessible for taking readings on the post with a Cellcorder or similar ohmic measurement testing device.

d. Intercell connector may utilize material that provides safety and anti-corrosion benefits. PVC material is not allowed. If insulated material is used with connectors, the material shall be low-smoke, zero halogen. (See NFPA 130) FRE Fiber-glass. Intercell connectors can be lead or lead/tin plated copper connectors. Hardware (bolts, nuts, and washers) shall be 316 stainless steel.

e. Container cover:

1) Cover must be sealed to provide a permanent leak proof seal. Sufficient clearance is required from the plate grids to allow for expansion and contraction of plate without cracking or splitting. Cells determined to have a cover leak within the warranty period shall be replaced at no additional cost to the Authority.

2) Insulating material: Free from circuit leakage and impurities detrimental to plates or separators and impervious to absorption of electrolyte.

3) NEMA flame arrestor vent plugs are required as part of the battery accessory package. If flip-top flame arrestor is available from Manufacturer, one shall be provided per cell.

4) Flammability Rating: UL 94-VO, ASTM D635, self-extinguishing shall be available as an option if requested by the Authority.

f. Post seal: Historically proven and demonstrated leak-proof design. Cells determined to have a post seal leak within the warranty period shall be replaced at no additional cost to the Authority.

g. Factory test and shipping capacity: Batteries shall exhibit 100-

percent capacity at time of delivery from factory. Cells shall be factory tested to confirm voltage and capacity. Float voltages shall also be confirmed to be within plus or minus 0.05 volts from the average cell voltage prior to shipment.

3. Accessory equipment: (For Battery Rooms System wide – AC Rooms, Traction Power Substations (TPSS), Traction Power Tie Breaker Stations (TBS) and other Facilities)

a. One thermometer.

b. One insulated (rated 1000V) torque wrench for battery connection. (Option when specified.)

c. Insulated tools for battery maintenance, testing, and installation, 1000V AC/DC rated insulation (Maximum Exposure) shall meet following standards:

1) IEC 900 or equivalent US Standards for insulated Hand Tools

2) ASTM 1505, Standards for insulated Tools

3) Impact Resistant and Flame Retardant

4) Comply with OSHA requirements 29 CFR Part 1910.331 to 335 Sub-part K, Meet NFPA 70E requirements

Tools for BAE OPzS Bank:

Quantity	Description
6	3/8” square drive torque wrench (50-250 inch-pounds)
6	3/8” square drive socket wrench
6	3/8” square drive socket wrench mini
6	3/8” square drive 8MM male hex bit socket
3 sets	3/8” square drive male hex bit sockets 1/8”, 5/32”, 3/16”, 7/32”, 1/4”, 5/16”, 3/8”, 7/16”, and 1/2”

Note: Check with BAE if 17MM tools are required for batteries being supplied. If 17MM tools are required, provide six each of 3/8-inch square drive sockets and six each of 3/8-inch square drive sockets long in addition to tools listed above.

d. One cell-lifting device complete with strap and spreader per 60-cell string.

e. One set of stainless steel connecting hardware, (e.g., bolts, and nuts and lock washers Stainless steel type 316 plus 10 percent spares.)

f. One set of cell numbering kits; if multiple strings, shall include A-xxx, B-xxx, etc. - The positive cell for each bank shall be labeled #1. The negative shall be labeled #60.

g. One set of terminal plates, insulated if available. Spare single lug on cell numbers 1 and 60.

h. Set of inter-cell connectors per new order.

i. One set of manufacturer-recommended inter-racking cable and load terminal lugs.

j. One flame arrestor per cell with 20 percent additional spare flame arrestors if standard arrestors are supplied. Prefer a flame arrestor with flip-top opening for easy access to water-fill and specific gravity readings and 10 percent spare flame arrestors with flip-top per bank. Flip-top type BAE P/N 4322252 or approved equal.

k. Two portable lifting jigs may be required for battery/batteries as recommended by battery manufacturer, for each battery room for new installations. (This will be a separate order option as set out in the individual Project specification Section requirements document when required.)

l. Battery Monitor (BM): Alber model UXIM or approved equal, stationary battery monitor system designed for use in Industrial applications. Monitor shall be a standalone system, in that no external computer is required for normal operation and capable to integrate to SCADA. The monitor shall measure voltage, current and temperature and performs the internal resistance test on all connected batteries and constantly monitored against defined thresholds, provide early warning of potential battery problems by performing a proactive, resistance test, to reliably predict battery performance to ensure optimal battery performance and battery life. The battery monitoring system shall include remote monitoring capabilities with the following features:

1) Communication Protocol: DNP3.

2) Embedded Web servers permit Web browsing from PC on the network for quick real-time battery viewing to inspect data in easy to interpret graphical views for all cell and string level parameters, active monitor status and state of active or latched alarms.

3) Embedded Web servers permit Web browsing from PC on the

4) Optional Embedded email clients for alarm notifications and data delivery of battery parameters (XML format) with priority handling of message sent to responsible service technicians.

5) Local USB connectivity to view and analyze battery systems using laptop computers.

6) Cell Level Measurements

    a) Individual Cell Resistance
    b) Individual Cell Voltage
    c) Individual Intercell Resistance

d) Electrolyte Level (Optional)

7) System Level Measurements

a) Overall Volts

b) String current (Charge/Discharge/Float)

c) Ripple Current (Optional)

d) Ambient Temperatures

e) Ground Fault Currents (Optional)

8) System Alarms

Monitored parameters shall have assigned alarm threshold, when goes outside the normal range, the Alarm LED lights and a Form C contact energizes. The event shall be programmed to stay latched until the alarm is cleared.

Install monitor on a 19” rack mount or in a wall mount enclosure. Provide rack or cabinet, signal wiring, communication wiring, power wiring and conduits to ensure correct operation. Provide power wiring and conduits from nearest available distribution panel as selected by the Engineer. The Cat6 communication cable shall be connected to the substation network switch.

4. Battery rack:

a. Rack shall be constructed to properly house tubular-plate cells as a continuous battery string. The rack shall be of non–seismic construction.

1) Two-tier type fabricated from rugged steel construction that is painted with anti-corrosive, acid resistant, flame retardant, maintenance-free Santoprene (non-PVC) or approved equal covered rails to provide an electrically isolated surface on which the cells can rest.

2) Suggested Racks (or approved equal):

a) The following racks are suggested for the 60 Cell String of Selenium- Lead Batteries:

i) BAE Rack No. BAE 172001072B for BAE 2V 4 OPzS 200 Batteries. (2-Step 2 Tier)

b) For Battery replacement at an existing location, a 3-step or other configuration rack may be used in lieu of a 2-tier rack if space is limited. Approval is required prior to installation of 3-tier or other configuration rack.

c) If a different rack configuration is chosen and approved by WMATA, consult with battery manufacturer to ensure that a correct spill containment system is ordered.

5. Training for Storage Batteries:

a. Training requirements for storage batteries should be divided into two types of scheduled sessions:

1) Installation and annual/bi-annual maintenance testing as recommended by the manufacturer.

2) Quarterly and regular scheduled maintenance requirements as recommended by the manufacturer.

b. Training for each segment shall take approximately 1/2 day (4 hours) each, and the schedule will be mutually agreed upon by the Authority, Contractor, and the manufacturer. A set of up to 4 days of training shall be provided at no-charge to the Authority. Additional sessions shall be subject to a training fee if required.

c. Course material shall include installation instruction manual(s) and operations and maintenance manuals as provided by the manufacturer.

d. Storage battery training shall be provided by a qualified instructor who has demonstrated experience in the installation and service of batteries and is agreed upon by the Authority, Contractor, and the manufacturer.

6. Battery Electrolyte Spill Containment

a. Battery Spill Containment and Safety Equipment: The following stationary battery compliance equipment shall be included to meet all the requirements of the building and fire codes including OSHA, NFPA, EPA, International Fire Code (IFC), International Building Code (IBC), Underwriters Laboratory (UL)-VXMB, and UL NEBS.

1) Each spill containment barrier shall have a 4-inch sill at least 1 inch greater than the overall rack dimensions. Barriers shall be coated in safety yellow to ensure resistance to acid and dielectric properties. The barrier shall be of adjustable design. Barriers shall be complete with all hardware for assembly and shall be anchored to the floor with drop-in anchor bolts.

2) A liquid-tight containment liner with a minimum thickness of 80 mils shall protect the flooring within the containment area. The liner shall be ULC recognized, Class A fire rated, acid resistant, with dielectric properties and meet the flame-retardant requirements of ASTM.

b. Battery Electrolyte neutralization and absorption pillows shall be included unless otherwise specified to completely fill the spill containment area. Each pillow shall be double lined and individually serialized and tagged for traceability. Each pillow shall have the ability to absorb at least 3 quarts of liquid. All battery electrolyte neutralization and absorption pillows shall be treated with fire-retardant material that meets ASTM standards. Provide 30 percent spare pillows Acceptable Spill Containment Systems (or approved equal).

1) Enviroguard Spill Containment System for 2V 4 OPzS 200 Batteries and Rack Model: Eagle-19-148 UL listed Barrier

system, 14 ga painted barrier w/80-mil Polymeric Liner, includes thirteen 12x12 color indicating acid absorbing pillows and fourteen Socs.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Initial Energizing

1. Initial energizing will be under the guidance of the manufacturer's engineering representative who will advise Contractor and Authority personnel on step-by-step procedures.

3.2 FIELD QUALITY CONTROL

A. Field Testing and Inspection

1. General:

a. Conduct field inspection and field testing.

b. Battery shall be installed and placed on charge by manufacture “charge-by date” listed on each cell. Battery must be placed on temporary charge if not installed and charged by such date. Batteries placed on temporary charge must be witnessed and approved by WMATA.

2. Field inspection

a. Prior to field testing, check equipment installation in accordance with manufacturer's recommendations and applicable IEEE and ANSI standards, including verification of the following:

1) Connection of circuit in accordance with wiring diagram.

2) Tightness of cable and busbar connections.

3) Battery-Intercell bus-link integrity.

3. Field Witness Testing

a. Provide services of manufacturer's engineering representative and supporting field crew for a period not less than 3 labor-days per location. Conduct tests in the presence of the Contracting Officer Representative. Perform approved tests including, but not limited to, those specified and applicable under IEEE.

b. Test grounding of equipment

c. Storage battery: Upon installation at Site, measure float voltage, equalize voltage, electrolyte specific gravity (with digital hydrometer), electrolyte level, internal resistance and inter-cell resistance with cellcorder or other approved Ohmic measuring device and record serial numbers. All measurements shall be submitted in a report form to the Contracting Officer Representative for permanent record; report shall be in electronic format. All cells shall be free of cracks, leaks, and defects.

1) Measure battery-charging voltage, electrolyte specific gravity, and level.

2) Compare measured value and correct to manufacturer's specified tolerances.

3) Acceptance testing:

a) Perform installation related measurement and acceptance testing in accordance with ANSI/IEEE 450 and ANSI/IEEE 484. In the event of a conflict between this procedure and the ANSI/IEEE documents, this procedure shall take precedence.

b) Calibrate test equipment used during this procedure, calibration date not older than 1 year from the date of testing, calibrations traceable to NIST. Have calibration stickers visible on all applicable equipment. As a minimum, calibrate the following equipment with accuracy as stated:

i) Equipment Accuracy:

Multimeter	±0.1%
Micrometer	±0.5%
Current measuring equipment	±1 amp
Cell voltage monitor equipment	±0.5%

c) Initial measurements:

i) Read and record individual cell voltages to two decimal places while the battery is on a normal float charge.

ii) Read and record Intercell connection resistance using a MicroOhm meter. Remake and re-measure connections that have a resistance measurement more than 10 percent or 5 microhms, whichever is greater, over the average for each type of connection.

iii) Read and record each cell's voltage, internal resistance, intercell connector resistance, temperature or conductance. Note make and model of meter.

iv) Read and record the specific gravity of each cell. (Digital Hydrometer)

v) Read and record the temperature of each cell and the ambient temperature of the room.

vi) Battery Monitor Test:

a) The Battery Monitor shall be fully functional before the battery discharge tests are conducted.
b) Using a laptop, the contractor shall verify access to the BM webpages.
c) Configure and program the battery monitor for SCADA.
d) The contractor shall program the BM with the approved alarm setting.

d) Battery Monitor Test:

i) The battery monitor shall be fully functional before the battery discharge test is conducted.

ii) Using a laptop, verify access to the BCM webpage for monitoring and programming.

iii) Program the BCM with the approved alarm setting.

iv) Verify and record all functions listed in the Battery Monitor description section of this specification.

e) Pass-fail criteria:

i) The battery is acceptable only if the battery operates for a minimum of 3 hours and the battery capacity is at least 90 percent. No individual cell capacity may be less than 80 percent. Base capacity on a temperature correction to 77 degrees F.

ii) Specific gravities shall be within the manufacturer's specified values.

iii) Intercell connection resistances shall be within 10 percent or 5 microhms, whichever is greater, over the average for each type of connection.

f) Report the following items:

i) Abnormal heating detected by the infrared thermography

ii) Time of battery operation under full load. Include final overall battery voltage at time of under-voltage device operation.

iii) Battery capacity percentage corrected to 77 degrees F. Base this on the battery manufacturers' constant power data.

iv) Graph of overall battery voltage versus time. Supply this data in tabular form.

v) Graph of individual cell voltages at the 3-hour point, at the final reading, and at the 80 percent, 90 percent, and 100 percent capacity points. Supply this data in tabular form.

vi) Graphical display of cell float voltages before and after test, with the required minimum and maximum values annotated Supply this data in tabular form.

vii) Graphical display of temperature-corrected, cell-specific gravities with the required minimum and maximum values annotated. Supply this data in tabular form.

viii) Graphical display of impedance/conductance values. Supply this data in tabular form.

ix) Current limit value of rectifier section of UPS.

x) Print-out of AC ripple voltage wave form during full-load and no-load conditions. Include AC ripple current values.

xi) After battery is discharged to level of 105 volts, initiate equalizing mode. After 12 hours, measure ampere-hours to determine that 90 percent of recharge condition remains; then recharge to 100 percent level.

g) Compliance:

i) If testing indicates failure to comply with specified requirements, replace, correct, or modify equipment so that it does comply.

ii) Conduct additional tests witnessed by the Contracting Officer Representative to prove compliance with specified requirements.

B. Field-Testing Personnel: See Special Provisions.

C. Submit certified test reports.

Table 16265-1

SCHEDULE OF SHOP DRAWINGS AND MANUFACTURES'S LITERATURE

Item	Requirements	Submit (a)	Within Days (b)
1.	Outline dimensions, including weights and foundation requirements for equipment furnished.	X	90 (c)
2.	Front views, floor plans, and mounting details for Equipment furnished.	X	90(c)
3.	List of standard symbols and nomenclature.	X	120(c)
4.	Interconnection wiring diagram	X	120(c)
5.	Equipment-arrangement drawings including battery racks.	X	120(c)
6.	Storage battery, including; a. Ampere-hour rating at 3-hour discharge rate. b. Available short-circuit current. c. Weight of each cell.	-	45(d)
NOTES AND LEGEND			

a) Initial submittal for approval. Unless otherwise shown, in accordance with General Requirements.
b) Approved final drawings or certified data.
c) After receipt of Notice to Proceed.
d) After completion of tests.

END OF SECTION

SECTION 16266
BATTERY CHARGER

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes requirements for providing battery charger to serve tie-breaker stations. This Section applies to systems with separate charger units (not combined into a single assembly.).

1.2 RELATED SECTIONS

A. Section 16052, BASIC MATERIALS AND METHODS FOR TRACTION POWER

B. Section 16060, GROUNDING AND BONDING

C. Section 16128, WIRE AND CABLE FOR TRACTION POWER

D. Section 16149, WIRE, CABLE, CABLE TRAY, AND TERMINATION PANEL FOR SCADA SYSTEMS

E. Section 16265, BATTERY AND BATTERY MONITORING SYSTEMS

F. Section 16291A, HUMAN MACHINE INTERFACE (HMI) PANEL FOR TIE BREAKER STATIONS

G. Section 16341, METAL ENCLOSED DC SWITCHGEAR FOR TIE BREAKER STATIONS

1.3 REFERENCES

A. Comply with codes and regulations of Jurisdictional Authorities.

B. National Electrical Code (NEC).

1.4 SUBMITTALS

A. General: Submit the following for approval in accordance with Special Provisions and with the additional requirements as specified for each:

B. Shop Drawings and related documentation:

1. Outline dimensions, including weights and foundation requirements for equipment furnished.

2. Front views, floor plans, and mounting details for furnished equipment.

3. One-line block diagrams.

4. List of standard symbols and nomenclature.

5. Elementary diagrams with description of each circuit.

6. Interconnection wiring diagram.

7. Rating information of rectifier/charger, and static inverter.

8. Wiring diagrams, showing external wiring of furnished equipment.

9. Details of cooling and filtering system.

10. Shipping and handling data, including instructions for unloading, handling, erection, and installation.

11. Bills of material.

12. Copies of field test data (to be submitted within 2 weeks after completion of testing)

C. Certification.

1. Field test plan and certified copy of test data dated and clearly identified within 2 weeks after completion of field testing.

D. Operations and maintenance training material: Five copies not later than 60 calendar days prior to commencement of training.

E. Operations and Maintenance Manuals:

1. Include in manuals general theory of operation of the equipment including description, purpose and function of:

a. Rectifier/charger.

b. Communication interface and protocols

2. Describe and include in manuals procedures for:

a. Alignment and adjustment of operating, detector and alarm circuits.

b. Troubleshooting, including test procedures and system logic in identifying malfunctions.

3. Include in manual copies of all Shop Drawings. Print Shop Drawings on folded pages in accordance with the General Requirements.

4. Include Submittals in electronic format in addition to hard copy Submittals.

1.5 QUALITY ASSURANCE

A. Source Quality Control

1. Design and production tests: Perform and submit, in accordance with the General Requirements, certified test results for the following tests on the inverter and charger system or provide certified test reports on identical unit. Furnish certified test reports showing test data and results as well as manufacturer's comments on results of short-circuit tests.

a. Storage battery: The storage battery associated with operation of these charger-inverter systems are either existing-to-remain or are to be replaced under this Contract.

b. The battery charger sized to charge a fully discharged Battery to 90 percent of its capacity within 12-hour rectifier/charger.

B. Furnish products of specified manufacturers.

C. The Authority reserves the right to witness any testing of equipment.

1.6 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Ship each unit securely packaged and labeled for safe handling in shipment and to avoid damage or distortion.

1. Temporary Bracing: Where necessary, brace each unit for hoisting, lowering, and skidding into position. Temporary internal bracing of the equipment shall be labeled as follows: TEMPORARY-REMOVE BEFORE OPERATION.

2. Store equipment in secure and dry storage facility.

1.7 SITE OPERATIONS AND MAINTENANCE TRAINING

A. Conduct Site training utilizing equipment in normal operating condition permitting trainees to perform hands-on work. Refer to Special Provisions.

PART 2 - PRODUCTS

2.1 PRODUCTS AND MATERIALS

A. Rectifier/Charger: Hindle Power (or pre-approved equal) AT30-130-050-E-480-M-X-M-X-A-G-L-F-S with Cabinet style 5018 with following options and requirements:

1. Input voltage: 480 volts, 3-phase, 60 hz; Output at nominal 130 volts DC: 50amps

2. Input and output circuit breaker rating: Trip rating as recommended by manufacturer with medium AIC.

3. Communication board with Ethernet and fiber optic interfaces; Fan control contactor; NEMA Type 2 drip shield.

4. Efficiency: 95 percent at nominal input voltage

5. Power factor: Input power factor 0.7 minimum with rated input voltage

6. Battery eliminator DC output filtering

7. Copper ground bus; AC lightning arrester; fungus proofing; static proofing; temperature compensation; barrier type alarm terminal blocks

8. Auxiliary Alarm Relay Board: Consists the following alarm relays combined together

on a single board. Each relay has one set of isolated, dry form C contacts (SPDT) wired to a terminal strip:

a. High-Low AC Voltage Alarm Relay

b. High DC Voltage Alarm Relay

c. Low DC Voltage Alarm Relay

d. Ground Detection Alarm Relay

e. Charger Failure Alarm Relay

f. Common Alarm Relay

10. 1% digital LED meter for Vdc, Adc, timer hours, alarm settings

11. Ground detection indicator lights.

12. High/Low AC voltage alarm and indicator lights.

13. Automatic charger shutdown due to battery room ventilation fan failure.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Equipment locations: Locations for equipment may require adjustment due to larger sizes of replacement equipment. Develop detailed layout plans for alternate locations as necessary (submit to Authority in accordance with requirements of Section 01110, Scope of Work) and Special Provisions; maintain all required code-required clearances and access requirements during development of alternate layouts.

B. Install charger in accordance with the following requirements:

1. Anchor equipment to floor. Install input and output power and control wiring as shown. Ground enclosures.

C. Initial Energizing:

1. Initial energizing of each inverter and charger shall be under the guidance of the manufacturer's engineering representative who will advise Contractor and Authority personnel on step-by-step procedures.

D. Apply touch-up paint where necessary.

E. Install all required communication cables between the inverter and charger and the facility RTU.

3.2 FIELD QUALITY CONTROL

A. Field Testing and Inspection:

1. General:

a. Conduct field inspection and field testing at each Site to ensure proper operation of devices and equipment provided.

b. Operation and protective-device setting: The Contractor is responsible for setting and calibrating protective devices for proper operation during field testing.

2. Field inspection:

a. Prior to field testing, check equipment installation in accordance with manufacturer's recommendations and applicable IEEE and ANSI standards, including verification of the following:

1) Connection of circuit in accordance with wiring diagram.

2) Tightness of cable and bus bar connections.

3) Battery-inter-cell bus-link integrity.

3. Field Testing:

a. Furnish equipment to perform tests.

b. Provide services of manufacturer's engineering representative and supporting field crew as required. Conduct tests in the presence of the Contracting Officer Representative. Perform approved tests including, but not limited to, those specified.

c. Test grounding conductors and enclosures on equipment for continuity to room ground bus.

d. Simulate battery room exhaust fan failure and observe the battery charger shutting down in accordance with code requirement.

e. The Contractor is responsible for testing communication between installed equipment and the facility RTU. Simulate the following failure and verify correct alarm status reported to the RTU:

1) Battery Charger Failure

f. The Contractor shall submit a discrepancy report for all I/O points indicating problems found and required action.

g. The Contractor is responsible for testing communication between installed equipment and the facility Network Switch to verify remote access to the equipment using a web browser.

B. Field-Testing Personnel:

1. Provide services of manufacturer's engineering representative and engineering technicians and journeymen personnel as necessary to set-up and implement testing.

2. Provide field testing to demonstrate load rating of inverter. Perform at each Site where an inverter is installed. Provide load bank to demonstrate output capability

of inverter to the satisfaction of WMATA.

C. Submit certified test report.

END OF SECTION

SECTION 16270
TRANSFORMERS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes requirements for transformers and automatic voltage regulators.

B. Design Criteria:

1. Floor loading: Transformer base compatible with floor design-loading of 250 pounds per square foot.

1.2 REFERENCES

A. Comply with codes and regulations of Jurisdictional Authorities.

B. NEC.

C. NEMA: ST1, ST20, 107, 250.

D. ANSI: C57.12.50, C57.12.51, Z55.1.

E. ASTM: D3487.

F. ANSI/IEEE: C57.12.00, C57.12.90, C57.12.91, C57.15, C57.94, C57.113, C57.124, C62.11.

G. IEEE: C57.12.01.

H. UL: 506, 1561, 1562.

1.3 SUBMITTALS:

A. Submit the following for approval in accordance with Special Provisions and with the additional requirements as specified for each:

1. Shop Drawings for the products of this Section.

2. Certifications:

a. Furnish certified test report of all design and short-circuit tests performed on one transformer of each type and rating furnished in this Contract or on identical transformers built by same manufacturer within the last 5 years.

b. Furnish certified test reports of all routine, impulse, and partial discharge tests performed on each transformer furnished in this Contract.

c. Furnish certificates from manufacturers verifying that products conform to specified requirements. Include certificates with submittal of Shop Drawings.

3. Documentation:

a. Field-testing plan

b. Operation and Maintenance Manuals

1.4 QUALITY ASSURANCE

A. Qualifications: Select a manufacturer who is regularly engaged in the repetitive production of transformers and automatic voltage regulators of the types and ratings described in these specifications using the latest technology and who has a proven record of successful manufacturing and testing of same or similar type equipment. The equipment manufacturer shall have and maintain ISO 9001 or ISO 9002 certification.

B. Factory Testing:

1. General requirements for distribution transformers:

a. Perform design tests and short-circuit tests on one transformer of each type and rating furnished in this Contract.

b. Perform routine tests, impulse test, and partial discharge test on each transformer furnished in this Contract.

2. Dry-type transformers: Perform design and routine tests in accordance with IEEE C57.12.01, ANSI/IEEE C57.12.91, and the following additional tests:

a. Perform impulse test without using surge arrestors to protect the transformer.

b. Perform partial discharge test to establish partial discharge inception and extinction voltage during induced voltage test in accordance with ANSI/IEEE C57.124 and the following requirements:

1) Measure partial discharge in pico-coulombs at 10-percent increments when the voltage is raised from 70 percent to 200 percent and lowered from 200 percent to 70 percent of rated voltage during the induced voltage test to verify the following requirements:

a) Inception of partial discharge occurs above 120 percent of rated voltage when voltage is raised from 70 percent to 200 percent. At 120 percent, the partial discharge reading shall be 10 pico-coulombs or less.

b) Extinction of partial discharge occurs above 120 percent of rated voltage when voltage is lowered from 200 percent to 70 percent and partial discharge level is below 10 pico-coulombs.

c. Perform short-circuit tests in accordance with IEEE C57.12.01 and ANSI/IEEE C57.12.91.

3. Oil-filled transformers: Perform design and routine tests in accordance with ANSI/IEEE C57.12.00, C57.12.90, and the following additional tests:

a. Perform lightning impulse test without using surge arrestors to protect the transformer.

b. Perform partial discharge test using one of the following test methods:

1) Perform partial discharge test to determine radio-influence voltage and associated partial discharge inception and extinction in accordance with NEMA 107 and the following requirements:

a) Measure radio-influence voltage in micro-volts at 25-percent increments when the voltage is raised from 100 percent to 200 percent and lowered from 200 percent to 100 percent of rated voltage during the induced voltage test to verify the following requirements:

i) Radio-influence voltage not to exceed 650 micro-volts for transformers with 34.5 kV primary voltage.

ii) Inception (i.e. sudden increase in radio-influence voltage as the voltage is raised from 100 percent to 200 percent) occurs above 120 percent of the highest tap voltage.

iii) Extinction (i.e. sudden decrease in radio-influence voltage as the voltage is lowered from 200 percent to 100 percent) occurs above 120 percent of the highest tap voltage.

2) Perform partial discharge test to determine terminal partial discharge level and partial discharge at 5-minute intervals on each terminal during a 60-minute period of induced voltage test in accordance with ANSI/IEEE C57.113 and to verify the following requirements:

a) Terminal partial discharge level not-to-exceed 200 pico-coulombs.

b) Partial discharge measurements during a 60-minute period meet the requirements of ANSI/IEEE C57.113.

3) Perform short-circuit tests in accordance with ANSI/IEEE C57.12.00 and C57.12.90.

4. Perform design and routine tests for general-purpose transformers in accordance with NEMA ST20.

5. Notify WMATA Engineering and all additional stakeholders not less than 14 days prior to factory testing to allow witnessing of tests.

1.5 PRODUCT DELIVERY, STORAGE AND HANDLING:

A. Ship each unit securely packaged and labeled for safe handling in shipment and to avoid damage or distortion.

B. Temporary Bracing: Where necessary, brace transformer for hoisting, lowering, and skidding into position. Label temporary internal bracing: TEMPORARY - REMOVE BEFORE OPERATION.

C. Protection against Concealed Damage: Include within shipping container mechanical impact recorder of rating recommended by manufacturer for shipment by railroad and submit impact-record chart with manufacturer's instructions for disposition of damaged materials.

D. Store transformers in secure and dry storage facility.

1.6 OPERATION AND MAINTENANCE TRAINING

A. In accordance with Special Provisions.

PART 2 - PRODUCTS

2.1 MATERIALS

A. General Requirements for Transformers:

1. Interchangeability: Components of the same type, size, rating, functional characteristics, and make shall be interchangeable.

2. Nameplate provided on each transformer in accordance with reference standard.

3. Efficiency/losses:

a. Dry-type, three-phase transformers, 501 kVA and larger:

1) Full-load efficiency: 98.0 percent minimum.

2) Half-load efficiency: 98.5 percent minimum.

3) No-load loss, maximum, of nameplate kVA rating:

a) 34.5 kV - 480Y/277-volt units: 0.7 percent.

b. Oil-filled, three-phase transformers, 501 kVA and larger:

1) Full-load efficiency: 98 percent minimum.

2) Half-load efficiency: 98.5 percent minimum.

3) No-load loss: 0.4 percent maximum of nameplate kVA rating.

4. Impedance voltages:

a. Three-phase transformers, 501 kVA and larger:

1) 34.5 kV - 480Y/277 volt units: 5.75 or 6.25 percent.

b. Other transformers, lower ratings, or lower voltages: In accordance with applicable standard or manufacturer's standard.

5. Magnetic circuit:

a. Material: Best quality non-aging silicon steel sheet with high-magnetic permeability and low hysteresis and eddy-current losses. Sheet insulated on both sides with inorganic material to minimize eddy current.

b. Laminations cut in direction of grain, free of burrs and uniformly stacked in same direction without gap. Lap and butt joints closely fitted and rigidly clamped to minimize core loss and noise level.

c. Capable of up to 10 percent overvoltage excitation while maintaining magnetic-flux density below saturation level.

6. Audible sound level: Distribution transformers designed to limit average sound level to within the following maximum values when measured at the factory in accordance with ANSI/IEEE C57.12.91 for dry-type transformers and in accordance with ANSI/IEEE C57.12.90 for oil-filled transformers:

a. Dry-type, three-phase transformers:

Transformer Rating (kVA)	Sound Level for Ventilated,Self-CooledRating (dB)	Sound Level for Ventilated,Forced-Air-Cooled Rating (dB)
150	55	-
225, 300	58	-
500	60	67
750, 1,000	64	67
1,500	65	68
2,000		69
3,500	68	71
3,750	70	73

b. Oil-filled, three-phase transformers:

Transformer Rating (kVA)	Sound Level for Ventilated,Self-Cooled Rating (dB)	Sound Level for Ventilated,Forced-Air-Cooled Rating (dB)
150, 225, 300	55	-
500	56	61
750	57	61
1,000	58	61

7. Winding:

   a. Dry-type, 3-phase transformer, 501KVA and larger.

      1) Copper conductors free from burrs, kinks or silvers. Each winding braced for high-mechanical strength and spaced to provide adequate circulation for coolant.

   b. Dry-type, 3-phase and single-phase transformer 500KVA and smaller.

      1) Copper or aluminum conductors free from burrs, kinks, or slivers. Each winding braced for high-mechanical strength and spaced to provide adequate circulation for coolant.

      2) Aluminum-to-aluminum conductor joints welded to withstand mechanical and electrical short-circuit stresses.

      3) Copper-to-aluminum conductor joints outside winding made using one of the following:

         a) AMP Copalum crimp connector consisting of tin-plated copper barrel with one perforated tin-plated brass cylinder inserted inside barrel or equal. Hydraulic crimping tool used for electrical and mechanical effectiveness of joint.

         b) Du Pont Detaclad explosively bonded aluminum and copper plate bus connection at transition consisting of aluminum face of Detaclad piece welded to aluminum leads from winding and copper face of Detaclad piece silver-soldered to copper bus.

8. Buses: Transformers equipped with adequately supported copper or aluminum buses, with the following additional requirements:

   a. Busbar silver-plated or tin-plated at bolted connection point.

b. Joints welded or bolted for mechanical and electrical short-circuit stresses.

c. For bolted connections on aluminum busbar, mark recommended torque permanently and legibly at points of connection. Joints treated to prevent corrosion.

d. For bolted connection of aluminum-to-aluminum or aluminum-to-copper buses, provide Belleville washers or helical spring locknuts to maintain positive pressure on joint.

9. Ground pad: Enclosure equipped with grounding pad, drilled and tapped for connection to station grounding system.

10. Finish: Metallic surfaces degreased, cleaned with iron-phosphate solution, rinsed with chromic acid solution, dried and finished with light-gray coating, ANSI Z55.1, Color 61; 2 mils minimum DFT as follows:

a. Indoor location: Electrostatically deposited polymer polyester powder or epoxy powder, cured by baking and UL recognized, or spray enamel.

b. Outdoor location: Epoxy enamel.

11. Nameplate: Provided on each transformer, showing manufacturer's name and brand designation, reference standard, type, class, rating, and other required information as applicable in accordance with reference standard.

12. Space heaters:

a. Each distribution transformer for indoor use provided with 120-volt, single-phase, 60 Hertz heating element to facilitate drying and prevent condensation under no load or light load conditions.

b. Heaters enclosed in grille guard with no sharp edges and located so that they are accessible for replacement. Heaters controlled by thermostat adjustable from 40 degrees F to 80 degrees F. Panel ammeter, approximately 2-1/2 inches square, marked to indicate heater load. Thermostat set in accordance with manufacturer's recommendations.

c. Power and control circuits to heaters and thermostat connected and protected up to devices and to incoming junction box with galvanized-steel rigid conduit or liquid-tight flexible conduit. Heater power junction box sized 4 inches square by 2 inches minimum depth and located at top of transformer for top entry of minimum 3/4-inch conduit. Remote connection leads to power source labeled: 120-volt and NEUTRAL.

B. Distribution Transformers:

1. Transformers for indoor use:

a. IEEE C57.12.01, ANSI C57.12.50, C57.12.51, ANSI/IEEE C57.12.91, UL 1562, floor-mounted, dry-type, ventilated self-cooled/forced-air-cooled, Class AA/FA, or ventilated self-cooled, Class AA, as specified, double-wound, three-phase, 60 Hertz with secondary neutral brought out, and using the following type of winding construction for both primary and secondary windings of a transformer:

1) Solid cast-epoxy windings.

b. kVA rating:

1) Transformers, 501 kVA and larger: Ventilated self-cooled kVA rating as shown, with capacity in current-carrying parts to permit 33-1/3 percent increase in kVA rating (Class AA/FA) by operation of integral forced-air cooling fans.

2) Transformers, 300 kVA and smaller: Ventilated self-cooled, Class AA, kVA rating as shown.

c. Voltage rating: 34.5 kV delta to 480Y/277 volts or 13.8 kV delta to 480Y/277 volts, as shown.

d. Enclosure:

1) NEMA 250, Type 2, drip-proof enclosure with removable front and rear panels and ventilation louvers to prevent entrance of falling dirt and liquids and accidental access to live parts.

2) Provision for jacking, lifting, skidding, and towing in any direction.

3) Provision for complete isolation of core and coils from the enclosure using rubber vibration isolation pads or other suitable means.

4) Core visibly grounded to ground pad with flexible grounding conductor sized in accordance with applicable ANSI and UL Standards.

5) Exterior surfaces of core and structural members of core and coil assembly protected from corrosion after assembly with a coating having a temperature rating exceeding the temperature rating of the associated transformer insulation system.

e. Rated insulation-level withstand:

1) 34.5 kV - 480Y/277 volt units:

a) High-voltage winding, lightning basic-impulse voltage (BIL) without the use of surge arrestors:150 kV

b) High-voltage winding, low-frequency withstand: 50 kV.

c) Low-voltage winding, lightning basic-impulse voltage (BIL):

i) Transformers with solid cast-epoxy windings: 30 kV.

d) Low-voltage winding, low-frequency withstand: 4kV.

f. Transformer terminals:

1) High-voltage side: Provide tin-plated terminal pads in air-filled transition compartment suitable to receive and terminate cable or bus connections from high-voltage switchgear, as applicable. Bushings or terminations through sidewall of transformer enclosure shall have minimum BIL equal to that of transformer.

2) Low-voltage side: Provide tin-plated terminal pads in air-filled transition compartment opposite high-voltage side, suitable for bus connection to low-voltage switchgear. Terminations and transformer secondary bus or terminal supports shall have short-circuit current-withstand equal to that of low-voltage switchgear; minimum BIL equal to that of transformer.

g. Insulation system:

1) 185-degree C insulation system for dry-type transformers having solid cast-epoxy windings with maximum allowable continuous full-load temperature rise above average ambient temperature of 30 degrees C and maximum ambient temperature of 40 degrees C:

a) By winding resistance: 80 degrees C.

b) By hottest spot in winding: 110 degrees C.

h. Taps:

1) Capable of delivering rated output at each setting.

2) 34.5 kV - 480Y/277 volt units: Two 2.5 percent taps above and two 2.5 percent taps below rated voltage on primary side.

3) Tap changing on face of coil using removable links accessible from front or back of transformer.

i. Temperature Monitoring:

1) Intelligent Electronic Device (IED) by SEL (SEL-2414) or equal to monitor the temperature of the transformer with the capability to interface with the AC feeder breaker (hared wired via the SEL equipment) and the SCADA RTU via the station network switch using fiber connection with DNP3 protocol.

2) Winding temperature monitoring (device 49T) shall initiate an alarm and trip sequence on detection, the IED shall annunciate a remote alarm through the SCADA system and trip the 34.5kV feeder breaker via its 86 lockout device. Additionally, on transformer rated 501kVA upwards, the IED will activate forced air cooling fans by means of an auxiliary relay, Auxiliary relay may be located in associated low-voltage switchgear.

3) Winding temperature settings as recommended by the transformer manufacturer.

4) Winding temperature to be displayed on a digital readout on the IED and remotely via SCADA and on local HMI panel via SCADA/Ethernet switch.

5) The IED shall communicate using DNP3 protocol.

6) The IED shall permit remote access from the SCADA system and shall be configurable by a personal computer as defined in Specification Section 16146.

j. Solid cast-epoxy winding construction:

1) Each winding for each phase separately cast as a rigid tubular coil and installed coaxially around the core.

2) Each winding reinforced with glass cloth.

3) Epoxy characteristics:

a) High electrical, mechanical and thermal strength.

b) Non-flammable and self-extinguishing.

c) Coefficient of expansion compatible with that of copper windings.

d) Suitable for operation in ambient temperature range from minus 40 degrees C to plus 40 degrees C without cracking or degradation.

e) Nonhygroscopic and suitable for operation at 40 degrees C ambient temperature and 100 percent humidity.

4) Epoxy cast in metal mold under vacuum to ensure homogeneous casting free from voids.

5) Windings fabricated in a facility with successful experience in the manufacture of solid cast-epoxy transformer windings.

k. Forced- air cooling fans and control panel:

1) Forced-air cooling fans to permit 33-1/3 percent increase in transformer ventilated self-cooled kVA rating.

2) Power supply for fans and control panel provided from associated transformer. Fans, control panel, and associated circuits equipped with protective devices.

3) Control panel flush mounted with transformer enclosure and equipped with the following:

a) Automatic-manual selector switch for controlling forced-air cooling fans. Fans activated by thermometer in automatic position.

b) Indicating lights:

i) Green light for control power available.

ii) Amber light for fans operating.

c) Automatic exercising of fans, once per month

2. Transformers for outdoor use:

a. ANSI/IEEE C57.12.00, C57.12.90, floor-mounted, oil-filled, self-cooled/forced-air cooled, Class OA/FA or self-cooled, Class OA, as specified, double-wound, three-phase, 60 Hertz with secondary neutral brought out through insulating bushing.

b. kVA rating:

1) Transformers, 501 kVA and larger: Self-cooled kVA rating as shown, with capacity in current-carrying parts to permit 15 percent increase in kVA rating (Class OA/FA) by operation of integral forced-air cooling fans.

2) Transformers, 300 kVA and smaller: Self-cooled, Class OA, kVA rating as shown.

c. Voltage rating: 34.5 kV delta to 480Y/277 volts as shown.

d. Enclosure:

1) Sealed-tank construction with lifting brackets, cooling radiator, braced and anchored to withstand jacking, skidding and towing.

2) Equipped with two 1-inch pipe fittings, one at top and one at bottom of tank, for filling and filter connection; one 1-inch drain valve; and one 3/8-inch sampling valve.

e. Insulating oil: ASTM D3487. Mineral insulating oil free from polychlorinated biphenyl (PCB) contamination.

f. Rated insulation level:

1) For 34.5 kV to 480Y/277-volt transformers: Class 34.5 kV, capable of withstanding:

a) Low-frequency voltage: 70 kV.

b) Full-wave basic-impulse voltage: 200 kV.

g. Bushings:

1) 34.5 kV - 480Y/277-volt transformers:

a) Primary bushings with glazed-porcelain surface, located on sidewall of transformer, with 34.5 kV insulation class with minimum 200 kV BIL in an air-filled junction box.

b) Secondary-line bushings with glazed-porcelain surface, located on sidewall of transformer opposite primary bushings, with 1.2 kV insulation class with minimum 10 kV BIL in an air-filled junction box.

2) Secondary neutral bushings:

a) Low-voltage neutral bushings to be provided for each transformer.

b) Low-voltage neutral bushings same as low-voltage line bushings, except neutral bushings may have reduced low-frequency insulation level in accordance with ANSI/IEEE C57.12.00.

3) Provide silver-plated terminal pads suitable to receive cable terminals on high-voltage side and to receive cable terminal on low voltage side, as necessary.

h. Maximum allowable temperature rise under continuous full-load above ambient temperature of 30 degrees C average, 40 degrees C maximum.

1) By winding resistance: 55 degrees C.

2) By hottest spot in winding: 65 degrees C

i. Taps:

1) Capable of delivering rated output in each position.

2) For 34.5 kV to 480Y/277-volt transformers: Two 2.5-percent taps above and two 2.5-percent taps below rated voltage on primary side.

j. Tap changer:

1) Externally mounted and manually operated no-load tap changer with locking provision for each position.

2) Tap-change operating handle arranged for operation at no-load only through key interlocking with associated primary breaker in open position.

k. Monitor/auxiliary relay: As specified for transformers for indoor use.

l. Liquid-level indicator: Float-operated magnetic-type continuously indicating liquid level, installed for easy removal and replacement without unsealing transformer enclosure.

m. Pressure-relief device: Mechanically operated self-resetting and self-reclosing type with manually resettable visual indicator and set of NO contacts to initiate tripping of associated primary breaker when pressure-relief device is activated.

n. Pressure vacuum-gauge range: Minus 10 to plus 10 psig.

o. Forced-air cooling fans and control panel:

1) Forced-air cooling fans to permit 15 percent increase in transformer self-cooled kVA rating.

2) Power supply for fans and control panel provided from associated transformer. Fans, control panel and associated circuits equipped with protective devices.

3) Control panel with NEMA 250, Type 3R enclosure and equipped with the following:

a) Automatic-manual selector switch for controlling forced-air cooling fans. Fans activated by thermometer in automatic position.

b) Indicating lights:

i) Green light for control power available.

ii) Amber light for fans operating.

iii) Automatic exercising of fans once per month.

p. Surge arrestor: ANSI/IEEE C62.11, intermediate class with metal-oxide varistor construction, one per phase, mounted on high-voltage terminals in air-filled junction box with the following requirements:

1) For 34.5 kV - 480Y/277 volt unit: Hubbell/The Ohio Brass Company Type PVR, Catalog Number 218629; General Electric Company Tranquell XE, Catalog Number 9L12PGB036; or approved equal; with ratings as follows:

a) Duty-cycle voltage, kV, rms: 36.

b) Maximum continuous operating voltage, kV, rms: 29.

c) Insulation-withstand impulse test voltage, kV: 200.

C. Automatic Voltage Regulator:

1. ANSI/IEEE C57.15, indoor, self-air-cooled, induction-type.

2. Compensating automatically for voltage drop on long feeder runs of nominal 480-volt, three-phase, three-wire or nominal 480/277-volt, three-phase, four-wire, 60 Hertz system as shown.

3. Range of regulation: As necessary to maintain output voltage of regulator at receiving end of feeder not less than 466 volts or 480 volts as specified, minimum range of plus 10 percent and minus 10 percent range of regulation. Regulation adjustable over full range in increments of 1 percent or less.

4. Circuit kVA rating: 45 KVA

5. Equipped with automatic solid-state control for maintaining output voltage within plus or minus 1 percent of pre-selected voltage level over temperature range of minus 30 degrees C to plus 40 degrees C.

6. Speed of response: Voltage correction to start within four cycles and complete within 3 seconds for 2 percent change and within 10 seconds for adjustment to required voltage.

7. Capable of withstanding a minimum of 15 times rated full-load current under short-circuit condition.

8. Provide Powersmith's Cyberhawk Model EX3-B-600W-10A-EB-D or equal power meter with communication. This unit will have display motion included.

9. Operating mechanism permanently lubricated.

10. Full-load efficiency: 98 percent minimum.

11. 150-degree-C insulation system; maximum allowable temperature rise under continuous full-load above an average ambient temperature of 30 degrees C and maximum ambient temperature of 40 degrees C: 80 degrees C.

12. Enclosure: Fabricated from sheet steel, wall-mounted or floor-mounted as appropriate, as follows:

    a. Electric rooms, traction-power substations and tie-breaker stations: NEMA 250, Type 1.

    b. Fan shafts and pumping stations: NEMA 250, Type 3R.

PART 3 INSTALLATION

3.1 INSTALLATION

A. Install each transformer and automatic voltage regulator in position shown and in accordance with manufacturer's recommendations and NEC requirements.

B. Make power-conductor and control-wire connections in accordance with manufacturer's drawings and as shown.

C. Ground each transformer and automatic voltage regulator as shown and in accordance with Section 16060, GROUNDING AND BONDING.

D. Connect space heater circuit to prevent condensation during installation.

3.2 FIELD QUALITY CONTROL

A. Prior to testing, check transformer installation in accordance with ANSI/IEEE C57.94.

B. Submit field-testing plan including, but not limited to, the following tests. Furnish equipment and perform the following tests in the presence of the Contracting Officer Representative, in accordance with approved procedure:

1. Distribution transformers: In accordance with applicable standards

2. General-purpose and specialty transformers:

   a. Perform insulation-resistance tests winding-to-winding and winding-to-ground. Record and correct resistance value to temperature.

   b. Perform AC high-voltage tests between high-voltage winding and low-voltage winding, between high-voltage winding and ground and between low-voltage winding and ground. Perform tests at 65 percent of factory test voltage for 1-minute duration.

   c. Test voltage ratio of each tap. Results must not to deviate more than 0.5 percent from calculated ratio. Set taps as directed.

   d. Check polarity by means of vector check.

3. Automatic voltage regulator:

   a. Test circuit for connection in accordance with wiring diagram.

   b. Test insulation of non-grounded conductors to ensure 10-megohms minimum resistance to ground.

   c. Test regulator enclosure for continuity to grounding bus.

   d. Set output voltage and check actual output voltage and speed of voltage correction as follows:

      1) For regulator supplying ventilation fans in fan shaft, set output voltage to 466 volts minimum and check actual output voltage and speed of voltage correction for providing required voltage output within specified time for each increment of additional load brought on line by sequential automatic starting of fan motors when load is supplied by each of two sources.

      2) For regulator supplying pumps in drainage pumping station, set output voltage to 466 volts minimum and check actual output voltage and speed of voltage correction for providing required voltage output within specified time for each increment of additional load brought on line by automatic starting of the first pump followed by the second pump when load is supplied by each of two sources.

      3) For regulator supplying facilities other than fan shafts and drainage pumping stations described above, set output voltage to nominal 480 volts and check actual output voltage and speed of voltage correction for providing required voltage output within

specified time to the connected load.

e. For regulators supplying ventilation fans in fan shafts and pumps in drainage pumping stations, check actual output voltage and speed of voltage correction for providing required output when total load of all connected motors is transferred from one source to the second source by simulating power failure in each of the two sources connected to the automatic transfer switch.

f. Verify functionality of the protective devices.

g. Verify functionality of the remote indications through SCADA.

C. Submit certified test reports.

END OF SECTION

SECTION 16291A

HUMAN MACHINE INTERFACE PANEL (HMI) FOR TIE BREAKER STATIONS

PART 1 GENERAL

1.1 SUMMARY

A. This section includes the following:

1. This section specifies Human Machine Interface (HMI) system required at each Tie Breaker Station (TBS)

2. Each TBS shall be equipped with a Machine Interface (HMI) system that will communicate with the Remote Terminal Unit for local monitoring & control of various station equipment and perform as an annunciator panel.

3. At the TBS, the HMI shall interface to the RTU via the station network switches for controls and monitoring of DC switchgears, UPS/battery chargers, PLC, DC trace recorder and/or other various Intelligent Electronic Devices (IEDs).

4. Fully assembled and tested HMI unit and its accessories shall be provided and installed by the CONTRACTOR at location as shown in the drawings. Contractor is responsible for verifying the locations shown in the drawings. Where the location shown in the drawings needs to be changed due to a field condition, the contractor shall communicate with WMATA's SCADA group, and submit an alternate installation location for approval by WMATA prior to installation. The Contractor is further responsible to locate HMI in the remaining TBS and submit design drawing of the equipment layout for approval

5. The Contractor is responsible for the installation of all wirings (including power and network wirings) for the HMI unit. The Contractor is responsible for all tests and simulations required to verify that the installation is done consistent with WMATA requirements and applicable standards for the proper functioning of the HMI system.

6. The Contractor is responsible for the programming and testing of the HMI.

B. Related sections

1. Section 16051B - Scope of Work for Traction Power Substations & Tie Breaker Stations

2. Section 16051D - Supervisory Control and Data Acquisition (SCADA) Scope of Work

3. Section 16052 - Basic Materials and Methods for Traction Power

4. Section 16149 - Wire, Cable, Cable tray and Termination Panel for SCADA System

5. Section 16602 - RTU for Traction Power Systems

6. Section 16060 - Substation Grounding and Bonding

7. Section 16604 - Network Switch for SCADA and Automation Systems

8. Section 16606 - SCADA System Integration Site Acceptance Test Plan

C. Power Requirement

1. 125 Volts DC from the station DC Panel.

1.2 REFERENCES

A. Codes, Regulations, Reference Standards and Specifications:

1. Codes and regulations of jurisdictional authorities (AHJ)

2. NEC

3. NEMA: 250, ICS-6, 12

4. IEEE: C37.90.1

5. ANSI Z55.1

6. UL: 94, 508A

7. EIA: RS 232.C

8. ASHRAE/ANSI : 135-2001

9. ICEA: S-68-516

B. Drawings:

1. HMI Cabinet Layout

2. HMI Cabinet Wiring Diagram

3. HMI Buzzer circuit wiring diagram

1.3 SUBMITTALS

A. Submit the following for approval in accordance with the General Requirements in accordance with Special Provisions and with the additional requirements as specified for each:

1. Shop Drawings: Show the following as a minimum:

a. Proposed changes and revised equipment layouts

b. Electrical wiring termination diagrams

c. Electrical and mechanical installation detail drawings

d. Wire and cable schedules and interconnection diagrams

2. Product Data: Submit annotated product data for each item of equipment and re-submittal for mechanical or electrical equipment which changes as a result of required modification.

3. As-Built Documents: Prior Substantial Completion develop an as-built documents as follows:

   a. As-built drawings of the installation: 11-inch by 17-inch composite interconnection wiring diagram showing the entire HMI interface system. Provide sufficient copies to be stored in each HMI interface cabinet door pocket.

   b. Approved copies of each submittal.

   c. Provide As-built drawings in both AutoCAD and PDF formats on CD in sleeves.

B. Certification:

1. Certificates from manufacturer verifying that equipment conforms to the specified requirements.

2. Certification of current (not pending) UL listing and labeling for the assembled HMI panel.

C. Spare Parts Lists: in accordance with original manufacturer recommendation.

1.4 QUALITY ASSURANCE

A. Qualifications:

1. Schneider Electric's Industrial HMI model: Magelis # XBT GT 7340, in an enclosure as shown on the reference drawings and specified here shall be provided.

2. Audible Alarm System: Horn/buzzer capable of reproducing sustained tones through the use of HMI control. Federal Signal Model Streamline part #LP4-09-028.

3. For accessory circuit components for the HMI System, provide as shown in the reference drawings or equal.

4. HMI Assembler: The HMI cabinet assembly shall be UL certified. The assembly of HMI System, including but not limited to the flushing of the HMI unit to the cabinet, the internal power and communication wiring and piping shall be performed in accordance with UL 508A requirement and as such, each HMI cabinet would carry the 508A Label sticker on it

B. Coordination:

1. HMI installer coordinates with electrical installers and other contractors as to the exact locations for the installation of HMI cabinet inside the station and sizes of new conduits and their proposed routes to be used by HMI wiring systems.

2. The contractor shall provide all software and licenses required for installation, testing and configuration of the HMI.

C. For Codes, Regulations, Reference Standards, and Specifications, refer to Article 1.02 above.

D. End-to-End Test:

1. The end-to-end test is scheduled and supported by the installation contractor.

2. The Contractor shall demonstrate the proper functioning of the completed HMI system including all components and telemetry between each piece of equipment monitored or controlled by the HMI in the presence of the WMATA Engineer.

3. Verification that the HMI is communicating with the RTU at the station.

4. Verification that each device monitored by a remote sensor is monitored from the RTU and operation of the device is observed in the field thru the HMI.

5. Verification that each device controlled by the RTU system is be operated with the control command initiated at the HMI.

6. Simulation of sensors by shorting contacts is to be avoided unless other activation is not possible.

E. Submit certified test report within ten days after completion of field tests.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Equipment for each facility shall be delivered in accordance with the access dates in Special Conditions, and shall be coordinated with the Engineer.

B. Ship each unit securely packaged braced and labeled for safe handling in shipment and to avoid damage or distortion.

C. Temporary Bracing: Where necessary, brace each unit for hoisting, lowering and skidding into position. Temporary internal bracing of the equipment labeled as follows: TEMPORARY-REMOVE BEFORE OPERATION

D. Store equipment in secure and dry storage facility.

PART 2 PRODUCTS

2.1 PRODUCTS AND MATERIALS:

A. HMI Unit System Hardware

1. System Hardware : The system shall consist of stand-alone industrial Graphical displays manufactured by Schneider Electric Industries model: Magelis # XBT GT 7340 with the following configuration as a minimum:

   a. Display/Screen:

      1) Screen Size: 15" with multi-window capability.

      2) Resolution/Type: XGA/TFT Color

      3) Color: 65,536 colors.

      4) Backlighting: CFL - 50,000 h with adjustable contrast and brightness.

      5) Entry Mode: Analog touch pad, resolution 1,024 X 1,024.

   b. Memory:

      1) Application/Backup: 32 MB/512 KB.
      2) Additional: Compact Flash Card: 512 KB.

   c. Power Supply: 24V dc.

   d. Software – Vijeo Designer with 10 Licenses.

   e. Interface:

      3) Serial: COM1 SubD9 (RS232C-422) & COM2 RJ45 (RS485).
      4) USB: Two Ports Type A Master.
      5) Ethernet: 1 Port 10/100 Base T.
      6) Auxiliary: 3 digital outputs and 1 digital input, 1 speaker output.
      7) Multimedia: 1 video/sound input.

   f. Configuration: Secure data sharing between terminals, user-friendly, multi-language, fonts, simulation on PC.

   g. Construction: UL-listed, Class 1, Div 2. - IP56 construction for water spray protection

   h. Station Power Source to Unit Power Supply: 125 VDC from Station DC Panel.

B. Cabinets:

1. The HMI shall be installed in a stand-alone cabinet (Saginaw Part number 24EL2012LP) or equal.

2. Construction: NEMA 12.

3. Apply two finish coats, ANSI No. 61, Light Gray, to exterior surface.

4. Paint interior per manufacturer's standard.

5. Fabrication

   a. Cabinet with fixed side, rear and roof panels, front swing, full hinged door with flush latch operable by both Screwdriver and hand.

   b. Provide Cut-out for flush mounting of the HMI.

   c. The cabinet layout as referenced in Section 1.02. B.1

6. Mounting: Cabinet shall be wall mounted type using metallic mounting ears, welded to the enclosure. No holes at the back of the enclosure are allowed for mounting.

7. Field Wiring Terminals:

   a. Provide terminal blocks in the HMI cabinet to accommodate all field wires including spares.

8. Nameplate:

   a. Black laminated plastic composition with permanent white engraved lettering, and beveled edges.

   b. Nameplate 2-1/2 inches by 6-1/2 inches, inscribed in letters ½ inch high: "SCADA HMI"

   c. Fastened to panel using small round-head screws.

   d. Installed inside cubicle and cabinets with cement.

   e. Submitted for approval.

9. Audible Signal (Buzzer Circuit):

   a. Provide a horn/buzzer mounted on the HMI cabinet capable of reproducing sustained tones through the use of HMI control. The recommended horn is supplied by Federal Signal, Model Streamline part
   #LP4-09-028 or equal.

   b. The audible signal shall be triggered by the HMI under WMATA's defined alarms.

   c. The buzzer circuit as referenced in Section 1.02.B.3

C. Wiring/Cabling: Wiring for the HMI system operation shall be done as shown in the drawings, referenced in Section 1.02. B and specified here and other related Sections.

D. HMI CONFIGURATION

1. The contractor is responsible for the development of HMI configuration files and the complete point to point tests of all HMI points.

2. The development of the HMI configuration will use as inputs:

a. I/O point listed on Section 16051D Part 4.0 Tables

PART 3 EXECUTION

3.1 INSTALLATION

A. HMIs shall be delivered and installed as shown in accordance with approved shop drawings at the following facilities:

1. Tie Breaker Stations

B. Perform work in accordance with the NEC.

C. Terminate interface points in the HMI cabinet.

D. Ground HMI cabinet and power supplies as shown on the drawings, in accordance with Section 16060 and as specified here.

E. Communications between HMI and RTU shall be via the station Network Switch (gateway) using Ethernet connection. HMI accesses each power system equipment through the RTU.

G. The Contractor is responsible for testing all HMI input signals to verify correct status and telemetry signal levels, control and annunciation. I/O equipment supplied under this contract that is not reporting properly shall be corrected and retested at no extra cost to WMATA. The Contractor shall submit a discrepancy report for all I/O points indicating problems found and required action.

3.2 FIELD QUALITY CONTROL

A. The Contractor shall perform polarity and continuity test on all interconnection wiring.

B. HMI field test shall be integrated with the SCADA field acceptance test. Refer to section 16606 SCADA System Integration Site Acceptance Test Plan.

C. The Contractor shall label all wiring terminations to reflect the connection points.

END OF SECTION

SECTION 16341

METAL-ENCLOSED DC SWITCHGEAR

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Related Work Specified Elsewhere: Special Provisions

1. This Section includes requirements for the design, manufacture, install and test 750V dc Switchgear.

1.2 REFERENCES

1. Reference Standards:

a. ASTM B187/B187M – Standard Specification for Copper, Bus Bar, Rod, and Shapes and General Purpose Rod, Bar, and Shapes

b. IEEE C37.14 – Standard for Low-Voltage DC Power Circuit Breakers Used in Enclosures

c. IEEE C37.16 – Preferred Ratings, Related Requirements, and Application Recommendations for Low-Voltage AC (635 V and below) and DC (3200 V and below) Power Circuit Breakers

d. IEEE C37.17 – Trip Systems for Low-Voltage (1000 V and below) AC and General Purpose (1500 V and below) DC Power Circuit Breakers

e. IEEE C37.20.1 – Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear

f. IEEE C37.34 – Standard Test Code for High-Voltage Air Switches

g. IEEE C37.90 – Standard for Relays and Relay Systems Associated with Electric Power Apparatus

h. IEEE C37.100 – Standard Definitions for Power Switchgear

i. ISO 9001 – Quality Management Systems - Requirements

j. NEMA CC1 – Electric Power Connection for Substations

k. NETA ATS – Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

l. NETA MTS – Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems.

m. NFPA 70 – National Electrical Code

n. NFPA 130 – Standard for Fixed Guide way Transit and Passenger Rail System

2. Reference Specification Section: Refer to the contract Scope of Work.

1.3 SUBMITTALS

A. Submit the following for approval in accordance with Special Provisions and with the additional requirements as specified:

1. Product Data:

2. Shop Drawings: In accordance with Scope of Work, Table I.

3. Certification

a. Design Tests reports or certified copies of test reports for identical units performed for each type and rating of switchgear and circuit breaker as assembled in its complete switchgear unit, furnished under this contract.

1) Tests shall conform to the most recent applicable standards requirements prior to submittal to the Authority.

2) Certified test reports shall be certified by and be representative of tests performed by an independent IEEE certified laboratory in the USA.

b. Certified test reports for specified factory production testing.

c. Certificates from manufacturer verifying that equipment conforms to the specified requirements

d. Certify switchgear complies with floor design loading of 250 pounds per square foot.

e. Factory design and production test data

f. Factory calibration report for Transducer

4. Spare Parts Lists: In accordance with the original manufacturer recommendation

5. Operating and maintenance manual

1.4 CLOSEOUT SUBMITTALS (NOT USED)

1.5 QUALITY ASSURANCE

A. Manufacturer Qualifications:

1. Select a manufacturer/installation contractor who is regularly engaged in production of similar switchgear and has demonstrated a successful record of providing/installing equipment of similar type and rating for extra heavy duty traction service for at least five similar projects.

2. The equipment manufacturer will be required to submit documentation to support

these qualifications as part of the Pre-Award process.

3. The equipment manufacturer shall have current ISO 9001 certification at the time of bid.

B. Preconstruction Testing:

1. Design Testing:

a. The manufacturer shall provide copies of circuit breaker design tests in accordance with the requirements of IEEE C37.14 (test requirements-9.1 through 9.3) and IEEE C37.20.1 (Test Requirement-6.2), as supporting evidence of a “test - certified design”, as defined in IEEE C37.100.

1) A table of compliance for these requirements shall be included, with all laboratory test data, photographs, etc. provided as attachments.

2) Certification that the equipment being offered is compliant with the current applicable Standards

b. For additional design tests, requested by the Authority and conducted after contract award, notify the Authority Representative 21 (twenty one) working days prior to testing to allow witnessing of tests in an independent ANSI certified lab.

c. All test reports shall be provided in electronic format

2. Production Testing:

a. Certified test reports shall be provided prior to granting a release for shipment from the Authority for shipment of the switchgear.

b. All tests in accordance with the requirements of IEEE C37.14 (Test Requirements, 9.4).

c. Submit test plans and procedures for all production tests and scheduled test dates for approval at least 21(twenty one) working days in advance of scheduled test dates.

d. No test results will be accepted prior to receipt and approval of test plans and procedures.

e. Allow for witnessing of all tests by Authority Representative at the option of the Authority

f. Notify the Authority Representative 21 working days prior to factory testing to allow witnessing of tests.

g. All test reports shall be provided in electronic format

3. Design and production Tests requirements are as follows:

1) Unless noted otherwise, the circuit breaker design and production tests in accordance with the latest edition of IEEE C37.14 Section 9, IEEE C37.16 including the following as applicable:

2) Design tests:

a) Sequence 1:

i) Short-time current test

ii) Continuous current test

iii) Load (low) current switching tests

iv) Endurance test

v) AC dielectric withstand test at 60%

b) Sequence 2:

i) Trip device calibration check test

ii) AC dielectric withstand test

iii) Peak current test

iv) Short-circuit current test

v) Trip device calibration check test

vi) AC dielectric withstand test at 60%

3) Production tests shall include the following:

a) Calibration test

b) Control, secondary wiring, and device check

c) Dielectric withstand voltage test

d) No-load operation test

4. Switchgear assembly tests: Table of compliance for these requirements shall be included, with all laboratory test data, photographs, etc. provided as attachments. The following tests are required in accordance with the requirements of IEEE C37.20.1

(a) Design Tests:

(i) Dielectric tests

(ii) Rated continuous current test

(iii) Momentary current tests

(iv) Mechanical endurance test

(v) Rod entry test

(vi) Flame resistance tests for applied insulation

(vii) Short time current withstand test

(viii) Paint qualification test

(b) Short circuit current withstand test

(c) Production Tests: All tests in accordance with requirements of IEEE C37.20.1

(d) Control wiring tests:

(i) Check wiring for accuracy, open circuits and short circuits, ground connections, and insulation integrity by means of high-potential, continuity and operational tests.

(ii) Subject wiring to high-potential test of 1,500 Volts 60 Hertz to ground for one minute.

(iii) Verify that wiring is in accordance with manufacturer's wiring diagrams.

(iv) Check wiring complete, including interconnections at shipping breaks

(e) DIO, DTR and Cable Shield system wiring and functional tests:

(i) Check wiring for accuracy, Verify that wiring is in accordance with WMATA DIO control schematic and contract drawings Check DIO function in accordance with DIO terminal block assignments in DIO specification.

(ii) Through secondary injection verify performance of the Digital Trace Recorder (DTR) and Cable Shield Monitoring System

(iii) Factory installation and functional testing of DIO, DTR and Cable Shield System should be complete and ready for connection to the SCADA system.

(5) Concurrent Scheduling of Factory Tests: The manufacturer shall schedule factory testing, through concurrently testing multiple switchgear lineups, to minimize the number of days needed to witness testing.

C. Major Components: All major components shall be products of the same manufacturer.

D. Components, Limit Switches, Relays, Assemblies and Sub-assemblies: All shall be listed or labeled and be rated for utility or heavy-duty industrial use. All components that are not UL Listed shall be identified as NOT LISTED in the parts list submitted for approval prior to manufacture.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Delivery and Acceptance Requirements:

1. Equipment for each facility shall be delivered after its completion and in accordance with the Special Provisions and shall be coordinated with the Authority.

2. Ship each unit securely packaged braced and labeled for safe handling in shipment and to avoid damage or distortion.

3. Temporary Bracing: Where necessary, brace switchgear for hoisting, lowering and skidding into position. Label temporary internal bracing: TEMPORARY- REMOVE BEFORE OPERATION

4. Protection against Concealed Damage: Include within shipping container mechanical impact recorder of rating recommended by manufacturer for shipment by railroad and submit impact record chart with manufacturer's instructions for disposition of damaged material.

5. Assembly for Shipment:

   a. Design enclosures to permit lifting by jacks or slings and moving horizontally on rollers or skidding in any direction.

   b. Maximum dimensions of shipping sections to be coordinated with the dimension of doors and access hatches to ensure shipping dimension will allow movement of switchgear through structure without damage to equipment or structure or undue difficulty.

   c. Draw-out relays mounted in their proper cases with moving parts properly secured and packed for shipment.

   d. Removable circuit breaker elements packaged separately.

   e. For shipping split, interconnecting wiring coiled on one side of the shipping split with matching terminal block on other side of split. Wiring and terminal block points identified for reconnection.

6. Store switchgear in secure and dry storage facility.

7. Temporary Bracing: Where necessary, brace switchgear for hoisting lowering and skidding into position

PART 2 PRODUCTS

2.1 MANUFACTURERS

A. Manufacturer List:

1. The switchgear/breakers shall be manufactured by the following or pre-approved equal:

   a. Secheron

b. Myers Controlled Power LLC

c. Powell

2.2 PERFORMANCE REQUIREMENTS

A. The furnished switchgear and cubicle lineup shall contain Distributed I/O (DIO) devices mounted within that physical switchgear, with all interconnections wiring and interfaces devices to communicate with the substation remote terminal unit (RTU) for remote control and indication. This shall include: DC cathode breaker, DC feeder breakers and DC positive and negative tie breakers. DIO shall communicate with the substation RTU using DNP3 protocol. Each DIO module shall be connected to the substation network switch by fiber optic cable.

B. The furnished switchgear and cubicle lineup shall contain Multi-function microprocessor-based relays as well as their associated equipment. Multi-function protective relays shall communicate with the substation RTU using DNP3, IEC61850 or and/or Modbus TCP protocols. Each relay shall be connected to the substation network switch by fiber optic cable.

C. The furnished switchgear and cubicle lineup shall contain a Digital Trace Recorder mounted on the switchgear to measure DC system parameters and provide stream data to station HMI and to remote servers. The DTR shall communicate the servers using DNP3 protocol over fiber optical cable

D. The furnished switchgear and cubicle lineup shall contain Cable Shield Monitoring system mounted within that physical switchgear, with all interconnections wiring and interfaces devices to communicate with the substation remote terminal unit (RTU) for remote indication. The cable shield monitor system shall communicate with the substation RTU using DNP3 or IEC61850 or Modbus TCP protocols. Each cable shield system shall be connected to the substation network switch by fiber optic cable.

E. Switchgear design shall be suitable for installation of shielded feeder cables, including termination of cable shields and feeder conductors.

F. For replacement of an existing DC switchgear, the new switchgear cubicle arrangements shall match with the existing breaker element sequencing and that of the dc positive (rectifier) bus duct and bus connections to utilize existing traction power feeder cable and to minimize field modification to the equipment. Locations where new bus ducts are being provided, the replacement bus duct termination points shall be coordinated with the opening in the switchgear

G. Cathode breaker busway connection interfaces shall be designed for connection to existing or replacement busway as indicated. For substations at which the existing cathode bus ducts are to be reconnected to new DC switchgear, and at which the existing cathode bus ducts are rated at less than 8000 amperes, the DC switchgear bus duct connections shall be designed to accommodate not only the existing bus duct but also a future retrofit to 8000 bus duct. Include all necessary hardware, adaptors, etc.

H. Replacement switchgear cable connectors shall be so located that the existing feeder cable can be re-used without making cable splices to the outgoing DC feeders. The specified control and interlock of the replacement switchgear shall be coordinated with the existing to remain equipment. Any modification to the existing equipment to achieve these interlocks shall require Authority written approval.

I. The switchgear shall be suitable for anchoring to new or existing insulated flooring without alteration of bus duct and cable tray height.

J. Comply with all requirements of Supervisory Control and Data Acquisition (SCADA) as specified herein and in other relevant sections of the specifications.

2.3 EQUIPMENT

A. DC Switchgear: Metal-enclosed, draw-out power circuit breaker switchgear in accordance with the following:

1. The switchgear shall be manufactured in accordance with specifying standards and shall have latest NEMA/IEEE certification as applicable prior to award of contract.

2. IEEE C37.20.1 for indoor use

B. Ratings

1. Maximum voltage: 1000 Volts, dc

2. Nominal voltage: 750 Volts, dc

3. Power frequency withstand: 3.7 kV, rms

C. Insulation Structure

1. Not to support combustion, produce toxic gases, absorb moisture or track

2. When subjected to electric arc, emission of conducting materials from insulating structure limited so as not to interfere with performance of circuit breaker.

D. Power circuit breakers:

1. IEEE C37.14, IEEE C37.16, IEEE C37.17, Roll-out type, single-pole, single-throw, air break, high-speed, direct acting, direct release series trip device, with electrically controlled solenoid closing, mechanically or electrical latching, and electrically controlled tripping, mechanically and electrically trip-free, complying with applicable parameters in Table 10 of IEEE C37.16 and with the following additional requirements:

a. Definition: A single-pole breaker constitutes a switching device with a single current path and a single arcing path during current interruption

b. Nominal voltage: 750 Volts dc

c. Rated maximum voltage: 1000 Volts dc

d. Insulation dielectric withstand: 3700 Volts RMS

e. Continuous Current ratings: 6000A for feeder or 8000A for cathode rated as indicated

f. Short-circuit interrupting capacity: 200 kA.

g. Operation counter: Non-resettable with at least four digits for recording trip operations

h. Endurance: Electrical and mechanical endurance performance not less than requirements in IEEE C37.16 (Table 12).

i. Control voltage:

1) 125 Volts dc nominal and individually fused

2) Upon loss of control voltage, a DC feeder circuit breaker shall automatically open.

a) The under voltage release mechanism shall be designed and rated to operate at 135V DC continuously without overheating.

j. Racking mechanism:

1) The circuit breaker alignment, shutter mechanism and racking mechanism are considered an integral part of the circuit breaker.

2) There shall be adequate clearance between equipment of the circuit breaker element and all equipment mounted on the switchgear enclosure.

3) The racking mechanism shall be designed and constructed for moving the breaker between three (3) positions:

a) Disconnected, test and connected positions

b) Clockwise rotation of the racking mechanism shall result in breaker movement toward the connected position and when in the fully racked-in connected position the racking mechanism shall turn freely.

c) Counterclockwise rotation of the breaker racking mechanism shall result in breaker movement from the connected to the test and then to the disconnected position.

4) The racking mechanism shall be a manually operated closed-door mechanism, designed to prevent over-travel, and equipped with guides for alignment of the breaker with a stationary unit and an indicator to show breaker position within the compartment.

5) Use of an electro-mechanical toggle device for racking mechanisms will not be permitted.

6) An inertia block device shall be installed in the cubical to absorb the force of the circuit breaker being inserted.

7) Breaker cubicles shall include guides to align the breaker with the stationary unit.

a) An indicator shall be provided, visible from the exterior of the switchgear, to indicate the breaker position within the compartment.

8) Racking mechanism gear ratio shall be designed in combination with the design of the shutters so that the shutters can withstand the force of the racking mechanism if the shutters fail to open as the breaker is racked in.

k. Connected position: Both primaries disconnect device and secondary disconnect device in full contact, breaker ready for normal operation.

l. Test position: Primary disconnects device open and separated by a safe distance, secondary disconnect device in full contact.

m. Disconnected position: Both primaries disconnect device and secondary disconnect device open and separated by a safe distance.

n. Primary connection (main disconnects): Connections between the removable and stationary unit made by male-and-female contacts, with the following additional requirements:

1) Silver-plated, high pressure contacts

2) Automatic shutter to cover the contact orifices when the breaker is in the test or withdrawn and uncover the orifices when breaker is returned from test to connected position.

3) The racking mechanism gear ratios shall be designed in combination with the design of the shutters covering the main stationary disconnect, such that the shutters can withstand the force of the racking mechanism if the shutters fail to open as the breaker is racked in.

o. Secondary connection (control and auxiliary disconnects): Control and interlocking circuit connections between stationary and removable elements of switchgear made using device consisting of recessed stationary receptacle and set of self-aligning contacts to accommodate control and interlock circuits, including spares, without resorting to auxiliary relays. An unbiblical chord arrangement satisfying the secondary connection requirements will be acceptable.

p. Auxiliary switch contacts: MOC Operated by breaker mechanism in both the connected and test position with sufficient number of contacts for operation, indication and interlocking of the breaker together with at least four spare sets of reversible contacts, each wired through secondary disconnect device contacts to accessible terminal blocks. The Truck Operated Contacts TOC for position remote indication and circuit breaker control and interlocks.

q. The breaker Shunt trip device shall operate from 125 Volts dc (nominal) control system.

r. Electrically operated, mechanically latched, electrically and mechanically trip free, non-pumping, quick make, quick break mechanism insuring full contact pressure until the time of opening with following additional requirements:

1) Voltage requirement:

a) Closing by means of closing solenoid mechanism and coil capable of operation from 90-140 Volts dc.

b) Tripping by means of tripping solenoid mechanism and coil capable of operation from 70-140 Volts dc.

2) Equipped with mechanical device on front of breaker, available with door closed, to manually (without electrical power) actuate tripping operations and with indicator, visible with door closed, to show open or closed condition.

a) Operable in the disconnected, test and connected positions.

s. Arc chute: Provided to house the main contacts, confine and direct opening arcs until extinguished.

1) The arc chute shall be comprised of a number of vertical steel arc splitter plates designed to confine and direct the arc and break the arc into a number of smaller arcs which are cooled and extinguished as the arcs move toward the top of the plates.

a) Ceramic plates are not permitted.

b) Proper extinguishing devices are to be included in the metallic splitter plates.

c) Splitter plates are to be insulated at the extremity to ensure that the arcs are extinguished.

2) The arc chute is to be constructed to prevent the escape of arc plasma and the emission of metal from beneath the arc chute.

3) The manufacturer shall demonstrate to the satisfaction of the Authority that the design of the switchgear does not result in operation of Energized Structure Relay or Grounded Structure Relay during fault interruption or opening under load fault openings, and that a voltage is not impressed on control wiring under fault conditions.

t. Main contacts: Surfaced with silver, non-welding silver alloy or equivalent combining high conductivity and necessary arc-resistant properties.

u. Integral wheels for moving a circuit breaker element in and out of a cubicle and sized to carry breaker weight without deforming or cutting into the concrete or amazite surface.

1) Plastic wheels are not acceptable.

2) The wheels shall roll (not slide) and guide the circuit breaker between full length guide bars to align the circuit breaker element to engage the racking mechanism.

3) No lifting devices shall be permitted to lift the circuit breakers in and out of its switchgear cubicle.

v. Removable elements for the same type and rating completely interchangeable.

E. Space Heater:

1. Each unit of switchgear including control panel provided with 120 Volt, single phase, 60 Hertz (rated for 240V) heating element to facilitate drying and prevent condensation.

a. Each switchgear unit shall be equipped with a separate ammeter for each heater.

b. No ground wires are allowed in the space heater.

2. Heaters shall be enclosed in grill guards with no sharp edges and located so that they are easily accessible for replacement only on de-energization of the switchgear bus and not located close to any equipment which may be adversely affected by their heat.

3. Heaters thermostatically controlled.

a. Thermostat adjustable from 40°F to 80°F

b. Thermostat set in accordance with manufacturer’s recommendation

c. Panel ammeter shall be approximately 2-1/2 inches square, ampere range to indicate heater load.

F. Positive Bus Bars:

1. General requirements:

a. ASTM B187, 98% conductivity bare copper

b. Maximum voltage rating: 1,000 Volts DC

c. Continuous current rating:

1) Size as shown

2) Maximum current density of 800 amperes per square inch

Capable of withstanding mechanical stresses and heat due to maximum short-circuit current

d. Bus contact surface silver-plated or tin-plated at connections

e. Each joint having impedance not more than that of bus bar of same length, clamped to maintain that impedance throughout life of equipment and treated to prevent corrosion

f. All connections to bus made with galvanized or similarly coated, high-strength steel bolts of sufficient number and size to provide solidly bolted connections.

1) Bolted connections shall be torqued in accordance with NETA MTS, Table 10.12 or per manufacturer's recommendation

g. Bus shall be mounted on barrier type insulation or post type insulators of sufficient strength to withstand without damage or permanent distortion all stresses produced by short-circuit current equal to the interrupting rating of the circuit breakers.

h. Designed to accommodate reconnection of existing feeder and supervisory control/indication cables without requiring extension, splicing, or shortening of existing cables

1) Cable lug connection points shall match the connection points of existing equipment which will be replaced with the new (manufactured) equipment

G. Control Buses:

1. Switchgear control bus:

a. 125 Volts dc ungrounded dc bus; constructed of two #6 AWG minimum 600 Volts insulated copper conductors extending the full length of the switchgear assembly.

1) Terminated on terminal blocks and marked in each cubicle for connection to individual cubicle control power circuits

b. Provide one two-pole knife switch in each switchgear cubicle for disconnecting the control power circuit of associated breaker only.

c. Provide one two-pole knife switch for positive and negative control power in switchgear cubicle next to the DTR panel for disconnecting the control circuit to the DC trace recorder. This control power switch shall not be installed in the DC trace recorder cabinet.

d. UL Class J fuses used for control and auxiliary service protection

e. Separate fuses in the closing and tripping circuits of each breaker.

1) A blown fuse in the closing circuit shall not prevent operation of trip circuits.

f. Provide auxiliary relay and wiring to transmit signal of loss of control power for each fused control power circuit to respective DIO.

2. Switchgear negative reference bus:

a. 2000 – Volts dc, insulated #6 AWG minimum wire, extended the full length of the switchgear assembly as shown.

1) The bus shall be terminated on terminal blocks in each cubicle for connection to individual cubicle control and metering functions, and for connection to the negative switchboard or Impedance Bond as indicated.

H. Enclosure:

1. Dead-front, free-standing, indoor ventilated steel enclosure, high resistance grounded and provided with suitable hardware for insulated anchoring to a concrete floor which has been covered with an insulating topping.

2. Steel structure with framework of welded or bolted structural steel, free from distortion and welding strain and sufficiently rigid to support equipment under normal and short-circuit conditions.

a. Reinforced as required to form a rigid self-supporting structure

b. All sheet-metal shall be 11-gauge minimum and each cubicle shall have edges formed by appropriate metal brake tooling with joints welded and ground smooth and having insulated edges.

c. The bottom of the cubicle shall be 1/8" steel plate provided with ½ inch steel angle minimum guide rails welded to the frame to support position and guide the wheels of the circuit breaker carriage.

d. Suitable opening shall be provided in each cubicle for power and control cables to enter from top or bottom.

e. Cable entries for the new switchgear shall be positioned in the same location as the existing switchgear, on a station by station basis

3. Designed with an insulated stack constructed on top of the switchgear cubicle above the arc chute of each breaker to vent ionized gases when interrupting rated short circuit current at rated maximum voltage

a. The ionized gases discharged from the arc chute thru the stack will be confined to the breaker enclosure.

b. The stack is to be designed to prevent the ingress of water into the switchgear cubicle.

4. The switchgear cubicles shall be designed to allow adequate clearance for dissipation of ionized gases from the breaker arc chutes without hazard to personnel or the possibility of establishing a conducting path to the grounded structure or other cubicle appurtenances, including cubicle control wiring, when interrupting rated short- circuit current at rated maximum voltage.

a. Insulation barriers shall be provided to prevent ionized gases contacting the metallic enclosure, control wiring or breaker carriage.

b. Include adequate provisions for release of gases from the units by means of suitable stacks, louvered vent openings, or vent openings covered with grilles, and arranged in such a way that hot gases or other materials cannot discharge in a manner hazardous to personnel.

c. Ventilation openings on top are not permitted.

5. Switchgear cubicles and circuit breaker compartment equipped with hinged front door with suitable handle, latch and doorstop

a. Rear door shall be hinged lift-off with tamper resistant latching hardware.

6. Each power circuit breaker shall be in a separate metal-enclosed compartment, equipped with stationary disconnect device contacts and carriage with integral wheels to permit withdrawal without use of additional lifting device.

a. Minimum allowable cubicle width: 24 inches

7. Circuit breaker compartment door designed not to hinder movement of breaker in and out of compartment when door is open and doorstop set.

a. Circuit breaker compartment doors capable of being closed with breaker in test or disconnected position

8. Circuit breaker compartment to provide for interchangeability of removable elements within frames of same size and operating characteristics

9. Breaker compartment:

a. Transducers assembly (Current and voltage) and fuses used by the protection devices shall be located outside of the breaker compartment.

10. Control panel: Hinged door, panel mounted on the front of the switchgear.

a. Support flush and semi-flush devices without distortion from plane surface in any position

b. Supported by hinges allowing the panel to swing open to provide free access to the equipment and wiring behind the panel

c. Secured in the closed position by captive wing-headed bolts, captive knurled knobs or other captive devices capable of being tightened or loosened by hand

d. Equipped with door stop to prevent damage to equipment due to over swing of the panel

11. Mechanical and electrical interlocks:

a. Prevent moving the circuit breaker in or out of the connected position with main contacts closed

b. Prevent closing the circuit breaker mechanically unless the breaker is in the test or disconnected position

c. Prevent closing the circuit breaker electrically while in the connected position unless the compartment door is fully closed and latched, or in the test position

d. Allow for closing the circuit breaker electrically while in the test position with the compartment door in the open or closed position

e. Prevent opening the compartment door when the circuit breaker is closed in the connected position

12. Key Interlocks:

a. Prevent the cathode circuit breaker closing unless the rectifier anode disconnect switch is closed

b. Prevent opening of the rectifier anode disconnect switch unless the cathode circuit breaker is open

13. Finish:

a. Metal surfaces shall be thoroughly cleaned of scale, oil, grease, rust, and other foreign matter immediately before painting.

b. Surfaces of the enclosure shall have three coats of paint, namely, a primer, a body, and a finish coat, each being thoroughly dried before the application of the next.

c. A paint system utilizing epoxy (preferred) or dry powder polyester in a three stage process consisting of cleaning, phosphatizing and coating is acceptable.

d. The priming coat shall be made up of materials best suited to retard corrosion.

e. The body and finish coats shall be according to ANSI Gray No. 61 (light gray enamel) in accordance with referenced standard.

f. Pigment paints rather than metallic flake paints shall be used. Hardware, nuts, bolts, washers, etc., shall be treated for corrosion resistance.

14. Cathode bus duct entrance: Provisions for connecting cathode bus to the cathode circuit breaker compartment through a bus duct. Cathode bus duct insulated from the DC switchgear to an insulation level of 3700 Volts ac rms.

15. Feeder cable connections: Provisions for support and termination of up to eight-1000 kcmil feeder cables

16. Feeder cable terminal connectors: NEMA CC1, long barrel, double indentation type with two hole contact pad for copper conductors

17. Digital Trace recorder shall be provided with each DC switchgear to measure DC currents and voltages and provide stream data to station HMI and to remote servers.

18. Distributed I/O module shall be installed in each breaker instrumentation compartment to provide breaker remote control and indications.

19. Cable Shield Monitor system shall be installed in each breaker instrumentation compartment to monitor the shielded cable.

I. Protective devices and metering

1. Furnish meter, instrument and relay circuits in accordance with the One Line Diagram

2. All control and protective devices provided in this contract shall be UL listed or label rated for utility or heavy-duty industrial and must be specifically approved by the Authority prior to use.

   a. All protective relays provided in this contract shall be microprocessor-based relays with Modbus TCP protocol (Modbus over TCP/IP Ethernet) or IEC 61850 or DNP-3 protocol and should support webpage feature.

3. Provide additional components such as auxiliary relays, isolating diodes and similar devices not shown but required for complete and functional switchgear.

4. Provide a #4 contactor (same model as load measuring contactor) in the load measuring circuit to operate in such a manner that no voltage is imposed on the third rail when DC Breaker is in tripped position and negative reference connection is disconnected.

5. Semi-flush mounted, plumb and square, on the control panel.

   a. Arranged in a neat, modular and logical order and readily accessible and easily visible

   b. Cases finished in dull black

   c. Devices of the same general type manufactured by the same company

6. Lockout relay (device 86): Rotary, hand-reset, 125 Volt dc, equipped with green light for indicating reset position

   a. Wired to trip and lockout all cathode and feeder circuit breakers

7. Auxiliary and other relays: Provided where required. 125/24 VDC relays by General Electric Company Type HGA or HFA or approved equal, as indicated and mounted inside instrument compartment.

8. Circuit breaker control Switch, Heavy-duty industrial rotary switch, pistol-grip operating handle, switch position marked TRIP/CLOSE, with spring return to normal including a mechanical target showing green or red for the last activated position

9. Enclosure ground detection system: To monitor enclosure insulation as manufactured by SMC (Swartz type relays), or approved equal as follows:

   a. A high resistance ground relay, connected between the dc switchgear enclosure and ground to detect any accidental grounding of the dc switchgear metal enclosure.

      1) Fail-safe auxiliary contact shall be sure which may become

energized in the event of a fault between the enclosure and any of the current carrying components, , with auxiliary contacts connected to the dc switchgear lock-out relay to initiate tripping and lock-out of the dc circuit breakers in the switchgear.

2) Fail-safe auxiliary contact shall be connected to the breaker DIO to initiate a remote alarm via SCADA RTU on Device 64D energized structure activation.

3) The 64D circuitry should be designed to prevent the tripping and lock-out of the DC breakers while tripping the circuit breaker under fault or opening under load or in presence of transient voltage or induced voltage of milliseconds duration on the DC switchgear enclosure.

b. Control power requirements: 125 V dc +/- 10%

10. Cathode circuit breaker shunt (for each cathode breaker): 10000A/50 mV

a. Cathode circuit breaker metering (for each cathode breaker): High Shock Sealed Models, Digital Analog combinations, dc 50 mV movement, NEMA C12.1, switchboard type with 250 or 270 degree scale with one percent accuracy complete with ammeter shunt and zero for 8000 Ampere breakers.

11. Yard Positive and Negative tie circuit breakers shunt: 7500A/50 mV

a. Yard Positive and Negative tie circuit breakers metering: High Shock Sealed Models, Digital Analog combinations for 6000 Ampere breakers.

12. Feeder circuit breaker shunt (for each feeder breaker): 7500A/50 mV

a. Feeder circuit breaker metering (for each feeder breaker): High Shock Sealed Models, Digital Analog combinations, dc 50-0-50 mV movement, NEMA C12.1, switchboard type with 250 or 270 degree scale with one percent accuracy, with 15,000-0-15,000 Ampere scale, for 6000 Ampere feeder breakers.

b. Bus voltage metering: One DC voltmeter High Shock Sealed Models, Digital Analog combinations, NEMA C12.1, switchboard type with 250 or 270 degree scale with one percent accuracy with zero to 1000 Volt scale complete with current limiting fuses for each 1000 V DC positive bus.

13. Cathode circuit breakers shall be equipped with a direct acting direct release reverse current series trip device (Device 32) to trip the breaker in the event the current reverses.

a. Reverse current trip series device trip setting range 500-4000A.

b. On detection of device 32 operation, a signal shall be sent to the DIO for remote monitoring

14. Cathode circuit breakers shall be equipped with microprocessor-based relays with forward current trip device (Device 76) and protection coordinated with DC feeder breakers to trip the breaker upon failure of any feeder breaker to clear a

fault.

a. Microprocessor-based type multifunction relays with Modbus TCP protocol (Modbus over TCP/IP Ethernet) or IEC 61850, DNP-3 protocol shall be used for the overcurrent detection system as manufactured by VG controls (MPR), Siemens (Sitras Pro) or approved equal.

b. The relay shall incorporate fiber ports for connection to the substation network switch.

15. Yard Positive and Negative tie circuit breakers shall not be equipped with protective relays and shall be equipped with shunts and current transducers for connection to the Digital Trace recorders. Both Positive and Negative tie circuit breakers shall be equipped with DIOs for remote control and indication.

The feeder breakers (including gap breakers) MPR relay, in addition to providing protective functions as indicated in these specifications, shall include feeder breaker automatic reclosing equipment as follows

a. Provided for each feeder circuit breaker, including voltage divider type load measuring relay (Device 182), load measuring resistors, adjustable time delay reclosing relay (Device 183), time delay relays, counters, and other devices required to perform the following functions; all (except for load measuring resistors) assembled in a separate, isolated plug-in housing within the breaker cubicle.

b. Relays used for the reclosing system shall be Microprocessor-based relays with Modbus TCP protocol (Modbus over TCP/IP Ethernet), IEC 61850 or DNP-3 communication protocols, as manufactured by VG controls (MPR), Siemens (Sitras Pro) or approved equal.

c. All equipment, except load measuring resistor, shall be panel mounted for ease of removal.

d. The relay shall incorporate fiber ports for connection to the substation network switch.

1) Operates only when the breaker is in the connected position

a) Prevents reclosing and disconnects from 750 Volts dc potential when the circuit breaker is in the test or disconnected position, or when the circuit breaker is tripped manually. This includes tripping by the emergency trip circuit, tripping from Remote and tripping from the local control switch.

2) Closes circuit breaker if bus or track voltage is above pre-set voltage at dc

a) If track voltage is below a pre-set voltage (different from the previous limit), closes load measuring contactor to allow for measurement of load resistance.

b) If load resistance is measured to be above a pre-set value, closes circuit breaker.

c) Acceptable levels for pre-set voltage limits and load resistance shall be adjustable.

d) Provide device 182 settings and calculations to WMATA for approval.

3) Load measuring compensates for a voltage drop in the track circuit

4) Reclosing circuitry is disconnected if closure of the circuit breaker does not occur within a preset time and after four closing attempts. Failure to automatic reclose the breaker shall not lock the breaker out requiring a reset, but would require a close command to close the breaker.

5) All timers and counters are adjustable.

a) Load adjustments shall have calibrated set points over the specified range and the indicators shall be visible from the front panel of the draw-out unit.

6) The load measuring automatic re-closure equipment shall be designed for ease of calibration with convenient input terminals with either an internal or external calibrator provided for testing entire circuit operation.

a) All calibration instructions shall be fully addressed in the O&M manual.

b) Detailed circuit analysis and operation with corresponding drawings shall be provided for each circuit function, printed circuit board, etc. to permit component level troubleshooting.

7) Gap breaker re-closure circuitry shall be interlocked with adjacent breakers such that it shall not commence load measuring until adjacent breakers are closed

16. Feeder breaker series trip device (Device 176):

a. Direct acting, direct release series trip device adjustable between 100% and 400% of circuit breaker continuous current rating.

b. Provided for each feeder circuit breaker and gap breakers

c. Use of control power to accomplish series tripping shall not be permitted.

17. Each feeder and gap breaker shall be equipped with a dc Microprocessor-based relays with an Instantaneous and Rate-of-rise trip device protective functions (Device 150).

a. Microprocessor-based relays communication shall be via Modbus TCP protocol (Modbus over TCP/IP Ethernet), IEC 61850 or DNP-3 communication protocols, as manufactured by VG controls (MPR), Siemens (Sitras Pro) or approved equal. The relay shall incorporate fiber ports for connection to the substation network switch.

1) Include rate of rise sensing circuitry, adjustable rate of rise trip level, adjustable time delay trip and a flag or an indicator lamp to verify operation.

2) Designed to detect short circuit and initiate breaker tripping if the magnitude of short circuit current is below the setting of the breaker direct acting series overcurrent trip device.

a) Capable of discriminating between short circuits and switching of the auxiliary load of the train and insensitive to transients. This protection feature shall be bi-directional

3) The Microprocessor-based relay shall include low level fault detection circuitry.

a) This protection is intended to differentiate between the low current faults and starting of the train.

b) This protection function shall be bi-directional.

c) The trip threshold of this low level fault detection shall be adjustable, 0.05 to 5 time the shunt rating with trip delay adjustable, 0.5 to 120min. The relay shall be equipped with Ethernet fiber communication port.

18. MPR shall be manufactured by:

a. VG controls, Siemens (Sitras Pro) or approved equal .Each microprocessor relay shall display both the DC line and load side voltages.

19. Surge Arresters for each feeder circuit breaker:

TPSS/TBS facilities located outside the tunnel and close to the Portals, provide DC surge arrestors as follows.

a. 1000 volts continuous DC surge arrester, metal-oxide, for indoor and outdoor use, high current impulse peak of 200kA and switching current impulse peak of 2000A, manufactured by ABB, SMC or equal, suitable for heavy rail transit system.

b. DC surge arresters shall be enclosed in silicone or fiberglass enclosures with visible windows and vent holes to avoid explosion, mounted outside preferably the on the top of the switchgear with base insulated from switchgear enclosure, and the discharge (ground) cable connected to the station ground shall be in a fiberglass conduit.

c. Surge arrester enclosure shall be designed to allow fast dissipation of ionized gases when surge arresters explode due to failure.

d. Surge arrester mounting hardware and installation provisions shall not allow for movement of the surge arrester under operation.

e. Conductors from surge arresters to bus connection points shall be secured and shall enter the switchgear through tight insulating bushing

20. Shunt/Isolation/Amplifier (Voltage Transducer):

Selection of the shunt isolators for voltage and current transducer shall be coordinated with the Digital Trace Recorder (DTR) and as follows

a. Provide one voltage transducer in the DC switchgear at each substation for the Voltmeter and the DC Trace Recorder.

b. Provide a separate voltage transducer for input to relay and Circuit Breaker Control Module

c. The shunt amplifier shall be a linear amplifier designed to amplify dc shunt millivolt signals.

d. The input shall be from 0-1,000 volt and output shall be 0- 1 milliamp.

e. Provide complete isolation of the input signal.

f. A magnetic amplifier shall be used in the input circuit to isolate the inputs from all other circuits and grounds.

g. The input shall be tested at 4,000 Volts dc for one minute to insure that no breakdown will occur when connected to shunts operating at high voltage above ground.

h. The output shall be a hybrid amplifier operating in the trans-conductance mode to provide a constant current output.

i. Load resistance variations from 0-10K shall have less than 0.1% effect on the output current to make the amplifier an ideal device for telemetering, scaling and recording applications.

j. The output should be filtered.

1) A variation resistor from zero to maximum gain adjustment shall be provided and be accessible through the top cover.

2) Large gain changes should be accomplished by changing the auxiliary gain resistor.

a) Power Requirements: 125 Volts dc + 10%, 10VA (Max)

b) Input Impedance: 5000 ohms/Volt

c) Load Impedance: Any load between 0-10K

d) Accuracy: + 0.5% Rated Output @ 25°C

e) Temperature Range : -10°C to + 70°C

f) Temperature Coefficient: + 0.04% per °C

3) The transducer shall be compatible with the rating of the DC switchgear furnished under this contract.

4) The Shunt/Isolation/Amplifier shall be SWARTZ type or approved equal.

5) Provide current limiting fuse at connection to DC Bus.

6) The transducer shall be factory calibrated.

a) Calibration report for each transducer shall be provided with each switchgear

7) The transducer calibration shall be field verified,

a) Report shall be submitted as part of the field test reports.

8) Output of the voltage transducer shall be connected to the DC digital trace recorder for remote monitoring.

21. Shunt/Insolation/Amplifier Current Transducer

a. In each DC switchgear provide a current transducer for each of the feeder breaker and cathode breaker.

b. Provide separate current transducer for feeder breaker Circuit Breaker Control Module (CBCM).

c. The shunt amplifier shall be a linear amplifier designed to amplify dc shunt milliamp signals

1) Provide complete isolation of the input signal

a) A magnetic amplifier shall be used in the input circuit to isolate the inputs from all other circuits and grounds.

b) The input shall be tested at 4,000 Volts dc for one minute to insure that no breakdown will occur when connected to shunts operating at high voltage above ground.

c) The output shall be a hybrid amplifier operating in the trans- conductance mode to provide a consistent current

output. Load resistance variations from 0-10K shall have less than 0.1% effect on the output current to make the amplifier an ideal device for telemetering, scaling and recording applications.

d) The output should be filtered.

2) A variable resistor from zero to maximum gain adjustment shall be provided and be accessible through the top cover.

a) Large gain changes should be accomplished by changing the auxiliary gain resistor.

i) Input range: -100 to +100 mV

ii) Output range: -2 to +2 mA

iii) Power Requirements: 125 Volts dc + 10% 10VA (Max)

iv) Input Impedance: 5000 ohms/Volt

v) Load Impedance: Any load between 0-10K

vi) Accuracy: + 0.5% Rated Output @ 25°C

vii) Temperature Range: -10°C to + 70°C

viii) Temperature Coefficient: + 0.04% per °C

3) The transducer shall be compatible with the rating of the dc switchgear furnished under the Contract.

4) The transducer shall be factory calibrated.

a) Calibration report for each transducer shall be provided with each switchgear

5) The transducer calibration shall be field verified.

a) Report shall be submitted as part of the field test reports

6) Output of the current transducer shall be connected to the DC digital trace recorder for remote monitoring.

22. Signal from the voltage and current transducers shall be connected to the DTR for remote through SCADA system.

a. A variable resistor from zero to maximum gain adjustment shall be provided and be accessible through the top cover.

1) Large gain changes should be accomplished by changing the auxiliary gain resistor.

a) Input range: -100 to +100 Mv

b) Output range: -2 to +2 mA

c) Power Requirements: 125 Volts dc + 10% 10VA (Max)

d) Input Impedance: 5000 ohms/Volt

e) Load Impedance: Any load between 0-10K

f) Accuracy: + 0.5% Rated Output @ 25°C

g) Temperature Range: -10°C to + 70°C

h) Temperature Coefficient: + 0.04% per °C

b. The transducer shall be compatible with the rating of the dc switchgear furnished under the Contract.

c. The transducer shall be factory calibrated, calibration report for each transducer shall be provided with each switchgear.

d. The transducer calibration shall be field verified; report shall be submitted as part of the field test reports.

23. DC Switchgear Distributed I/O module: The DIO will interface with the SCADA system for remote control and status information.

24. Provide 4mm Safety Jack (socket) accepts sheathed banana plugs and meets the latest international safety standard IEC 61010-031 to 1,000 V CAT III and 600 V CAT IV.

a. Banana jacks at each breaker cubicle to allow for connection of portable instrumentation to measure breaker load currents and bus voltage.

b. The banana jacks (2 per breaker) shall be mounted on a piece of fiberglass insulation board installed in the bus chamber of the respective DC breaker cubicle.

c. The banana jacks shall be wired to the breaker DC current shunt.

d. Each connection point shall be insulated.

e. Connections at breaker shunt shall be fused; the fuses shall be dedicated for the banana jack circuits.

1) Provide 2 KV rated Judd wire to connect from shunt to fuses and from fuses to banana jacks.

f. At the top of the respective breaker cubicle, provide a ½" x 2" slot or knock-out on the bus chamber compartment for direct access to the banana jacks.

1) Interior and exterior edges of the slot shall be de-burred, rounded, and smoothed to prevent chafing of instrumentation test leads.

2) Provide a sliding cover over the slot with tamper resistant captive hardware.

a) The cover shall slide horizontally, shall be designed so that the cover and associated hardware will not fall inside the switchgear if it is broken.

g. Each banana jack shall be permanently labeled:

1) For current Banana Jack:

a) Breaker Shunt Ratio

b) "Danger 750 Volts dc"

c) +/- for lead terminals

2) For Voltage Banana Jack:

a) Bus Voltage

b) "Danger 750 Volts dc"

c) +/- for lead terminals

J. Control and indication:

1. Control switch: Provided on each circuit breaker for electrical closing and tripping of the breaker.

2. Local-Remote selector switch: Provided on each feeder circuit breaker for transferring control from the local control switch to the remote control system.

a. Contact from local-remote selector switch shall be wired to the breaker DIO.

3. Remote Control: Remote control of breaker by OCC or HMI is through the SCADA DIO via interposing relays.

4. Indicating lights: LED panel indicator lamp, General Electric Type ET-16 or equal provided on each circuit breaker as follows:

a. Red: Breaker closed

b. Green: Breaker open

c. White: Selector switch in local position

5. Emergency tripping: Fail-safe means provided on each feeder circuit breaker to electrically trip the breaker from a remote emergency trip system (e.g. ETS), when the breaker is in the connected position, regardless of Local-Remote selector switch position.

a. The emergency tripping circuits shall be independent and isolated from other tripping circuits of the circuit breakers.

b. Emergency trip system activation shall be monitored at the substation HMI annunciator panel and at MOC (via SCADA).

6. Loss of control power: Means provided on each feeder circuit breaker to automatically trip the breaker on loss of control power.

a. Separate relays, for close and trip circuits shall be provided to monitor loss of control power and provide 2NO and 2NC contacts on each for connection to switchgear DIO for remote monitoring.

b. The local HMI annunciator panel shall include a window to display "DC Switchgear Control Power Failure".

7. Acceleration gap feeder circuit breaker control: Automatically trips when either of the adjacent contact rail section dc feeder circuit breaker trips.

   a. Allowed to reclose automatically when both adjacent contact rail section dc feeder circuit breakers are closed.

   b. Automatic reclosing should initiate only after both adjacent breakers are closed.

   c. Automatic tripping and reclosing interlock shall only be possible when all three breakers are in connected position and the Section Gap breaker was originally closed.

8. Positive and Negative Bus Tie breaker shall have their own respective DIO installed. Remote control of these breakers shall be from the Yard Control Tower and the sequence of operation shall be as follows.

   a. With both positive and negative breakers in connected position, a local or remote close command to the DIO shall initiate the closing of the Positive bus Tie Breaker.

   b. The Positive bus Tie breaker is hardwired interlocked with the Negative bus tie breaker and shall closed only after the Negative bus tie breaker is closed. The interlocking between the Positive Bus Tie breaker and the Negative Bus Tie breaker shall not utilize the DIOs or the SCADA system.

   c. A local or remote trip command to the DIO will trip the positive bus tie breaker followed by automatic tripping of the negative bus tie breaker. Positive bus tie breaker shall automatically trip if negative bus tie breaker is open.

      1) DIO shall be wired to provide remote control and indications listed.

      2) Both positive and negative bus tie closed (Yard de-isolated) “followed by a close command”

      3) Both positive and negative bus tie open(Yard isolated) “followed by a trip command”

9. Control and instrument wiring:

   a. Factory-installed

      1) For lengths of control wiring which cross shipping splits or installation splits, coil adequate lengths on one side of the split prior to shipment and provide terminal connections on each side of split.

   b. Insulation rated 2000 Volts for conductors entering high voltage bus compartment (e.g., for connection to millivolt shunts).

      1) Conductors, 14 AWG minimum copper conductor, unless otherwise specified.

2) Flexible Class C or higher stranded insulated copper wire used for wiring across hinged joints. These wiring shall be covered with an insulating material sleeve for protection against abrasion.

c. One continuous length of wire used from terminal to terminal without splices or taps

d. Removable element control wiring installed and connected according to manufacturer's standard for circuit breaker wiring.

e. Control wiring so designed and installed that fault in one main circuit cannot be transferred to control wiring of another main circuit

f. Connections made at terminals of device, on terminal blocks, or on control buses

1) Wiring connection made using insulated flange fork tongue type terminals

g. Interconnecting wiring between cubicles and compartments terminated on terminal blocks before being wired to components

h. Terminal blocks: With screw terminals, circuit marking strips for indicating control wire number, phenolic laminated dust cover and minimum of 10% spare terminal points.

i. For each individual wire, corresponding identification used on terminal block marking strips

j. Internal wiring identified at each termination, with same number shown on wiring diagram, using suitable plastic sleeve attached within six inches of terminal connections.

1) Terminals shall be color-coated for ready identification of voltage (e.g. 750 Volts dc, 125 Volts dc, 24 Volts dc etc.)

a) For Distributed I/O modules with 24 Volts DC Keying voltage, indication wire terminals shall be color-coated blue for ready identification of voltage class.

b) For Distributed I/O modules with external 125 Volts DC Keying voltage, indication wire terminals shall be color-coated the same as the DC switchgear control wires.

2) No wiring for the instrument/ protection relays shall be directly connected to 750V bus or shunt. These wiring shall be install through properly sized current limiting fuses as required or shown.

a) One line diagram.

k. External wiring: Provision made for external control wiring to enter from top and with space allowed to terminate external multiple-conductor copper control cable.

1) Top entrances provided with removable cover plates for field drilling of conduit and cable entrance holes.

a) For Fiber optical jumper cable protection, fiber jumper cable shall enter the breaker instrument cubicle in separate cable entrance hole.

K. Remote control and indications:

1. Control: Distributed Input Output (DIO) device mounted within each switchgear cubicle shall be wired for all data points ,required for remote control closing and tripping and indications and shall be ready for connection to the SCADA system.

a. This unit shall interface with the substation SCADA-RTU via fiber optic cable connection.

1) Provisions for remotely closing and tripping feeder circuit breakers except cathode circuit breakers, from the OCC or from the Yard Control Tower.

a) Remote control enabled only with Local-Remote switch in Remote position and circuit breaker in connected position.

2) Provisions for closing and tripping feeder circuit breakers from the Local HMI remote control system

a) Remote control enabled only with Local-Remote switch in Remote position and circuit breaker in connected position

3) Provisions for closing and tripping each cathode circuit breaker, from the local HMI remote control system with Auto/Manual switch in the manual position

4) The DIO module installed in each breaker cubicle shall provide the remote control closing and tripping of the circuit breaker via interposing relays.

5) General Electric Type HGA or HFA relays, equipped with arc suppression shall be used as interposing relays:

a) At existing TPSS and TBS where DTS is still utilized for remote controls by OCC, four interposing relays shall be provided for parallel supervisory control operation of breakers by DTS and DIO.

i) Relays directly connected to Mainline DTS systems, coils to be rated at 24 Volts dc, 15 VA maximum.

ii) Relays for yard substations directly connected to DTS, coils to be rated at 125 Volts dc, 15 VA maximum.

iii) All interposing relays controlled by the breaker DIO, coils to be rated at 125 Volts dc, 15 VA maximum.

iv) Refer to DIO control schematics for DTS and DIO interposing relays connections for parallel operations.

6) DIO shall interface with the substation RTU via Network Switch using DNP 3.0 Ethernet protocol on fiber.

2. Indication:

a. Contacts from each circuit breaker and relay shall be wired to the breaker DIO for remote indications of circuit breaker status, as follows and as indicated in the SCADA data points

1) Closed: Circuit breaker closed indication provided by the breaker MOC “a” contact in series with the breaker TOC “a” contact

2) Tripped: Circuit breaker open indication Provided by a breaker MOC “b” contact connected in series with a breaker TOC “a” contact

3) and in the connected position

4) Local/Remote Switch Position Automatic/Manual Switch Position

5) Relay 201C Pickup

6) Relay 201T Pickup

7) DC SWG 86 Lockout

8) Loss of control power (Both the closing and tripping circuits)

9) Racked-In

10) DC SWG energized structure (64DX)

11) DC MPR critical failure

12) DC SWG grounded structure (64YX)

13) Cathode breaker reverse current device pickup

14) Feeder breakers overload 176 device pickup

15) Rack out Position

16) Breaker CBCM TRIP CKT supervision failure as applicable

17) Breaker CBCM controller failure, as applicable

18) Breaker CBCM overload operation as applicable

19) Breaker Forward and Reverse current Tripping shall provide signal to SCADA via DIO.

3. Control voltage for mainline and Yard remote control DIO interposing relay is 125 Volts dc

4. Control voltage for mainline remote control DTS interposing relay is 24 Volts DC

L. Auto/Manual control of Cathode Breaker:

1. An Auto/Manual selector switch shall be provided to control the cathode breakers locally when the selector switch is placed in the Manual position.

2. When Auto selection is made the cathode breaker shall be controlled by the position of the respective rectifier transformer 15 kV AC or 34.5 kV AC feeder breaker.

3. The local HMI shall control the cathode breaker only when the selector switch is placed in the Manual position.

M. Nameplates:

1. Three-ply, laminated phenolic plates engraved through black face to white core and attached by means of stainless steel rivets or screws.

a. Vertical gothic lettering using a round or square cutter

b. V-shaped groove is prohibited.

2. Nameplate provided on each switchgear showing manufacturer's name and brand designation, the referenced standard, type, class and rating as applicable in accordance with referenced standard

3. Additional functional nameplates for each component:

a. Each switchgear compartment labeled, front and back, with nameplate 2-1/2 inches by 6-1/2 inches, inscribed in letters ½ inch high: CATHODE CIRCUIT BREAKER NO. 2, FEEDER CIRCUIT BREAKER NO. 1, POSITIVE TIE BREAKER, NEGATIVE TIE BREAKER etc. as appropriate

b. Each circuit breaker compartment labeled, front only, with nameplates 2-1/2 inches by 6-1/2 inches, inscribed in letters ½ inch high with the circuit breaker Supervisory Control Identification Number.

c. Provide nameplates for all internal components such as relay, fuse, terminal block, etc.

d. In addition to other information normally displayed on equipment, provide one inch nameplates showing, in letters ½ inch high, switch positions, meaning of indicator lamp and all other displayed equipment which was not labeled under another section in the specifications.

e. The feeder breakers shall be so arranged that the lower series breakers (31 and 32 etc.) shall supply in-bound section of the contact rail and the higher series breakers (33 and 34 etc.) shall supply out-bound section of the contact rail.

N. Accessory equipment: One set of the following provided for each substation:

1. Cranking device to be used for moving the circuit breakers to and from the connected, test, and disconnect positions.

2. Removable closing lever or crank for manually closing the circuit breakers, if required

3. A set of test plugs for draw-out relays and instruments where applicable

4. A set of wrenches for the primary disconnecting devices of the circuit breaker, if required

5. Fuse tongs or hook sticks, depending on the requirements

6. Twenty-five feet of test cable for each switchgear assembly to permit operating a circuit breaker when completely removed from its compartment.

   a. This cable will be required to connect the control circuits of the withdrawn breaker and operate the breaker without the use of the test cabinet.

7. Test cabinet, suitable for wall mounting, for operating, testing and inspecting the circuit breakers when removed from their compartments

   a. Include test jumper not less than twenty-five feet long for connection between the breaker and the test cabinet

8. Set of test jumpers for connecting breaker units to the test cabinet

9. Pegboard: Hardboard, tempered, 1/4 inch nominal thickness, perforated, sized to accommodate all products specified.

   a. Framed with one-inch by one-inch hardboard

   b. Frame and hardboard painted with color selected by the Engineer

   c. Include hardware for wall mounting and pegboard accessories suited to the products to be mounted

   d. Provide nameplates as specified, one inch high with accessory names inscribed in ½ inch vertical letters

O. Additional Circuit Breaker Elements: Provide additional spare circuit breakers/elements as indicated in the contract documents.

P. For FKI DC Breakers, provide emergency close plug on each DC breaker cubicle to close breaker in emergency upon loss of control power. Provide emergency manual closing device with each DC Switchgear. The CBCM will be provided with its own current transducer for tripping of the breaker in both forward and reverse directions up to 22,500A current that is adjustable by potentiometers on the CBCM.

Q. Cable Shield Monitoring System: Provide a microprocessor-based system to monitor failure or degradation of insulation or jacket of the 1000 kcmil shielded track feeder cables.

1. A shield sensor shall be mounted inside each DC switchgear feeder breaker compartment where access for replacement does not require de-energization of the DC bus; all sensors for the same DC switchgear lineup shall be interconnected to the main module by fiber optic cable.

   a. Each sensor shall support and monitor up to eight DC track feeder cable shields.

2. The cable shield monitor shall support Modbus TCP or DNP3 communication protocols to transfer cable status and alarms to the substation RTU and monitoring system via the substation network switch.

3. Time synchronization Via NTP: Each sensor shall be provided with time synchronization and high time resolution using standard Network Time Protocol (NTP).

   a. Alarm log and data capture shall have time stamp with resolution 1 mms

4. Web Interface: The cable shield monitor shall have web access for data retrieval using PC Windows Internet browser.

5. SCADA alarm: The relay shall be provided with a common alarm for SCADA and remote monitoring.

   a. This alarm shall be activated for all alarm conditions and enabled for local and remote monitoring.

6. Cable shield relays and all associated components shall be isolated from 750 Volts dc, and shall withstand dielectric testing of 3700 volt AC for one minute from signal inputs to power supply, output contacts, relay faceplate, and enclosure.

7. Failure alarm and insulation failure alarm shall be designed so as to facilitate selective identification of feeder(s) with failed or deteriorated cable(s).

   a. Relay shall include sufficient filtering and adjustable trigger points and time delays to minimize nuisance alarms.

8. This cable shield monitor shall detect and provide remote indications for the following faults:

   a. Insulation failure between the cable core and the shield

   b. Insulation failure between shield and ground

   c. Open shield connection to the Sensor

   d. Sensor module over-temperature

9. Graphic Operator Interface: Touch pane land LED backlight Graphic Color Operator Interface with 800 x 480 graphic LCD display shall be provided with

each main module.

a. Five red LED on the display panel simulate the following indications of the alarm conditions:

1) Current – indicating high shield leakage current

2) Voltage – indicating high shield voltage

3) Resistance – indicating low resistance from shield to ground

4) VAC (Connection) – indicating broken connection from shield to the sensor

5) Temperature – indicating sensor over temperature

R. General requirements for dc microprocessor-based relay:

1. The multi-function DC protective relay shall be a high performance microprocessor based relay , which implements all the relay functionality in the digital form, improves reliability, and provides the capability for setting of all parameters and store data in the memory. Setting of the parameters shall be a secured, time stamped, code protected and shall annunciate a local and remote alarm of unauthorized security breach.

a. The relay materials and equipment shall be designed to ensure satisfactory operation and operational life in the environmental conditions where the equipment will be installed, and shall be designed so that it is readily accessible for operation and maintenance.

b. The relay shall be manufactured by VG controls (MPR relay), Siemens (Sitras Pro), DC switchgear multifunction relay with cable shield monitor) or equal approved by WMATA.

2. Protective Functions:

a. The relay shall perform the protective and monitoring functions for DC switchgear.

1) The relay shall measure voltage across the shunt (in mv) as well as the line and load side bus voltages.

2) The multifunction relay shall issue a circuit breaker trip command if any of the specified overcurrent conditions are detected.

3) After a trip occurs, the relay shall provide load side fault verification and initiate automatic reclosing if the line appears healthy.

4) The multifunction relay shall send a trigger signal to the DTR for each issued circuit breaker trip command.

b. DC multifunction relay equipment shall include all hardware, software, and ancillary circuits connecting between the various equipment modules so as to implement the protection, indication, load measuring, automatic reclosing functions and monitoring specified herein.

c. The DC multifunction relay shall implement the functionality of the following relays:

1) Instantaneous Overcurrent

2) Inverse (Timed Overcurrent)

3) Extreme Inverse Overcurrent

4) Forward and reverse current protection.

5) Low Level Fault

6) Current Rate of Rise

7) Straight Time-Over-Current

8) Long Time delay to protect cables

9) Load Measuring/ Reclosing

10) Contact Rail Potential Indication

11) Cable insulation Monitor (for Siemens Sitras Pro)

d. DC multifunction relay equipment shall include operational modules located in the following dc switchgear compartments:

1) A main relay located in the associated dc feeder breaker control compartment.

2) An isolated high voltage signal measurement transducer located in the associated 750V dc feeder bus compartment.

3) Operator interface located on the exterior door of the associated dc breaker control compartment.

3. Data Acquisition Functions:

a. The multifunction DC protective relay shall be capable of storing 8 records, or “traces or “oscillograms” of voltage and current samples, each record containing two sets.

1) The first set stores 4096 samples for the period of time from approximately 220 mms before the trip to 40 mms after the trip; the sampling interval shall be 65 µs (256 times a cycle).

2) The second set stores 4096 samples for the period of time from approximately 230 sec before and 30 sec after the trip, with the sampling interval of 65 Ms.

3) Non-volatile flash memory shall be included each relay to prevent loss of recorded data if control power is lost or the relay is reset.

b. The multifunction DC protective relay system shall have a built–in alarm log stored in a nonvolatile memory and keeps the last 200 alarms.

1) Each alarm record shall include a time/date stamp and alarm description.

2) All the current alarm conditions shall be displayed on the operator interface LEDs (Light Emitting Diode).

c. The multifunction DC protective relay shall have 8 general purpose relays, which can be programmed to perform various functions.

d. The relay shall be capable of providing data for real time remote monitoring.

4. Graphic Operator Interface and Security Level Protection:

a. LCD Graphic Color Interface display with touch panel shall be provided to set and monitor the multifunction DC protective relay parameters, to view the alarm conditions, and to choose a security level.

1) HMI (Human Machine Interface) or LCD (Liquid Crystal Display) display with LED (light-emitting diode) back light shall be provided.

b. The system shall have six security levels for protection of critical parameters.

1) An access security level is assigned to each menu item.

a) If an attempt is made to exceed the security level, a warning message is displayed and the action is denied.

b) The operator can choose a security level using a menu command.

5. Communication, Web Interface and NTP:

a. The multifunction DC protective relay shall be capable of communicating with substation SCADA RTU using Modbus TCP, IEC61850 or DNP3 protocol, via substation network switch.

b. Each relay shall include standard Ethernet Fiber Optical Interface 100Base-FX, and connected to the substation Network switch via fiber optic cable.

c. DC Switchgear Fiber Network System:

1) Fiber patch cabinet for the DC switchgear shall be installed on the external side of the switchgear or on the wall immediately behind the DC switchgear for termination of outgoing multimode fibers to the substation network switch as follows:

a) Patch cabinet shall be installed in locations where access by IT does NOT require the switchgear to be de-energized.

b) Location of fiber patch cabinet shall be approved by WMATA.

c) Fiber Patch cabinet shall be manufactured by Ortronics or equal approved by WMATA.

d) Fiber patch panel installed on the external walls shall be Ortronics #OR-615SMFC-48P/S or equal approved by WMATA.

2) Fiber Cables and pre-terminated patch cords (jumpers).

a) SC to ST jumper: 50/125um, multimode, duplex, OM-3 type pre- terminated fiber patch cords (jumpers) shall connect the end devices (MPRs & DIOs) to the DC switchgear patch panels.

b) Jumpers shall be routed through the communication cable tray to the DC switchgear patch cabinet. 50/125um, multimode, fiber optic cable shall link the Switchgear patch panel to the patch panels inside substation Network switch cabinet.

i) The cable shall be routed on the dedicated communication cable tray as specified here and related sections and shown on the contract drawings.

c) SC to LC jumper: 50/125um, multimode, duplex, OM-3 type pre-terminated fiber patch cords shall connect the

Network switch Panels associated with the DC Switchgear devices to Network switch.

d) All fiber cable, jumper cables shall be labeled.

3) WMATA Network termination diagram drawings shall be used as a template for all fiber cable terminations and labeling.

d. Relays shall be provided with option to disable remote access to relays for configuration changes. This option to enable or disable the remote access shall be available only through the local operator interface panel.

1) SCADA shall monitor the status of the remote access option as follow:

a) “Remote Access Enabled” or “Remote Access Disabled”

e. Time synchronization Via NTP: Each relay shall be provided with time synchronization and high time resolution using standard Network Time Protocol (NTP).

1) Alarm log and data capture shall have time stamp with resolution of 1 ms.

f. Web Interface: The microprocessor-based relay shall including web server functionality for remote monitoring of status, MPR parameters, alarm log and measurement data using PC Windows Internet browser.

1) Relay shall be provided with option to disable relay configuration changes via webpages. This option to enable or disable the webpage configuration shall be available only through the local operator interface panel.

2) SCADA shall monitor the status of the option as follow:

a) “Web configuration Enabled” or “Web configuration Disabled”

g. SCADA alarm: The relay shall be provided with a common alarm for SCADA and remote monitoring. This alarm shall be activated for all alarm conditions.

6. Environmental requirements:

a. Temperature: Per IEEE 37.90.

b. Humidity: Per IEEE 37.90.

c. Dust: Equipment shall be capable of operating in an extremely dusty environment; and shall at a minimum meet the requirements of NEMA 12 type installation.

1) All solid state and electro-mechanical equipment, relays, microprocessors, and ancillary equipment shall be rated for continuous operation in this environment.

d. Equipment shall function as intended when subjected to all electromagnetic interference present in the vicinity of 750V dc power circuits and traction power equipment.

7. Other Features: The multifunction DC protective relay shall also include the following features:

a. Built in voltage/current metering

b. Built in Soft Scope (system level troubleshooting)

c. Self-Diagnostics

d. Multiple Protections

e. Plug in Connectors

f. Fault Annunciation

g. Bi-Directional Load Measuring

h. Internal Power Supply operates on and auto-compensates for 125 Volts dc

i. Capability to accept an independent backup power source

j. High resolution measurements of voltages and current to check the sensor drift, available through PC interface

k. User interface (PC) with English language

8. Each microprocessor-based relay shall be connected to the substation Network switch using fiber cable

S. DC Breaker and Relay Test Equipment

1. The contract shall provide one (1) portable High Current Injection Test set for DC breakers and relays tests.

2. The test set shall perform a primary current injection up to 20KA.

3. The Test set shall be programmable and capable to generate user defined waveforms/curves in order to test protective relays deployed in substations.

4. The test set shall be a compact and modular solution that eases portability into switchgear rooms with limited space.

5. Provide one of the following test sets:
   a. Gillam-Fei -Model /Part # IDC20K
   b. Stevo Electric Balto-Model /Part# BM20D00
   c. or approved equal.

PA EXECUTION

3.1 INSTALLATION

A. Secure equipment to floor using insulated anchors in accordance with approved shop drawings from the equipment manufacturer. Maintain electrical isolation of equipment structure and enclosure from ground.

B. Make connections at switchgear shipping splits in accordance with equipment shop drawings.

C. Install switchgear as shown and in accordance with approved shop drawings.

D. Install busways as shown and in accordance with approved shop drawings.

E. Install conduit, raceways and bus duct as shown.

F. Make final connection of power and control cables.

G. Connect space heater circuit(s) to prevent condensation during installation.

H. Install DC circuit breaker test cabinet and connect to 125 Volts dc power source.

I. Install a DC Trace recorder cabinet on the side of the DC switchgear as shown.

Provide a 125 Volts DC control power from a knife switch located inside of a DC switchgear cubicle.

J. Install cable shield monitor as shown.

K. Each microprocessor-based relay shall be calibrated per the provided coordination study settings and connected to the substation Ethernet switch or RTU using fiber cable.

L. Install a dedicated communication cable tray for routing the Remote monitoring fiber and copper cables to the network switch cabinet and SCADA RTU.

M. Install insulated floor topping in accordance with section 16052

N. In the prefabricated structures install switchgear as shown and in accordance with approved shop drawings. Provide the following information.

1. The number of shipping splits for the following facilities

Name OF FACILITY	NO. OF SHIPPING SPLITS IN DC SWITCHGEAR	NO. OF PIECES

2. Provide anchors including installation details to be used by the Contractor for installation of DC switchgear over the insulated floor topping. Also furnish required number of anchors at each facility given below:

NAME OF FACILITY	ANCHOR

O. Furnish number of 1000 KCMIL cable lugs for the DC switchgear as follows:

TPSS feeder breaker 8 each

TBS feeder breaker 7 each

Section gap breaker 5 each

P. Provide services of manufacturer’s engineering representative for assistance in field assembly and installation and commissioning of the switchgear.

Q. Supply space heater circuit through isolation transformer.

R. Install DC circuit breaker test cabinet and connect it to 125-volt DC supply as shown.

S. Install isolated station ground bus on the top of DC switchgear for mounting the feeder breakers surge arrestors directly on the ground bus. Bus shall be designed and supported to carry dead weight of the surge arrestors. The cable connecting the surge arrestors and the load side of the DC bus shall be through adequately supported fiberglass conduits.

3.2 FIELD QUALITY CONTROL:

Field tests shall be performed after the equipment installation is complete and to the satisfaction of the installation contractor it is safe and ready for field quality assurance tests. Tests results shall be documented on appropriate forms used for testing similar equipment and are acceptable in the industry. In addition to manufacturer's recommended field test, following tests shall be included in the field test plan.

3.2.1 INSTALLATION TESTS:

A. Check the switchgear is installed per the approved design drawing and the proper clearances have been maintained.

B. Check switchgear doors for proper opening and protection against over-travel causing damage to the devices.

C. Check surge suppressors and the device 64 connections for tightness.

D. Check the wiring crossing the hinges for proper sleeved protection and adequate slack to avoid straining the wires.

E. Check breaker movement in and out of the switchgear at least five times for proper alignment with the secondary disconnect and the shutter operation.

F. Verify inter-changeability of same size breaker element.

G. Verify that the feeder breaker can't be inserted in the cathode breaker housing and vice- versa.

3.2.2 ELECTRICAL AND FUNCTIONAL TESTS.

A. Disconnect Surge Suppressors, 64 device and other electronics equipment that may get damaged during switchgear high pot tests. With feeder breakers connected and open, apply voltage 75% of the factory test value, between the bus and the cable terminal plate for one minute. Record the leakage current for data base. Apply 2775vac rms between the switchgear and the station ground for one minute to verify switchgear isolation from the ground. Control wiring for the DC switchgear normally should be checked for wiring accuracy and should not be subjected to high potential tests.

B. Test the breaker electrical close open operations in the test position with open and closed

C. In connected position, and switchgear door closed, Simulate signals from the DIO to 201C and 201T interposing relays and observe circuit breaker closing and tripping operation and record:

a. Change in status of indicating lights

b. DIO signals output for communication to the SCADA network switch/RTU (For input and output data points see technical specifications for the DIO.

c. Attempt to open the door should result in tripping of the closed breaker and an attempt to close the breaker with door open should not result in closing the breaker.

d. With selector switch in remote, try to close breaker with breaker control switch.

D. Simulate signals from the ETS relay cabinet and verify tripping of the corresponding feeder breakers.

E. Touch the DC switchgear and the station ground with a wire and observe Grounded Structure indication and also record the alarm signal input to DIO (Device 64).

F. With breaker connected and closed, using a variable DC source, slowly increase potential between the switchgear and the station ground bus and record the impressed current and the potential at which the Energized Structure relay operates the lockout relay and tripping all breakers. Record signal input from the lockout relay to the DIO for remote monitoring.

G. For cathode breaker, with selector switch in Auto, simulate signals from the Rectifier Transformer Feeder breaker to the DIO and observe cathode breaker automatic closing and tripping operation Record input signals to DIO for remote monitoring of the cathode breaker status.

H. Through secondary injection at the shunt verify calibration of the metering devices and MPR as recommended by the manufacturer.

I. Verify that the section gap breaker is electrically interlocked with the adjacent section feeder breaker only when all three breakers are in the connected position.

J. Measure and record resistance of breaker's contacts.

K. At the shipping splits, measure and record bus joints resistance. It should be the same as an equivalent length of bus.

L. Verify that loss of control power is properly communicated to the DIO and it does result in tripping the feeder breakers.

3.2.3 MECHANICAL INTERLOCKS:

A. Verify that the breaker can't be moved from test to connected position when closed.

B. Verify that a closed breaker in the connected position can't be raked out to test position.

C. Try to remove Key from the connected and closed cathode breaker, the key shall not be retrieved. Verify and record that the key can only be retrieved when the cathode breaker is open and in test position.

D. Verify that the cathode breaker can be racked from the test to connected position in the absence of the retrieved key.

3.2.4 SCADA INTEGRATION TESTS:

CONTRACTOR shall retain the services of the DC switchgear manufacturer to support the SCADA system tests, supervise and/or perform the following system integration tests on the provided DC Relay, DIO, DTR and Cable shield monitor system components.

A. DC Switchgear Microprocessor Relays (Use the Relay test set provided)

a. Set all overcurrent relays per the approved coordination study.

b. Set all overcurrent relays communication mapping per the approved protocol communication mapping.

1. Verify proper target operation for each mapping point

2. Verify proper communication with the SCADA system using the substation HMI.

3. Disconnect Shunt input plug from MPR Isolation amplifier and connect the relay test set directly to the MPR Isolation amplifier (Observe correct polarities)

   1) Note: When the shunt connection to the isolation amplifier is disconnected, the relay sees fault and protection functions will be activated.

4. Change MPR setting from Feeder type to cathode type.

5. Record relay protection as found settings

6. Disable all other functions except the function under test. For functions with long time delay, adjust time to the lowest possible time delay to complete tests faster

7. Inject 0mv and reset the relay targets

   1) Observe 0 amp on relay

   2) Observe 0 amp on HMI display.

8. For each point listed for test, inject the appropriate mV.

   1) Observe full scale ampere on relay

   2) Observe full scale ampere on HMI display.

   3) Observe correct target on relay

   4) Observe correct target on HMI

9. At the end of each feeder relay test

   1) Reset feeder breaker setting to feeder type

   2) Reset relay functions and settings as found

10. Test Form: Place a check mark on the form as each step is completed.

B. DC Positive & Negative DTR Test

a. Connect a laptop to the DTR and run the DTR software.

b. Current Transducers Calibration

1. Connect test equipment leads to the terminals of the fuse connected to the transducer (Observe correct polarities). Ensure test leads are not connected to the terminal of the fuse connected to the shunt.

2. Inject 50mv, observe breaker meter is reading full DC shunt ratio scale

3. Observe on DTR software that the signal is on the correct DTR channel

4. .Observe correct reading on HMI

5. Calibrate as necessary using transducer Zero and Gain

6. Inject 100mv observe breaker meter is reading 2X full DC shunt ratio scale

7. Observe HMI reading is correct

8. Calibrate current transducers for all feeder and cathode breaker

c. Voltage Transducer Calibration

1. Identify the correct Voltage Transducer for the DTR

2. Connect a variable 1000V DC power supply test leads to the fuse terminals (Observe correct polarities)

3. Inject 1000v, observe breaker meter is reading 1000V

4. Observe on DTR software that the signal is on the correct DTR channel.

5. Calibrate as necessary using Zero and Gain

6. Inject 0V, 750V and 1000V DC observe breaker meter reading is correct

7. Observe HMI reading is correct

d. DC Relay Fault Trigger Verification : For Verification of DTR trigger points and fault recording functions

1. Simulate a DC switchgear fault that will initiate the tripping of the DC breaker by the MPR.

2. Verify and record fault type on DC switchgear.

3. Download the DC fault recorded by the MPR relay.

4. Download and compare the fault recorded by the DTR with the fault recorded by the MPR.

5. Discrepancies between the two recorded faults must be addressed by the DTR manufacturer representative.

C. DC Switchgear Distributed Input Output Module (DIO) Test

a. Energize control power to the unit(s).

b. Verify DIO communication with RTU

c. Verify breaker status display on HMI

d. Perform a functional check of all control and indication circuitry.

1. Specific functions include tripping, closing, remote operation, rack-out, 86 lockout, local remote switch position, 201C pickup, 201T pickup, 64 energize/ground, AC MPR critical failure, Loss of DC control Power and DIO failure

3.2.5 Thermographic Inspection & Documentation

A. After substantial completion, Testing Firm shall perform an infrared thermographic survey of all newly installed equipment supplies within this contract and included in the list of the equipment types below. Thermographic Survey and Report shall be in accordance with NETA ATS 1999, Section 9.

1. Equipment Type:
   (a) Switchgear
   (b) Branch Circuits & Feeders
   (c) Transformers
   (d) Points of Power connection rated equal to or greater than rated amps
   (e) Panelboards

END OF SECTION

SECTION 16343B

TEMPORARY POWER JUMPER CABLE FOR CONTACT RAIL AT TIE-BREAKER STATIONS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section is applicable for work at tie-breaker stations where the existing DC switchgear is to be replaced by the Contractor. Temporary power jumper cable shall be installed across the gap at trackside by the Contractor to ensure the reliable connection between contact rails while tie-breaker stations are under construction.

1.2 RELATED SECTIONS

A. Section 16052, BASIC MATERIALS AND METHODS FOR TRACTION POWER

B. Section 16128, WIRE AND CABLE FOR TRACTION POWER

1.3 REFERENCES

A. Codes and regulations of the Jurisdictional Authorities.

B. NEC

C. NEMA CC1

D. NETA

1.4 DELIVERY, STORAGE, AND HANDLING

A. Store all equipment in secure and dry storage facility before installation at no additional cost to the Authority.

PART 2 - PRODUCTS

2.1 EQUIPMENT

A. Temporary Power Jumper Cable:

1. Rated voltage: 2000 volts.

2. 1000 KCMIL, copper conductor, standard duty, 127-strand, or extra flexible 427-strand power cable.

3. Insulation: Ethylene-propylene rubber, rated 90 degrees C, suitable for dry and wet locations.

4. Jacket: Overall nonmetallic jacket of T-33-655 thermoset type II or cross-linked polyolefin.

5. UL labeling: Type RHW-2.

6. Additional requirements:

   a. Insulation power factor: Two percent maximum.

   b. Bond jacked to insulation to prevent moisture pockets. Minimum peel strength of the jacket from insulation: Four pounds per inch width for cross-linked polyolefin, and 10 pound per inch for heavy-duty neoprene.

B. Compression Connector for Cable Connector Assembly:

1. Long-barrel, double-compression type.

2. Material: 98 percent pure copper tongue

3. Not less than 9/16 inch thick, with four holes and drilled for 1/2-inch bolts on 1-3/4-inch centers.

4. Complete with silicon-bronze flat washers, lock washers, nuts, and bolts.

C. Terminal Lug for Composite Rail:

1. Terminal lugs shall be compression-type lugs compatible with 1000-Kcmil, 427- strand cable. Terminal lugs shall be 98 percent pure copper. The entire lug shall be hot-dip, tin-coted, 0.3-mil minimum thickness. Tongues shall not be less than 2 square inches by 2-inch thick and drilled for a 5/8-inch diameter compression fastener.

D. Cable Connector Assembly:

1. MAC Products, Inc. No. B-9180 or approved equal.

2. SELCO Manufacturing Corp., No. 2610 or approved equal.

3. Insulating cover and gasket:

   a. Type: Two-piece.

   b. Material: Glass-reinforced polyester.

   c. Thickness: Not less than 0.125 inch.

   d. Color: Orange.

   e. Watertight.

   f. Complete with neoprene gaskets, sealing collars and captive screw fasteners.

   g. Each assembly, except sealing collar, capable of easy disassembly.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install power jumper cable as shown in Contract Drawings to ensure the reliable connection between contact rails and reconfigure ETS system as required.

1. Coordinate with the Contracting Officer Representative to establish the specific schedule for connecting temporary power jumper cable to contact rails at each location.
2. Not used
3. Not used
4. Remove the gasket and open the two-piece insulating cover of the designated cable connector assembly. Disconnect the 1000 Kcmil feeder cable from the feeder breaker in tie breaker station from the existing cable connector assembly. The WMATA Information Drawing DD-TW-CR-017 exhibits the present configuration of the cable connector assembly.
5. Temporarily insulate the disconnected cable terminal with waterproof insulation tape to prevent water damage during the duration of tie breaker station upgrade.
6. Install the power jumper cable in the cable connector assembly the same way the 1000 Kcmil feeder cable from the feeder breaker in tie breaker station was installed.
7. Re-assemble the two-piece insulating cover and gasket.
8. Install the other end of the power jumper cable to the designated cable connector assembly, as shown in the Contract Drawings, following the same steps.
9. At the section of contact rail where the number of cable connector assembly is not enough to accommodate all jumper cables, clamp or exothermically weld jumper cables to steel contact rail or clamp or bolt jumper cables to composite contact rail. Submit the proposed connecting means to the Contracting Officer Representative for approval 10 days before scheduled Work commences.
10. Contract Drawings indicate the number of temporary jumper cables that shall be installed across each contact rail gap to ensure the reliable connection between contact rails. All jumper cables shall be tie-wrapped to fiberglass channels, which are laid perpendicular to the contact rail and properly anchored to the ground.
11. Upon completion of the DC switchgear upgrade in tie-breaker station, remove the temporary power jumpers and re-install all disconnected 1000 Kcmil feeder cables from the feeder breaker in tie breaker station to their original cable connector assemblies. Restore functions to appropriate DC feeder breakers.
12. Not used

B. Electric Cabling and Connections:

1. Temporary power jumper cable furnished and installed by the Contractor, including the lug terminals.
   a. All cabling shall be continuous without splices between terminations.
   b. Cables shall not be bent, either permanently or during installation, to radii less than ten times the outer diameters, except where shorter radii are approved for conditions making the specified radius impractical. Provide suitable installation equipment to prevent cutting and abrasions of cable during installation.

C. Cable Connector Assemblies:

1. Qualifications for Performing Compression Connections: Prior to installation, the Contractor shall have prepared, under the direction of each foreman who will supervise a crew performing compression connections, two compression assemblies. The test compression assemblies shall be made using the methods and equipment the Contractor proposes to use for the installation. The electrical resistance of the completed connection, when measured between the distal end of cable and the connector tongue, shall not be greater than the resistance of an equivalent length of uncut cable.

2. Installation of Compression Connectors: Compression connectors shall be attached to the cable with the manufacturer's recommended tooling. When bolting tongues together, a lock washer shall be installed under the head of each bolt and under each nut. All bolted connections shall be tightened with torque wrenches to a uniform torque of 450 inch-pounds.

3.2 FIELD QUALITY CONTROL

A. Field Testing and Inspection:

1. General requirements: Conduct field testing and inspection at each station to ensure proper operation of equipment provided and installed.

2. Field Inspection:

a. Prior to field testing, check equipment installation in accordance with manufacturer's recommendations including, but not limited to, verification of the following:

1) Tightness of connections.

2) Proper securing (anchoring) of temporary jumper cables to prevent movement under operational conditions or fault conditions.

2. Field Testing:

a. Notify the Contracting Officer Representative 1 week in advance of each test. Conduct tests in presence of Contracting Officer Representative.

b. Temporary Power Jumper Cable: Perform dielectric withstand test of 1 minute duration on each cable prior to connect the cable to contact rail. Test shall be performed at 2775 volts, rms, 60 Hertz or 3900 volts DC.

c. Not used

d. Upon completion of DC switchgear related installation, restore all functions to appropriate DC feeder breakers in tie-breaker stations.

B. Submit five copies of certified test reports within 10 days of Substantial Completion Inspection (SCI) for each tie-breaker station.

END OF SECTION

SECTION 16525

LIGHTING FIXTURES FOR TIE-BREAKER STATIONS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes requirements for providing lighting fixtures for tie-breaker stations.

1.2 RELATED SECTIONS

A. Section 16125, WIRE CONNECTION ACCESSORIES

B. Section 16130, RACEWAYS, BOXES AND CABINETS

C. Section 16145, WIRING AND CONTROL DEVICES

1.3 REFRENCES

A. Comply with codes and regulations of Jurisdictional Authorities.
B. NEC
C. UL: 496, 542, 1029, 1570, 1571, 1572, Electrical Construction Materials Directory.
D. FS: FF-B-588, FF-P-395, FF-S-325C.
E. MS: MIL-C-450.
F. FED STD: 595.
G. PEI: 1001.
H. SSPC: SP-8, SP-10.
I. ASTM: A53, A167, A276, A123, A507, A575, B26, B85, B117, B136, B137, B209, B221, B244, D635, D1056, D1400, D2240.
J. AASHTO: M314, LTS-3.
K. ITS: Directory of ITS Listed Products.
L. AA: Standard finishes as designated by the Aluminum Association and referenced in NAAMM Metal Finishes Manual.
M. ANSI/IEEE: C62.41.
N. IEEE Publication 587.
O. ANSI Standards.
P. FCC Rules and Regulations, Part 15, Part 18.
Q. NEMA 1
R. AISI.
S. IES: RP-20

1.4 SUBMITTALS

A. Submit the following for approval in accordance with Special Provisions and with the additional requirements as specified for each:

1. Shop drawings:

    a. Include photometric curves.

2. Samples: One of each type of fixture.
3. Certification:
4.

tion that each fixture is in compliance with applicable codes, regulations, reference standards, and specifications for the location at which it is to be used. Indicate requirements that each fixture meets.

b. Calculations: Submit calculations by a professional engineer registered in the jurisdiction where material is to be installed certifying that assemblies of foundation, anchor bolts, pole, arms, and luminaire will withstand specified wind pressure, wind speed, stress, deflection, vibration, and fatigue.

1.5 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. Ship each unit securely packaged and labeled for safe handling in shipment and to avoid damage or distortion.

B. Store lighting fixtures and mounting poles in secure and dry storage facility.

1.6 WARRANTY

A. Globes and Diffusers: In addition to warranty requirements of the General Conditions, furnish warranty against discoloration and distortion for a total of 4 years.

B. Lamps: Warrant the life of lamps for periods specified.

PART 2 - PRODUCTS

2.1 MATERIALS

A. General Requirements for Lighting Fixtures:

1. Interchangeability: Components of same type, size, rating, functional characteristics, and make shall be interchangeable.

2. Each lighting fixture shall be labeled or listed in accordance with referenced UL or ITS directory.

3. In accordance with UL 1570, UL 1571 and UL 1572.

4. Materials:

a. Steel:

1) Sheet: ASTM A507, 22-gauge minimum.

2) Bar: ASTM A575.

b. Steel pipe: ASTM A53, Type S.

c. Stainless steel:

1) Sheet: ASTM A167, 22-gauge minimum.

2) Bar: ASTM A276, Type 316.

3) Finish: AISI Alloy S30400, NAAMM Finish No. 4, unless otherwise shown.

5. Lamps:

ttage and size: As shown or specified.

2) Color: Warm white.

3) Type:

a) PL7 compact, PL13 compact.

b) F6T5/CW and F20T12WW, Preheat start.

c) F32T8/WW, F48T12/WW/SHO, F72T12/WW/SHO, and F96T12/WW/SHO: Rapid start.

4) Rated life:

a) Super-high output (SHO), very-high output (VHO) and high output (HO) lamps: 12,000 hours.

b) F32T8/WW: 20,000 hours.

c) PL compact lamps: 10,000 hours.

5) Base:

a) Super-high output (SHO), very-high output (VHO) and high output (HO) lamps: Recessed double contact.

b) F32T8/WW: Medium bi-pin.

c) PL7 medium.

c. High-pressure sodium:

1) Wattage: As shown.

2) Size: As shown.

3) Coating: Clear, unless otherwise shown or specified.

4) Base: Medium or mogul.

5) Rated life: 24,000 hours.

6. Lamp holders:

a. High-pressure sodium:

1) In accordance with UL 496.

2) Black or white thermosetting phenolic compound, glazed-porcelain or neoprene base and body as shown. Neoprene unit molded in one-piece, weatherproof, oil-resistant, with vibration-absorbing socket construction.

3) Provide mechanical self-retaining neoprene gasket for dust and moisture proof seal between lamp and lamp holder.

b. Fluorescent:

1) In accordance with UL 542.

hite, thermosetting phenolic-compound base and body, silver-plated phosphorous-bronze contacts, self-aligning neoprene gasket face.

7. Ballasts:

a. High-pressure sodium lamps:

1) UL 1029, high-power-factor type.

2) Operable on 120-volt or 277-volt, 60 Hertz as shown or necessary, type and rating suitable for associated lamp.

3) Capable of starting lamp at ambient temperature of minus 20 degrees F and above.

4) Equip with individual fuse protection installed in ballast compartment of fixture.

b. Fluorescent lamps:

1) FCC part 15 subpart J, UL listed Class P.

2) Operable on 120-volt or 277-volt, 60 Hertz, as shown or necessary, type and load rating suitable for associated lamps.

3) Capable of starting lamps at ambient temperature as follows:

a) F32T8/WW lamps: Zero degrees F.

b) F48T12/WW/SHO, F72T12/WW/SHO, and F96T12/WW/SHO lamps: Minus 20 degrees F.

4) Sound rating:

a) For use with F32T8/WW lamps installed in office areas: A.

b) For use with F32T8/WW lamps installed in ancillary areas: B or better.

c) For use with F48T12/WW/SHO, F72T12/WW/SHO, and F96T12/WW/SHO lamps: D or better.

5) Maximum utilization of two-lamp ballasts in public-area lighting fixtures.

6) Equipped with individual fuse protection, installed in the fixture- wiring channel.

8. Fixture body and housing: Shape, size, and material as shown.

9. Reflector: Shape, size and material as shown. Aluminum or stainless steel polished to mirror finish unless otherwise shown. Minimum thickness 22 gauge unless otherwise shown.

10. Diffusers:

acrylic or polycarbonate plastic having the following properties:

1) Interior diffusing with smooth exterior surface.

2) Self-extinguishing, in accordance with ASTM D635.

3) No material color change when used with 4500K fluorescent lamp.

4) No apparent yellowing after 500 hours exposure to fluorescent-lamp source under conditions similar to those existing in the lighting fixture.

5) No alteration to optical properties of the fixture when finished diffuser treated with anti-static wax.

b. Formed by carefully controlled processes so that the finished piece retains its design contours and dimensions at normal operating temperature.

c. Resistance to shrinking, warping, crazing, cracking, or discoloring, either in service or when stored in the manufacturer's standard shipping containers under normal conditions.

11. Lenses:

a. Plastic lenses: Clear polycarbonate as shown, minimum thickness 0.06 inch.

b. Glass lenses: 1/4-inch tempered glass, laminated glass, or 1/8-inch double-strength, clear glass as shown, capable of absorbing ultraviolet rays when used with mercury-vapor or metal-halide lamps.

c. Refracted lenses: Heat-resistant, annealed, clear borosilicate glass, with the following additional requirements:

1) Initial lumen distribution on horizontal plane evenly from zero to 90 degrees: 55 to 60 percent.

2) Minimum efficiency: 85 percent.

12. Gasket:

a. Keyed gasket: One-piece, extruded solid neoprene having Type A durometer hardness of 30 plus or minus 5 when tested in accordance with ASTM D2240.

b. Self-retaining gasket:

1) One-piece, closed-cell sponge neoprene, soft or medium density.

2) Resistant to aging, heat, ultra-violet light, water, oil, weathering and setting as determined by ASTM D1056.

3) Cemented to component with resilient neoprene sealing compound compatible with finish. Adhesive not applied to diffuser.

ware:

a. Latches, catches, release mechanisms, hinges, screws, bolts, studs, nuts, rivets, washers, and springs. Heavy-duty, stainless steel or bronze, as shown.

b. Latches and catches: Captive-type.

c. Operating hardware: Self-retaining type.

14. Construction:

a. Fixture body, reflectors, wiring channels, end caps and castings formed so as to prevent buckling or distortion.

b. Minimum of two wire clips provided in wiring channel to support wiring. Self-cleaning air filter provided on breather ports.

c. Seams and joints continuously welded and ground smooth.

d. When aluminum will be in contact with dissimilar metal, separate contact surfaces with gasket, non-absorptive tape, or coating to prevent corrosion.

15. Mark each fixture and its components in accordance with applicable reference standard.

16. Conduit: Section 16130, RACEWAYS, BOXES, AND CABINETS.

17. Fasteners: best suited to use.

a. Expansion anchors: FS FF-S-325C, Group II, Type 3, Class 1, stainless steel, Type 303.

b. Toggle bolts: FS FF-B-588.

c. Powder-actuated: FS FF-P-395.

d. Finish: Where exposed, custom finish exposed parts to match surface being fastened.

2.2 LIGHTING FIXTURES

A. Lighting Fixtures: Types as shown and as follows:

1. Type 1 fixture:

a. Open, industrial-type, fluorescent, Pendant or surface mount type

b. Lamps: Three 32-watt F32T8/WW.

c. Body: 20-gauge steel channel-shaped body, end plates, cover and reflector. Knockouts in body and end plates as shown. Attach end plates to body with noncorrosive screws. Double-strength construction for steel channel. The fixture shall be mounted with three pendants.

d. Finish:

1) Channel, end plates, and cover:

lector: White baked enamel for steel

2. Type 8 Fixture:

   a. Enclosed, weatherproof high-pressure sodium for wall mounting, UL-listed "Suitable for Outdoor and Wet Locations".

   b. Housing: Die-cast aluminum luminaire, integral ballast housing and grid guard, with tamper-resistant stainless-steel hardware.

   c. Refractor: Pressed, clear, prismatic, single-piece, thermal/shock-resistant, borosilicate glass or polycarbonate.

   d. Finish: Electrostatic powder-coated, FED STD 595 Color No. 20040.

   e. Lamp: One clear, high-pressure sodium, 250W

3. Type 10 Fixture: Emergency LED Light

   a. LED light fixture, Catalog Number LEDtronics LEDWSE200-2-4LR with three LED lamps LEDtronics LED48T8SM-192X2-XPW-001WA or approved equal. The lamps shall be 5200K bright white type. The fixture shall be suitable for connection to 125VDC power. The fixture shall be mounted with three pendants.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install lighting fixtures of types shown at locations shown as follows:

1. Mount fixtures rigidly in place. Use expansion anchors and machine screws for concrete surfaces and toggle bolts for hollow concrete-masonry surfaces. Use appropriate fasteners for attachment to other surfaces. Support lighting fixtures independent of suspended acoustical-panel ceiling systems.

2. Provide minimum of three pendants for each 4-foot ceiling mounted new light fixtures in the Tie-Breaker Stations. The pendant length shall match existing. The pendants shall be stainless steel and of adequate strength to support the light fixture.

3. Where aluminum contacts concrete or dissimilar metal, separate contact surfaces with gasket, non-absorptive tape, or bituminous coating to prevent corrosion. Use stainless-steel fasteners.

4. Mount fixtures plumb, level, and in straight lines. Install stems of suspended fixtures plumb. Group-mounted fluorescent fixtures shall appear as one unit.

5. Install 12-inch minimum length of liquid-tight flexible conduit for connection between fixture and outlet box unless otherwise shown in accordance with Section 16130, RACEWAYS, BOXES, AND CABINETS. Use fixture wire from outlet box in branch circuit to lighting fixture and connect fixtures to branch circuit.

6. Install chase nipple where fluorescent fixtures are installed in continuous groups. Clean lamps, diffusers, globes, reflectors, and exposed-to-view surfaces of fixtures after aiming and adjusting has been approved.

3.2 FIELD QUALITY CONTROL

A. Testing:

1. Furnish necessary personnel and equipment and perform tests and adjustments in the presence of the Contracting Officer Representative.

2. Test lighting circuits for continuity and operation.

3. Test fixtures for continuity of grounding system.

END OF SECTION

SECTION 16602

REMOTE TERMINAL UNIT (RTU) FOR TIE BREAKER STATIONS

PART 1 - GENERAL

1.1 SUMMARY

A. This section provides requirements for vendors who will design, supply, manufacture, install and configure Remote Terminal Units (RTU) required at Tie Breaker Station (TBS), for Supervisory Control and Data Acquisition (SCADA).

B. The specification defines requirements for Remote Terminal Unit, establishes functional and performance requirements for selection and system design of RTUs to be incorporated into the WMATA electrical SCADA network.

C. This specification is applicable to all new SCADA system RTU and to those that are replacing existing RTUs.

D. The RTUs interface to the electrical within TBS and monitor the status of the system via digital and analogue inputs. This data is transferred to the master stations located at the Carmen Turner Facility (CTF) and Jackson Graham Building (JGB) using DNP3 communication protocol over fiber optic cable.

E. The RTUs interface into Intelligent Electronic Devices (IEDs) such as Distributed Input Output (DIO) and electrical protection relays, provide for control outputs to switch circuit breakers, lighting contactors and Emergency Trip Station (ETS) amber light systems.

F. Provide at the time of bid, a certificate from an independent testing company that the RTU has not shown to be non-conforming to IEC 61850 communication networks and systems in substation.

G. Related Sections:

1. DELETED

2. Section 16051D- Scope of Work For Supervisory Control and Data Acquisition Systems

3. Section 16052- Basic Materials and Methods For Traction Power

4. DELETED

5. Section 16128- Wire and Cable For Traction Power

6. Section 16130 - Raceways, Boxes and Cabinets

7. Section 16145 - Wiring and Control Devices

8. Section 16149 - Wire, Cable and Termination Panel For SCADA System

9. Section 16291A - Human Machine Interface For Traction Power

10. Section 16341- Metal-Enclosed DC Switchgear For Traction Power

11. Section 16603 - DC Digital Trace Recorder

12. Section 16604 – Network Switch For SCADA and Automation Systems

13. Section 16605 – Distributed input output (DIO) module for traction power systems.

14. Section 16606 - SCADA Systems Site Acceptance Test Plan.

I. Operating Requirements

1. Designed for continuous, unattended operation to perform:

a. Analog, digital and pulse data acquisition.

b. Digital control.

J. Power Requirements

1. 120 Volts AC power for RTU light and receptacle.

2. 125 Volts DC from the Emergency DC Panel.

1.2 REFERENCES

A. Code, Regulations, Reference Standards and Specifications

1. Code and Regulation of jurisdictional authorities

2. NEC

3. NEMA 250, ICS-6, WC8, 12

4. ANSI C37.90, Z55.1, C12

5. EIA: RS 232.C

6. ASTM: B138

7. ASHRAE/ANSI : 135P

8. ICEA: S-68-516

1.3 DEFINITIONS AND ABBREVIATIONS

A. **CPU** Central Processing Unit

B. **DNP3** Distributed Network Protocol – a communications protocol in current use in the SCADA industry. DNP is an open and public protocol, creating interoperability between master stations and RTUs.

C. **IED** Intelligent Electronic Device, such as a PLC, protection relay, Distributed Input

Output modules or an RTU.

D. **I/O** Input/ Output

E. **LED** Light Emitting Diode

F. **Modbus** A communication protocol developed by Modicon in 1979 and now managed by the Modbus Organization

G. **PLC** Programmable Logic Controller

H. **RTU** Remote Terminal Unit

I. **SCADA** Supervisory Control and Data Acquisition

J. **Supplier** The supplier of the RTU

K. **DIO** Distributed input output module

L. **DTR** Digital Trace Recorder

M. **IEC 61850** International Electrotechnical Commission standard protocol for the design of electrical substation automation. This protocol can run over TCP/IP networks or substation LANs using high speed switched Ethernet to obtain the necessary response times below four milliseconds for protective relaying.

N. **TCP/IP** Transmission Control Protocol (TCP) and the Internet Protocol (IP)

1.4 QUALITY ASSURANCE

A. Qualifications:

1. RTU shall be of proven design and suited for traction power and electric power distribution SCADA applications.

B. Coordination:

RTU to be compatible with existing master station. The master station databas

shall be able to be created automatically from a RTU file using an intermediate conversion program.

1. The contractor shall be responsible for all RTU to master station DNP3 Protocol communication.
2. The contractor shall provide all software required for the normal operation, testing and configuration of the RTU's.
3. RTU installer shall review and modify if required existing mechanical and electric equipment designs to provide telemetering, operational status, and equipment control for items identified in the Interface Points List Requirements in PART 3 of this section.

C. For Code, Regulations, Reference Standards and Specifications, refer to Article 1.02 above.

D. Defects warranty period: RTU shall have defects warranty period, which shall be for a period of 24 months from the date of commissioning. During the warranty period, defective parts shall be returned to the Supplier for replacement on an exchange basis.

E. Factory Acceptance Test:

1. The RTU shall be supplied defect free. Defects found during site testing/commissioning and within the warranty period shall result in the part(s) concerned being returned to the supplier for immediate correction/replacement at the cost of the supplier.
2. An Inspection & Test Plan shall be submitted to WMATA SCADA engineer for approval, prior to the commencement of any tests.
3. Factory testing of each RTU shall be conducted at the RTU manufacturer's facility in the USA. Provision shall be made for witness testing of all equipment, although WMATA may elect to only undertake a visual inspection before accepting delivery. A minimum of 21(twenty one) working days notice shall be provided to WMATA prior to testing.
4. Each RTU shall be fully assembled and configured for factory testing, prior to dispatch.
5. Tests shall include, but not be limited to:

    a. Point to point wiring check including proper labelling of wires and wire termination devices.

    b. Confirmation of all digital inputs & outputs, from the field terminal through to the diagnostic laptop.

    c. Verification of analogue values received (at least zero, half full scale, full scale values and negative full scale values for bipolar analogues) using a

    DC current or voltage signal generator measured from the field terminals to the diagnostic laptop.

    d. Confirmation of control functions from the diagnostic laptop to the field terminals, including exercising the dummy circuit breaker, and the controls isolate switch.

    e. Confirmation of effective communications between the RTU and other devices using the specified protocols.

    f. All powered tests shall be carried out at the specified power supply rating of the RTU

6. Test results for each RTU showing tests undertaken, results and any corrective action taken shall be provided in an approved format and shipped with the RTU. Contractor shall retain copies of the factory test reports for inclusion as appendixes to the RTU Operation and Maintenance Manual (O&M).

F. End-to-End Site Test:

1. The Contractor shall demonstrate the proper functioning of the completed RTU system including all components and telemetry between each piece of equipment monitored or

controlled by the RTU by using a portable computer terminal connected to the RTU in the presence of the Engineer.

2. The RTU must be capable of communicate with the existing Master Station.
3. Each device monitored by a remote sensor shall be monitored from the RTU and operation of the device observed in the field.
4. Each device controlled by the RTU system shall be operated with the control command initiated at the RTU.
5. Simulation of sensors by shorting contacts is to be avoided unless other activation is not possible.
6. Each Intelligent electronic device connected directly to the facility network switch shall be tested for proper communication.

G. Submit certified test report within ten days after completion of field tests.

1.5 SUBMITTALS:

A. Submit the following for approval in accordance with the General Requirements in accordance with Special Provisions and with the additional requirements as specified for each:

1. Provide at the time of bid, a certificate from an independent testing company that the RTU has not shown to be non-conforming to IEC 61850 communication networks and systems in substation.

2. Shop Drawings: Show the following as a minimum:

   a. Equipment layouts

   b. Electrical wiring diagrams and detailed control schematics.

   c. Electrical and mechanical details

   d. Wire and cable schedules, interconnection diagrams, point assignment charts, and connection diagrams

   e. RTU point count for various facilities in accordance with Table-1.

   f. Composite control/status and telemetering sensing equipment schedule.

3. Product Data: Submit annotated product data for each item of equipment and revise resubmittal required when mechanical or electrical equipment are revised or modified.

4. IEC 61850 protocol certification: Provide a certificate from an independent testing company that conformance test has been successfully performed on the proposed RTU according the IEC 61850 conformance test procedures.

5. As-Built Documents: Prior to Substantial Completion develop as-built documents as follows:

a. As-built drawings of the installation: Submit as-built drawings of all the works done under this specification for approval. Submit approved as built drawings in both printed hard copies and as digital copies on approved medium. 11-inch by 17-inch printed copies of the interconnection wiring diagrams applicable to the specific location and or equipment shall additionally be provided in sufficient copies, laminated if required, to be stored in each RTU interface cabinet door pocket.

b. Approved copies of each submittal.

c. Provide As-built drawing in both AutoCAD and PDF formats on CD in sleeves.

6. Operation and maintenance (O & M) manuals:
Operations and Maintenance Manuals:

Operation manuals should contain information pertaining to the operation of the facility. The maintenance manual is shall be a compilation of all the technical information related to the maintenance of the facility, equipment, and/or system. Included should be information pertaining to equipment identification, location, data summary, preventive maintenance instruction parts lists, recommended spare parts, wiring diagrams, shop drawings, special tools, test equipment , factory and field test data and reports.

Operating and Maintenance Manuals and other supporting documentation shall be provided on CD, virus checked, in MS WORD format and PDF format with a Read.me file containing instructions.

Preventive Maintenance Instructions shall and other supporting documentation shall be provided on a separate folder on the CD, virus checked, in MS WORD format and PDF format. All photographs, drawings shall be provided in subfolders in native format (JPEG, DWG etc).

Following the acceptance of the equipment shop drawing, the equipment manufacturer shall submit the associated O&M documentation for review and approval.

After approval, the Contractor prepares and delivers the Contract specified number of copies of the O&M manuals for each site.

7. Preventive Maintenance Instructions:
The Operations and Maintenance (O&M) Manual provided for contractually furnished or installed equipment shall include a Preventive Maintenance Instruction (PMI) section, to ensure the continued safe and reliable operation of the specific system or equipment. The O&M shall specify any maintainer's training requirement and when specified the training curriculum shall be included in the appropriate PMI. The PMI shall recommend the minimum number of maintainers that will be required along with the lowest level of skill sets requirements. If a section contains more than one PMI procedure then the section shall begin with a Table of Contents.

PMI procedures shall be written in language easily understood by every maintainer skill level recommended in the PMI. Prior to acceptance, clarity and effectiveness of each PMI procedure shall be demonstrated in coordination with WMATA's maintenance department using the recommended minimum number and level of maintainers. The maintenance team or individual must be able to understand and successfully perform the draft PMI without intervention by the contractors or engineers. Each procedure shall be formatted similar to standard PMI formatting as currently approved by the WMATA maintenance discipline responsible for the maintenance of the equipment, including a standard approval signature cover sheet. Sample PMI, formats, may be obtained from the appropriate maintenance discipline after contract award. Each procedure shall contain:

1) A recommended performance frequency (interval) that is adjusted to the installed environment and expected level of use.
2) The maintenance crew size and average time for performance of the PMI
3) The system-specific and/or equipment-specific objectives of the PMI
4) Lists of:
    a) Prerequisites
    b) Required reference documents
    c) Industry standards or regulations governing the performance of the maintenance action
    d) Necessary tools and test equipment
5) Definitions and graphics, as much as practical to clarify the instructions
6) Warnings, Cautions, and Safety Notices, plentifully and prominently interspersed to prevent injury, damage, or unsafe operating conditions before any procedure step to which they apply
7) Data sheets and checklists, for data collection regarding conditions that are measured and to ensure that important steps are not skipped
8) Step-by-step instructions to verify and document that the tested mechanism or circuit or subsystem functions within design parameters
9) Step-by-step instructions, types of solvents, cleansers, and lubricants with intervals for lubrication and cleaning of mechanisms to prevent or minimize grime, corrosion, and wear
10) Step-by-step instructions to verify the adjustment of the system, equipment, or circuit which will allow it to operate properly (safely, reliably, and without causing excessive wear) until the next scheduled PMI
11) Step-by-step instructions to verify the integrity of all fasteners, couplings, electrical connections, etc. which may fail or loosen between scheduled maintenance intervals
12) Step-by-step instructions to document the measured condition of the equipment or circuit, to be used for abatement of deterioration, future failure analysis, and in case of catastrophe
13) Step-by-step detailed adjustment instructions for any mechanism or circuit found to be out-of-adjustment

8. Test Plans

Upon approval of the RTU system design, the contractor shall submit a System Functional test procedure and a factory test procedure for the new SCADA RTU's

9. Spare Parts Lists:

Recommended spare parts shall be detailed and listed for each RTU. Provide recommended spare parts sufficient to cover the complete range of RTUs supplied for a minimum of 12 month or as specified in Special Provisions, whichever is greater.

Unit prices shall be supplied.

The list shall include the following:

1) Item identification
2) Recommended spares quantities

3) Base price

10. Certification:
Certified test results for the specified tests on the Remote Terminal Unit or provide certified test reports on identical unit.
Certificates from manufacturers verifying that equipment conforms to the specified requirements

1.6 OPERATION AND MAINTENANCE TRAINING:

A. Operation and Maintenance Training is required. Training shall be based on training format in section 16051D.

B. Instructional Period: One day per session, three (3) Sessions

C. Instruction:
1. Train personnel in preventative maintenance on systems and to recognize malfunctions.
2. A minimum of one day devoted to hands-on demonstration of the equipment operation, trouble analysis, repair, adjustment and maintenance.
3. Provide copies of the O & M manuals as specified above for each person being trained. Use these manuals in organizing the instruction.

1.7 TRAINING OF RTU MAINTAINERS:

D. Training of SCADA System maintainers in the operation and maintenance of RTUs may be required. This shall be required normally for any new RTU products, but may also be required for familiarity training as part of a refresher course for both new and existing personnel.

E. The courses shall cover aspects of the RTU design sufficient for the maintainers to maintain the RTU over its design life. Contents shall include:

1. RTU operation and data communications protocols
2. Diagnostic tools provided with the RTU and test equipment to fault find an RTU
3. Failure modes
4. Configuration of the RTU

F. Instruction Period: One day per session, three (3) sessions
G. Training course material: Training courses shall be conducted at WMATA. The Supplier shall provide all teaching aids for each attendee for the conduct of the courses, which shall be independent of any other material provided the project or contract.

ENGINEERS' TRAINING COURSE:

essions of classroom and hands-on instruction in the development of RTU configurations files, the programming of the RTU. The course session shall be three days in length. The presentation of the course shall accommodate up to 7 engineers designated by the Owner.

A. The presentation of the course shall occur before the installation of the first RTU.

Course Description: In depth discussion of the configuration Software, development of complete configuration files for the TBS in the contract.

1.8 DELIVERY, STORAGE, AND HANDLING

A. The Supplier shall deliver RTUs to the address as indicated in the schedules. Full street address shall be confirmed at time of shipping.
B. RTUs shall be suitably packed to prevent damage during loading, unloading and transport. Equipment sub-assembly which could get damaged due to vibration shall be removed from assembly & packed separately for transport.
C. Each RTU and associated equipment shall be labelled as specified in the contract.

PART 2 - PRODUCTS

2.1 GENERAL:

A. The following RTU manufacturers are pre-qualified to manufacture and supply RTUs to WMATA on the condition the proposed equipment meet all the requirements in this specification. A certificate from an independent testing company that the RTU has not shown to be non-conforming to IEC 61850 communication networks and systems in substation must be provided at the time of bid for the propose RTU to be considered.

1. CG Automation Solutions (CGA)
2. Schweitzer Engineering Laboratories (SEL)
3. Novatech

B. RTU SIZE AND EXPANDABILITY
1. RTU shall be equipped for the point counts defined in Table 1 (Basic+20% spare (wired & hardware). It shall be possible to expand the RTU capability for additional 100 % of the basic point counts by way of addition of hardware such as modules, racks, panels; however, RTU software and database shall be sized to accommodate such growth without requiring software or database regeneration.

C. **TABLE 1: RTU CONNECTION POINT REQUIREMENTS**

RTU TYPE by Location	**Control Points**		**Status Points**	**Analog Points**		**Accum Points**
	Momentary	**Latching**		**0-1mA**	**4-20mA**	
Tie Breaker Station	8	8	24	16	16	8

D. Auxiliary contacts, modules and data interfaces added to equipment specified in other sections are to be provided by the particular equipment manufacturer or coordinated with the particular equipment manufacturer so as not to void any warranties.

2.2 REMOTE TERMINAL UNIT

A. RTU FUNCTIONS

1. All functional capability described herein shall be provided by the Contractor even if a function is not initially implemented. As a minimum, the RTU shall be capable of performing the following functions:
    a. Acquiring analog values from Multi-purpose relays, Digital Trace Recorders or other Intelligent Electronic Devices (IEDs) and the status inputs of devices from the substation, processing and transmitting to Master stations.
    b. Capable of acquiring analog values through transducers having output as 4-20 mA, 0-10 mA, 0-+10 mA or +/- 5 volts using analog input modules.
    c. Capability to receive pulses in the form of contact open/closure from 3-wire (Form C) pulse initiators.
    d. Receiving and processing analog commands from master station(s) and
    e. Capability of driving analog output card.
    f. Receiving and processing digital commands from the master station(s).
    g. Data transmission rates - 150 to 56,600 bps for Serial ports, 10/100baseT(X) or 100baseFX for TCP/IP Ethernet ports.
    h. DNP3 protocol to communicate with the Master station(s) ,
    i. Have required number of communication ports for simultaneous communication with at least three Master station(s),
    j. Have RTU configuration & maintenance tool.
    k. DNP3, IEC 61850, MODBUS protocol over fiber for end devices,
    l. DNP3 & MODBUS protocol over RS485 interface, to communicate with the other devices.
    m. RTU shall have the capability of automatic start-up and initialization following restoration of power after an outage without the need of manual intervention. All restarts shall be reported to the connected master stations.
    n. Remote database downloading of RTU from SCADA master stations,
    o. Act as data concentrator on all supported protocols,
    p. Internal battery backup to hold data in SOE buffer memory & also maintaining the time & date.
    q. Mandatory to guard the data/ equipment from intrusion/damage/breach of security & shall hve SSL/VPN based security,
    r. Capability of time synchronization with network master.
    s. Shall have SNMP

B. RTU System Design

1. The RTU shall be designed to work in a HV traction power substation by being of robust physical construction with immunity to electrical noise.
2. The RTU shall be assembled from modular units and shall be able to be arranged in the RTU rack in any order.
3. Modules shall be interconnected via a suitably robust plug and socket method. It shall not be necessary to unscrew individual wires/cables, internal RTU wiring and I/O wiring, to replace faulty modules. The failure of one module shall not affect the performance of any other module.
4. The RTU and the cubicles shall be designed to accommodate the actual number of input/outputs and IEDs at the specific substation, plus spare capacity.
5. Minimum RTU I/O quantities shall be developed in accordance with requirements specified in Table 1.
6. RTU shall be designed to interface directly and indirectly with electrical equipment and protection systems and other devices within the electrical and traction supply power distribution networks.

   a. Direct interface is via wiring directly from digital and analogue sensors located within the substation equipment to the RTU, and from relay outputs within the RTU to equipment panels in the substation.

   b. Indirect interface is via local network switches between the RTU and the IEDs in the substation.
7. RTU shall be configured to be compatible with existing master stations.
8. RTU to master station communication protocols shall be DNP3.
9. The RTU manufacturer shall provide a minimum of 1 week of on-site technical support for each RTU locations for systems integration.
10. The contractor shall provide all software and hardware required for testing and configuration of the RTU's.

C. RTU power supply
1. Power source – 125VDC substation battery
   At the Tie Breaker Station (TBS), the RTU shall derive its power requirements from the substation battery.
   Two pole thermal circuit breaker shall be provided to isolate the station battery supply from the RTU system.
   The RTU power supply shall be designed to operate at full-specified performance for DC supplies.

2. Power source – 120V AC general purpose
   A general purpose 120VAC supply is used for the RTU cabinet interior illumination and a GFI receptacle for maintenance use.

D. Remote Terminal Unit Controller
1. The RTU shall be microprocessor based automation platform capable of providing highly secure select-before-operate controls, status monitoring with 1 millisecond Sequence of Events (SOE) time tagging, and user programmable automation functions. Once power is supplied to the unit, it shall be designed to operate without manual intervention; additionally, it shall auto restart and be able

to communicate with the master station without reporting spurious state changes on power resumption after a power failure. Suitable, reliable indicators such as LEDs shall be provided for personnel to readily ascertain the status of the RTU.

2. The processor shall monitor the health of the RTU and shall have built in diagnostics., The RTU shall allow remote interrogation including but not limited to diagnostics for memory and bus errors, buffer overflows, local software routine health, communication ports status, input/output card health. Diagnostics shall also be supplied that shall permit complete testing of the RTU with a portable computer. Diagnostic checking of the communication ports shall be provided to permit checking by a portable computer.

3. Power supply and battery low volts or failure conditions shall be monitored.

4. The RTU shall possess memory to permit storage of a minimum of 2000 events (input changes) locally for subsequent transmission to the SCADA master station and these events shall not be lost on buffer overflow; an indication shall be provided of this latter condition. Events will be retained in the buffer until they are correctly read by the master station. As a minimum, separate buffers shall be provided for digital and analogue events.

5. A Separate event recording for the internal RTU events shall be provided and buffered The internal events shall include but not limited to the events such as health, time synchronization and any internal errors. This shall permit storage of up to 2000 events.

6. When memory is provided for the purposes of local control or communications routines, spare memory capacity equal to the amount utilized shall be provided.

7. The RTU shall have a real time clock, with a resolution of 1msec. It shall have the capability of time stamping events. The RTU clock is normally synchronized by the master station using DNP3 protocol every 5 minutes. In the advent that this does not occur, the RTU clock shall drift no more than 1 second in 24 hours.

8. The RTU shall be capable of reporting, events in 1msec steps with accuracy of +/-1% of the stamped time.

9. The RTU shall be equipped with a “controls isolate” switch, which shall inhibit all control outputs from being executed. The status of this switch shall be monitored by the RTU.

10. The RTU shall be capable of programming in a high level language to implement local control and logic routines.

11. The RTU shall incorporate a unique digital address or identifier. The addressing scheme shall allow operation of several RTUs on a common communications line as well as random access to individual RTU.

12. The RTU shall be an easily configurable unit capable of selectively concentrating data from multiple Intelligent Electronic Devices (IEDs) and local and distributed discreet I/O panels (status, accumulators, analog, controls) into communication channels with one or more SCADA Master Stations.

13. The RTU configuration software provided shall run on a standard Windows PC and shall provide drag & drop menus to configure the RTU's communication ports; status, alarm and control points; IED communication Clients; Master Station communication Servers; selective routing of data points between the IED Client databases and Master Station Server databases, and local calculations and stand alone control algorithms. Gateway configuration shall required secure login with a user'sID and pass-word login.

14. The RTU shall be scanned by the Operation Control Center (OCC) Advance Information Management System (AIM) master stations and the SCADA master stations. The protocol used is DNP3 over TCP/IP. The supplier must be able to demonstrate a significant history of satisfactory operation of the RTU connected to these master stations or similar.

15. The message exchange between the Master Station computer and the RTU shall be controlled and supervised by the master station computer. Commands to which the RTU shall respond may include, but not necessarily be limited to, the following:

    a. Full scan request - Initiates transmission of all measurement and status.

    b. Selective scan request - Initiates transmission of selected measurement and/or status points.

    c. Report by exception - Initiates transmission of only those points which have changed since the last transmission. A range of values or deadband, which may be set by the operator, shall determine whether an analog variable shall be transmitted. If the variable has changed by less than the specified deadband since the last reported value, the value shall not be transmitted. If the variable has changed more than the specified amount since the last reported value, the value shall be retransmitted

    d. Control point select and verify - Command to select a digital control point select.

16. Transmit information only after receiving the proper address from the master station. Design RTU so that it will not respond to the reply messages of other RTUs. Replies of the RTU shall include, but not necessarily limited to, the following:
Analog and pulse data value message.
Digital data value message.
Check back response - Acknowledgment of control point select.
End message - End of block of data.

E. Communication Interfaces
The minimum requirement for communications is as follows:

1. The RTU shall be capable of simultaneous communication over the following interfaces with both VPN and SSL security:
Ethernet 10/100baseT(X) or 100baseFX (TCP/IP and OSI)
RS232 ports: bit or byte oriented, synch or asynch, 150 B 57,600 bps
RS485 ports: bit or byte oriented, synch or asynch, 150 - 57,600 bps. A specified number of RS-485 channels may be required to interface to local computing devices such as IEDs and ETS system Distributed Input Output (DIO) modules. If required, will be specified at the time of the placement of an order. Currently, these IEDs communicate using the Modbus and DNP3 protocols.

2. The RTU shall simultaneously communicate with three independent Master Station communication servers using DNP3 protocol, and communicating over of any combination of serial or Ethernet ports, or using two different IP addresses. The RTU shall also communicate simultaneously with up to two HMIs and sixty IEDs.

F. Communication Software
1. The RTU communication software shall be capable of selectively concentrating data from multiple DIO Distributed I/O modules and Intelligent Electronic Devices (IEDs) into communication channels to one or more SCADA Master Stations, a local HMI, and a local Laptop communication port. The Data Concentrator shall be able to seamlessly transfer communication of select-before-operate control execution between the Master Station and distributed Control I/O modules without compromising security. Control execution shall employ secure, multi-step handshaking consisting of a Master Station point selection message, a Acheckback message from the end device, a control execution message from the Master Station, and an execution acknowledgment message from the end device.

As a minimum, client and server software shall be available to serve data to the following communication interfaces:
DNP3 protocol
IEC 61850
Modbus protocol
NTP Network Time protocol
Ethernet 100baseT to local Laptop
Utility remote meter ready

G. Instrumentation and Control Interfaces Input/Output Modules:
1. Include installed input/output modules to accommodate the specified point sand spares. Provide signal conditioning and filtering for each point and include in the modules protection sufficient to meet the surge test requirements specified in ANSI C37.90. "Guide for Surge Withstand Capability (SWC) Tests".

2. Analog Input Modules shall selectively connect analog data points to one or more analog-to-digital (A/D) converters under control of the common logic. The A/D converter shall have sufficient accuracy and conversion rate to satisfy the performance requirements specified previously. All A/D converters shall have a minimum of 8 bit depth unless special conditions warrants a lessor number of bits can provide the required accuracy. Prior approval of these special conditions shall be required. Design the analog input modules such that channel crosstalk is eliminated and a common mode rejection ratio of at least 80 dB and a normal mode noise rejection of at least 30 dB at 60 Hz can be achieved.
   Data multiplexing and transducer termination techniques utilized shall not effectively degrade these noise immunity characteristics. Analog input modules shall be capable of accepting the analog output of transducer with a signal output level of 0-1 mA dc, 4-20mA and 0-5V.
3. Digital Input Modules:

   a. Monitor status and alarm points via digital input modules. Digital input modules shall accept dry contact inputs.
   b. RTU shall be capable of accepting isolated dry (potential free) contact status inputs. The RTU shall provide necessary sensing voltage, current, optical isolation and de-bounce filtering independently for each status input. The sensing voltage shall not exceed 24Vdc.
   c. The RTU shall be set to capture contact operations of 20 ms or more duration. Operations of less than 20 ms duration shall be considered no change (contact bounce condition). The RTU shall accept two types of status inputs i.e. Single point Status inputs and Double point status inputs.
   d. To take care of status contact chattering, a time period for each point and the allowable number of operations per time period shall be defined. If the allowable number of operations exceed within this time period, the status change shall not be accepted as valid
   e. Single point status input will be from a normally-open (NO) or normally-closed (NC) contact which is represented by 1-bit in the protocol message.
   f. The Double point status input will be from two complementary contacts (one NO and one NC) which is represented by 2-bits in the protocol message. A switching device status is valid only when one contact is closed and the other contact is open. Invalid states shall be reported when both contacts are open or both contacts are closed.
   g. All status inputs shall be scanned by the RTU from the field at 1 millisecond periodicity.
4. Digital Control Output Modules:
   a. Control Security and Safety Requirements:
      1) The RTU shall include the following security and safety features as a minimum for control outputs:
         a) Select- check-before-operate (SCBO) sequence for control output.
         b) No more than one control point shall be selected and executed at any given time.
         c) The control selection shall be automatically cancelled if

after receiving the "control selection" message, the "control execute" command is not received within the set time period.

d) No control command shall be generated during power up or power down of RTU.

b. The RTU shall provide the capability for a master station to select and change the state of digital output points. These control outputs shall be used to control power system devices such as Circuit breakers relay disable/enable and other two-state devices, which shall be supported by the RTU.

c. A set of control outputs shall be provided for each controllable device. On receipt of command from a master station using the select check-before-execute operate (SCBO) sequence; the appropriate control output shall be operated for a preset time period which is adjustable for each point from 0.1 to 2 seconds. Outputs shall be latching continuous output contact closure. Receipt of a point selection address shall cause the RTU to return a verification message to the master station. Execute commands only after the dispatcher has verified that the selected point is the desired point and has issued an execute command for the function to be performed.

d. Control relays shall be installed between the output modules and terminal strips. Each control output shall consist of one set of potential free NO contact. The output contacts shall be rated for at least 10Amperes at 120 Volts ac resistive load. These output contact shall be used to drive heavy duty relays. In case Control output module of RTU does not provide potential free control output contact of this rating, then separate control output relays shall be provided by the contractor. These relay coils shall be shunted with diodes to suppress inductive transients associated with energizing and de-energizing of the relay coils & shall conform to the relevant requirements.

5. Analog Input Modules:

a. The real time values like, Active power, Reactive Power, Apparent power three phase Current & Voltage and frequency, power factor & accumulated values of energy values will be acquired by the RTU.

b. The RTU analog-to-digital (A/D) converters shall have a digital resolution of at least twelve (12) bits plus sign. The overall accuracy of the analog input system shall be at least 0.2%(i.e. 99.8%) at 25 ºC of full scale . Mean accuracy shall not drift more than 0.002% per degree C within the temperature range of –5 to +55 degree Linearity shall be better than 0.05%. Each input shall have suitable protection and filtering to provide protection against voltage spikes and residual current. Loading up to 150% of the input value shall not sustain any failures to the RTU input.

c. The ability of the RTU to accommodate dc inputs shall include the following signal ranges:

1) Unipolar Voltage:0-0.5V, 0-1V, 0-5V, 0-10V,
2) Unipolar Current: 0-1mA, 0-10mA, 0-20mA, 4-20Ma,
3) Bipolar Voltage: 0.5V, 2.5V, 5V, -20-0-20mA (- to +)
4) Bipolar Current: -1mA-0-1mA, -20mA-0-10mA, -20-0-20mA

d. The total burden imposed by the RTU/DC analog input circuit shall not exceed 0.5 volt-ampere for current and voltage inputs.

6. Pulse Input Modules:

Pulse input modules shall receive pulses in the form of contact open/closure from 3-wire (Form C) pulse initiators. The accumulated count shall not be altered, nor shall counting be interrupted when a count is transferred to the master station. Each counter shall have enough capacity to accumulate the number of pulses expected at the metering point in a 4-hour period without overflow, assuming an average pulse rate of 1 pulse per second. Pulse counter inputs shall be capable of accepting pulse inputs at a rate of 5 pulses per second. The pulse forming voltage, if required, shall be furnished from the RTU circuit.

The pulse count registers shall not be reset at the end of the interval and shall continue to accumulate and automatically roll over only when they reach maximum count.

7. Communications Modules:

A specified number of RS-485 channels may be required to interface to local computing devices such as IEDs and ETS system Distributed Input Output (DIO) modules. These shall be provided if indicated on the design drawings. Currently, these IEDs communicate using the Modbus and DNP3 protocols.

If the specified number of RS-485 channels exceeds the RS485 ports available on the RTU, separate industrial grade communication module shall be provided.

Isolated Multidrop RS-485/232 Converters shall be provided where daisy chained device communication ports are required.

8. IED pass through:

a. The Master Station user shall be able to perform a virtual connection with any IED connected to the RTU, provided the communication protocol functionality, to support the information transfer from and to the IEDs. For example, the Master Station shall gather on-demand IED data; visualize IED configuration parameters, and IED source code depending upon the IED capabilities. On the other hand, the Master Station shall be able to download to the IEDs configuration parameters, code changes, etc. depending upon the IED capabilities. The capability can be demonstrated with the upload & download of data from master station with IEDs connected to the RTUs using the support of protocols specified.

9. Local/Remote selector switch

a. A manual Local/Remote selector switch shall be provided for each RTU to disable all control outputs by breaking the power supply connection to the control output. When in the "Local" position, the Local/Remote switch shall allow testing of all the control outputs of RTU without activating the control outputs to field devices. A status input indication shall be provided for the Local/Remote switch to allow the SCADA system to monitor the position of the switch.

10. Dummy breaker latching relay
    a. The Contractor shall provide a latching relay to be used to simulate and test supervisory control from the Master station. The latching relay shall accept the control signals from the RTU to open and close, and shall provide the correct indication response through a single point status input.
11. RS485 Communications Ports:
    a. A minimum of 10 RS-485 and 4 RS232 connection ports shall be available and integrated on the RTU to interface to local computing devices. Currently, these IEDs communicate using the Modbus and DNP3 protocols.
    b. A separate serial to Ethernet port server to increase the number of serial ports is not acceptable.
12. Diagnostic and configuration utilities
    a. The contractor shall provide a laptop PC loaded with the diagnostic, configuration and maintenance tools mentioned below. The laptop PC shall be provided with all hardware accessories including cables, connectors etc. required for interfacing with Master station, RTU and end devices. A suitable Hub shall be provided to use the tool in monitor mode. A carrying case and a suitable power adaptor for laptop PC shall also be supplied.

    b. Diagnostic Software:

        1) Diagnostic Software shall be provided to continuously monitor operation of the RTU and report RTU hardware errors to the connected master stations. The software shall check for memory, processor, and input/output ports errors and failures of other functional areas defined in the specification of the RTU.

    c. RTU Configuration and Maintenance Tool
        1) RTU configuration & Maintenance software tool:
            a) The RTU database configuration & Maintenance software tool shall be required to perform the database modification, configuration, compilation and documentation. The database compiler shall provide error detection services. It shall also perform the downloading of the compiled database into the RTU database.
            b) Monitoring of all inputs, control of all outputs and testing of calculation logic. Monitoring of all inputs and logic at card level, logic level and DNP3 level.
            c) Display of communications statistics and eavesdropping of communications channels, including Ethernet, IP, DNP3, Modbus and IEC61850.
            d) Download & upload of RTU software, database configuration and calculations, upload the complete configuration from RTU to modify and then download to RTU.

e) On-line help.
f) Display current firmware, software and configuration running in the RTU
g) Configuration and diagnostic software must run on Windows 7
h) The diagnostic and configuration utility software shall be provided on a CD/DVD with Licenses. The current version number of such software shall be provided. Any costs in upgrading to subsequent version numbers shall be included in the pricing.
i)
j) Master station-to-RTU simulator & protocol analyzer software tool:
k) The Master station to RTU simulator tool shall be provided and used to test the communication interfaces of Master station, RTU and end devices. The Master station simulator tool shall be capable of emulating the master station for DNP3 protocols. The RTU simulator shall be capable of emulating the servers DNP3, IEC61850 and Modbus protocols. It shall also be possible to prepare illegal messages for transmission, such as messages having invalid checksum.
l) The protocol analyzer shall be used to monitor all communication traffic on a channel (between Master station & RTU and between RTU & end devices without interfering channels operation. Channel traffic captured in the active or passive modes of operation shall be displayed.
m) The Master station simulator and protocol analyzer tool shall also have the following features:
n) Each received message shall be checked for validity, including the check sum.
o) The tool shall maintain and display error counters so that the number of errors during a period of unattended testing can be determined.
p) All fields of a message shall be displayed. A pass/fail indication for the message shall be included.

13. Integrated HMI.

The information processor shall support an integrated web-based Human Machine Interface (HMI) that provides visualization and control of data tags.

Optional VGA port for direct connection of a monitor to be used as HMI.

14. Terminal Strips:

Provide barrier-type terminal strips within the RTU cabinet for all external connections for instrumentation and control signal. Direct connections to relay terminals will not be allowed.

15. Spare:

a. Provide a minimum of 20% spare points and 2 spare serial ports.

2.3 PERFORMANCE REQUIREMENTS

A. Environmental conditions

The RTU shall be designed and supplied suitable for indoor equipment conditions as specified by ANSI/IEEE C37.1 For new RTU not currently installed in WMATA facilities, heat dissipation calculations shall be provided to demonstrate the RTU's ability to comply with the temperature ratings of the equipment in the range specified. These calculations shall be done on the assumption that maximum spare capacity as specified in section 2.02 is implemented.

B. Maintainability

RTUs shall not require routine or planned maintenance. Therefore, no fans or moving parts shall be used in the RTU to avoid any need for maintenance. RTU should be constructed to resist the entry of dust. A single technician shall be able to remove and replace for repair purposes, without special tools and test equipment, all equipment involved in the operation of an RTU. It should not be necessary to dismantle or remove multiple pieces of the RTU in order to replace a module.

C. Reliability

RTU should normally remain in continuous service to provide SCADA. Failure can result in the interruption of the operation of the railway and a high level of reliability is therefore required. The supplier shall provide the predicted mean time to failure and the mean time to repair of the equipment. Where insufficient historical data is available, the supplier shall state the methods used to determine the reliability performance.

Availabilities achievable by non-redundant commercial grade equipment should exceed the following:

System Function	**System Availability**
Control and monitoring of any one breaker.	99.99%
Monitoring of any one single alarm	99.99%
Monitoring of any one analogue input	99.99%
Communication to Master Station	Error Free

D. Service life

The RTU supplied shall be capable of performing its intended purpose, for a minimum of 20 years from the date of supply.

2.4 RTU CONFIGURATION

A. CONTRACTOR shall retain the services of the SCADA RTU manufacturer or their authorized representative to be the system integrator, develop RTU configuration files, supervise and/or perform check-out and start-up of all system components.

B. The contractor's proposal shall include two weeks of services from the RTU manufacturer for the development of the TBS RTU configuration file template.

C. The first week: The system integrator shall develop the RTU configuration file template and initial testing at their factory.

D. The second week: The system integrator shall demonstrate at the WMATA SCADA LAB, that the provided RTU and configuration meet all requirements in this specification.

E. The contractor shall provide a full functional RTU on an open rack for the tests at WMATA

F. The RTU test Laptop and software specified in this section shall be used by WMATA SCADA engineers for the LAB tests and site tests.

G. In addition to a lump sum price for configuration, an hourly rate should be quoted for assistance with configuration and commissioning. This rate shall be used for telephone assistance where the person providing assistance will not be required to attend site.

2.5 SENSORS AND TRANSMITTERS:

A. General:

1. Power the transmitters by a 24 dc loop power supply located in the RTU interface cabinet.
   Auxiliary power supply, 120-volt AC input, 24-volt DC output shall be provided with each RTU for all transmitters.
   DC power rating shall be capable of supplying the connected load plus 20-percent spare capacity.

B. Sensors and Transmitters supply by others:

1. Room air temperature transmitters shall be an element contained within a cover, suitable for mounting on a wall
   Insulated base temperature range: Minus 20F to plus 120F
   Accuracy of calibrated points: Plus or Minus 0.5F.
   Sensing elements: Platinum wire resistance type.
   Transmitter output signal: 4 to 20 milliamperes DC.

2.6 RTU CABINET

Each RTU shall be supplied fully assembled, together with all ancillary equipment, including wiring terminals, mounting rails, wiring ducts & wiring, to form a complete system, subject only to connection of substation equipment to field terminals.

A. Ancillary equipment to be supplied with the RTU includes the following:
   1. 1 x 24v power supplies, 125V DC to 24V DC converters. This is used to power input/output circuits and RTU 24VDC circuits.
   2. 1 x 24v power supplies (120V AC to 24V DC converters. This is used for all external transmitters
   3. Cubicle switch/lighting and a 120V AC GFI receptacle. The GFI receptacle shall be mounted near the bottom of the RTU cubicle.
   4. RS485 Gas arresters (Quantity will be site specific and shall be specified at the time of order).
   5. 4x2 pole DC thermal circuit breaker
   6. 1X2 pole AC thermal circuit breaker
   7. Fuse blocks and fuses as required
   8. Factory install 4 x 24V DC interposing relays (type cube relay 24V DC or equivalent) . These 4 x 24V DC relays are for the Battery Charger, Inverter and transfer switch alarms to be fed to both the RTU and the DTS systems from a single alarm source.

B. Cabinet Construction:
   1. Cabinet shall be free-standing, floor mounted and height shall not exceed 72 inch.
   2. .
   3. Construction: NEMA 12.
   4. Apply two finish coats, ANSI No. 61, Light Gray, to exterior surface and Paint interior per manufacturer's standard.
   5. Cutout for cable entry at the top and bottom with Non-ferrous cover plates are required for cable entry.
   6. Cabinet with fixed side, rear and roof panels, front swing, full hinged door with three point latch, key, hasp and staple for padlock.
   7. Provide protective pocket inside front cover with schematic diagram, connection diagram, operating instructions, and layout drawing of control wiring and components within enclosure.
   8. Door & cover plates shall be fitted with gaskets, to provide a dust proof environment and shall be suitably earthed with earth straps using flexible earth cable.
   9. Dimension: 72”H x 36”W x 24”D
   10. All major items of equipment shall be labelled.
   11. Din mounting rails shall be sized to provide a minimum of 30% spare space for future expansion.
   12. The cubicle shall be grounded to the station ground bus.
   13. Provide a simplified means of connecting field cables and RTU cables such that spares can be utilized, additions and alterations can be readily made, and different voltage sources can be utilized.

   14. Terminal Blocks:

Terminal blocks located within the RTU cubicle shall define the point of separation between the electrical SCADA RTU and the substation electrical system.
Power Terminals: Rated 30 Amp, 600 Volt with insulating barriers between poles and washer-head binding screws on each pole to accommodate up to 10 AWG wire.
Signal and Control Terminals: Rated 10 Amps, 300 volts, modular construction type, screws to accommodate up to 14 AWG wire.
Labels shall be placed to describe each cable from the field and from the RTU.
Space shall be allocated between sections of terminals allocated to different cables to provide adequate space for labelling – a minimum label width of 9 mm shall be provided.
To facilitate troubleshooting, field cable terminations have been standardized.

15. Fiber Patch Panel for RTU equipment:
Install one Corning SPH-01P Fiber Patch panel with one Corning CCH-CP12LC for connection of multimode fibers.
Install fiber Jumper cable between the patch panel and the RTU units.

16. Equipment Rack:
19” rack fabricated from 11GA steel for mounting equipment modules shall be provided.
Size: 46” high with 25RU rack opening.
Network switches and fiber patch panels are mounted on the 46” high equipment rack. No RTU panels shall be mounted behind the rack.
.

17. Nameplate:
Black laminated plastic composition with permanent white engraved lettering, and beveled edges.
Fastened to panel using small round-head screws.
Installed inside cubicle and cabinets with cement.
Submitted for approval.

2.7 MARKING TAGS:

A. Dekafix 6.5-FS or equal, consecutive vertical, No. 4682.2 or No. 5766.6 as approved.

B. Group marking carrier with paper marking strip and transparent cover.
1. Type SCHT5, Catalog No. 2924.6.
2. Type ES05, Catalog No. 2937.0.
3. SST5, Catalog No. 2940.0.

2.8 RACEWAYS, BOXES AND CONDUIT

A. Provide conduit, raceways, boxes and fittings in accordance with Section 16130

2.9 WIRING:

A. Status, Control and Analog:

1. Multicolor cable, UL-listed conductors of 98-percent copper with type XHHW insulation rated 600 volts. Nonmetallic jacket material complying with ICEA S-68-516, NEMA WC8, free of PVC or PVC-based compounds.
2. Jacket: Chlorosulfanated polyethylene, crossed-linked polyolefin, or heavy duty neoprene.
3. Use shielded twisted pair cable for analog inputs and outputs..
4. All other IEDs shall be connected to the RTU through the substation network switch.

2.10 SPARE PARTS:

A. In accordance with special conditions and the following:
   1. Provide 20% spare of each type of circuit card, and 2 power supplies, Provide touch up paint in 1-quart container.

PART 3 - EXECUTION

3.1 SOURCE QUALITY CONTROL

A. Design and Production Tests: Perform and submit in accordance with the General Provisions, certified test results for the tests on each unit of Remote Terminal Unit supplied under this contract.
B. CONTRACTOR shall retain the services of the RTU manufacturer to be the system integrator, supervise and/or perform check-out and start-up of all system components.

3.2 INSTALLATION

A. RTUs shall be delivered and installed as shown in accordance with approved shop drawings at the following facilities:
   1. Tie Breaker Stations

B. The Contractor shall terminate all wiring on terminal strips in accordance with approved shop drawings and interconnection diagrams.

C. Perform work in accordance with the NEC.

D. Raceways Boxes and Cabinets:
   1. Install conduit, raceways, boxes, fittings in accordance with Section 16130 as necessary to facilitate connections in accordance with Table 2

Install RTU interface cabinets at locations in accordance with approved shop drawings.

2. Arrange terminations in interface cabinets in a sequence to facilitate maintenance. Terminations shall comply with the following requirements:
   Terminal strips shall be identified with markings tags as TB-1, TB-2, TB-3, ext. as required from left to right.
   Terminals shall be identified consecutively on the various terminal strips from top to bottom and from left to right.
   Terminations for equipment shall be grouped by equipment identification with control functions located on top and indication functions located on the bottom within the grouping.
   Spare terminals shall be concentrated in one area of the terminal strip to the extent possible.

E. Wiring:
1. Use shielded twisted pair cable for analog input and control output signals and multi-conductor cable for all other functions.
2. Install wiring for RTU interface circuits for all points identified for branch circuits to power supplies located in selected RTU interface cabinets and for circuits from power supplies to sensors and transmitters in accordance with the following requirements:
   Terminate shield drain wire of two-conductor, shielded twisted-pair instrumentation cable on a terminal strip in the RTU interface cabinet located directly below the associated two conductors for the cable. Drain wire shall not be grounded at the interface cabinet. (Drain will be grounded at the RTU)
   Terminate twisted pair instrumentation cables for analog circuits on terminal strips that are separate from terminal strips used to terminate non-analog circuits.
   Install twisted pair instrumentation cables for analog circuits in conduits that are separate from conduits used for non-analog circuits.
   All copper wires from DC switchgear and DC negative switchgear devices shall be terminated at the DC trace recorder terminal blocs,

F. Ground RTU, AEMS interface cabinets and power supplies in accordance with Section 16060

G. Install auxiliary contacts as required for remote monitoring implementation as shown on drawings.

H. Install thermostats and sensors at locations indicated on drawings with top of thermostat 5'-0" above finished floor.

I. Connections between each PLC and the RTU shall be per the PLC manufacturer’s recommendations.

J. Wiring between the RTU in the tie breaker station and equipment may be made as follow:
1. To the RTU without the requirement for an interface cabinet.

2. For IED devices through the facility's Network Switch.

3.3 FIELD TESTING:

A. The Contractor shall perform polarity and continuity test on all interconnection wiring.

B. The Contractor shall perform system start-up for each RTU in the presence of the manufacturing representatives. The manufacturing representative shall verify correct operation of each input/output data card using a simulated master control interface test unit. Additional checkout shall be made to verify wiring terminations, modem operation, power supply operation and CPU operation.

C. The Contractor shall label all wiring terminations to reflect the connection points.

D. The Contractor is responsible for testing all RTU input signals to verify correct status and telemetry signal levels. A test data sheet shall be developed for each RTU/AEMS Interface Cabinet which list all I/O signal points. The data sheet shall be submitted as part of the Contractors test plan. The Contractor shall submit a list of discrepant I/O signal points to the Engineer. I/O equipment supplied under this contract that is not reporting properly shall be corrected and retested. The Contractor shall submit a discrepancy report for all I/O points indicating problems found and required action.

END OF SECTION

SECTION 16603

Digital Trace Recorder (DTR) for Tie Breaker Stations

PART 1 - GENERAL

1.1 SUMMARY

A. This section provides requirements for vendors who will design, supply, manufacture, install and configure Digital Trace Recorder (DTR), a data acquisition system for Tie breaker stations (TBS) to continuously monitor and store large number of analog and binary inputs. This specification also covers the software requirement for system configuration, recording, data playback, and data analysis.

1. The data acquisition system records and saves DC currents, voltages and system disturbances on local hard drive securing data even if communications are lost during an even. All data will periodically be pulled into a central server location, for long-term archiving.

2. The DTR shall be interfaced with DC switchgear current and voltage transducers, relays, switches and contacts. These units are not to provide remote control of switchgears thru LAN/WAN.

3. The Digital Trace Recorder (DTR) shall be connected to the substation Network switch with fiber cable.

4. The DTR analysis software shall have the functionality of a power analyzer, a data logger, a transient recorder and a FFT harmonic analyzer.

B. Related specification sections include the following:

1. Section 16051D - Scope of Work For Supervisory Control and Data Acquisition Systems

2. Section 16149 - Wire, Cable, Cable Tray and Termination Panel For SCADA System

3. Section 16341 Metal Enclosed DC Switchgear

4. Section 16602 RTU for Traction Power Systems

5. Section 16604 Network Switch For SCADA and Automation Systems

6. Section 16606 SCADA system integration site acceptance test plan

C. Operating Requirements

1. Designed for continuous, unattended operation to perform:

   a. Analog, digital and pulse data acquisition.

   b. Digital control.

D. Power Requirements

1. 125 Volts DC from facility control power.

1.2 REFERENCES

A. Code, Regulations, Reference Standards and Specifications

1. Code and Regulation of jurisdictional authorities
2. NEC
3. NEMA 250, ICS-6, WC8, 12
4. ANSI C37.90, Z55.1, C12
5. EIA: RS 232.C
6. ASTM: B138
7. ASHRAE/ANSI : 135P
8. ICEA: S-68-516

1.3 QUALIY ASSURANCE

1. DTR equipment manufacturer: The following Data Acquisition System manufacturers are pre-qualified to manufacture and supply DTR to WMATA on the condition the proposed equipment and software meet all the requirements in this specification.

   a. CG Automation Solutions (CGA)

   b. Dewesoft

   c. Dewetron

   d. National Instrument

   e. Astro Nova Test Measurement

B. For Code, Regulations, Reference Standards and Specifications, refer to Article 1.02 above.

C. Coordination:

1. The DTR accessory parts or interfaces to the switchgear/switchboard shall be factory installed by the switchgear/switchboard manufacturers. Have the DC switchgear and switchboard equipment manufacturer review and design equipment to provide analog telemetering and operational status for items identified in the Interface Points List Requirements in PART 3 of this section.

D. The Contractor shall develop test procedures based on the section 16606 “SCADA

System Test Plan" and obtain Engineer approval prior to testing.

E. Contractor shall perform progressive tests in accordance with an approved test procedure to verify compliance with specified system performance requirements, including as a minimum, proper component operation, module input and output signal operation and telemetry between equipment sensors and each RTU.

1. All test discrepancies shall be corrected and test reports submitted to the Engineer prior to scheduling end-to-end testing.

2. Contractor shall notify the Engineer prior to commencing progressive testing and shall offer the Engineer the opportunity to witness the testing. Witnessing of any portion of the progressive testing by the Engineer shall not relieve the contractor from responsibility for any portion of follow-on testing.

F. End-to-End Test:

1. The contractor shall provide acceptance test procedures for both hardware and software.

2. The Contractor shall demonstrate the proper functioning of the completed DTR system including all components and telemetry between each piece of equipment monitored by the DTR by using a laptop connected directly to the DTR or to the facility's network switch. Simulation of sensors by shorting contacts is to be avoided unless specifically pre-approved as other activation method is not possible.

3. The Contractor shall demonstrate the recording performance of the DTR.

4. The Contractor shall demonstrate remote access to the DTR for data retrieval by server or remote computer.

5. The contractor shall demonstrate that the stored data can be viewed and analysis using the approved software..

G. Submit certified test report within ten days after completion of field tests.

1.4 SUBMITTALS:

A. Submit the following for approval in accordance with the General Requirements in accordance with Special Provisions and with the additional requirements as specified for each:

1. Shop Drawings: Show the following as a minimum:

a. Electrical wiring diagrams and schematics.

b. Electrical and mechanical installation details

c. Site specific schedules, interconnection diagrams and point assignment charts.

d. DTR point count for various facilities in accordance with Tables in this section

e. DTR data point assignments are listed in Table1 thru Table 3.

f. Composite control/status and telemetering sensing equipment schedule.

2. Product Data: Submit annotated product data for each item of equipment and resubmittal for mechanical or electrical equipment which changes as a result of required modification.

a. Manufacturer's technical specification of the DTR product or its subassembly indicating all parameters, including frequency responses, maximum sampling rate capability, A/D conversion speeds etc… and when requested, impulse responses of DTR component or its accessory

3. As-Built Documents: Prior Substantial Completion develop an as-built documents as follows:

a. As-built drawings of the installation: 11-inch by 17-inch composite interconnection wiring diagram showing the entire DTR interface system.
b. Provide laminated copy to be attached on each DTR interface cabinet door.
c. Approved copies of each submittal.
d. Provide As-built drawing in both AutoCAD and PDF formats on CD in sleeves.

4. Operation and maintenance (O & M) manuals:

a. Operation manuals should contain information pertaining to the operation of the facility. The maintenance manual is shall be a compilation of all the technical information related to the maintenance of the facility, equipment, and/or system. Included should be information pertaining to equipment identification, location, data summary, preventive maintenance instruction parts lists, recommended spare parts, wiring diagrams, shop drawings, special tools, test equipment and field test data and reports.

b. Operating and Maintenance Manuals and other supporting documentation shall be provided on a single CD, virus checked, in MS WORD format and PDF format with a Read.me file containing instructions.

c. Preventive Maintenance Instructions shall and other supporting documentation shall be provided on a single folder the CD, virus checked, in MS WORD format and PDF format. All photographs, drawings shall be provided in subfolders in native format (JPEG, DWG etc).

d. Immediately following the acceptance of the equipment shop drawing, the equipment manufacturer shall submit the associated O&M documentation for review and approval.

e. After approval, the Contractor prepares and delivers the Contract specified number of copies of the O&M manuals for each site.

5. Preventive Maintenance Instructions:

a. The Operations and Maintenance (O&M) Manual provided for contractually furnished or installed equipment shall include a “Preventive Maintenance Instruction” (PMI) section, to ensure the continued safe and reliable operation of the specific system or equipment. Training on these procedures shall be included in the contractor-provided maintainer training curriculum. If a section contains more than one PMI procedure then the section shall begin with a Table of Contents.

b. PMI procedures shall be written in language easily understood by every maintainer skill level of the responsible WMATA maintenance discipline. Prior to acceptance, clarity and effectiveness of each PMI procedure shall be demonstrated in coordination with the maintenance discipline using the recommended minimum number of the lowest skill level maintainers. The maintenance team or individual must be able to understand and successfully perform the draft PMI without coaching from contractors or engineers. Each procedure shall be formatted similar to standard PMI formatting as currently approved by the WMATA maintenance discipline responsible for future maintenance of the equipment, including a standard approval signature cover sheet. Sample PMI’s, as formatting examples, may be obtained from the appropriate maintenance discipline after contract award. Each procedure shall contain:

1) A recommended performance frequency (interval) that is adjusted to the installed environment and expected level of use.

2) The maintenance crew size and average time for performance of the PMI

3) The system-specific and/or equipment-specific objectives of the PMI

4) Lists of:

a) Prerequisites

b) Required reference documents

c) Industry standards or regulations governing the performance of the maintenance action

d) Necessary tools and test equipment

5) Definitions and graphics, as much as practical to clarify the instructions

6) Warnings, Cautions, and Safety Notices, plentifully and prominently interspersed to prevent injury, damage, or unsafe operating conditions before any procedure step to which they apply

7) Data sheets and checklists, for data collection regarding conditions that are measured and to ensure that important steps are not skipped

8) Step-by-step instructions to verify and document that the tested mechanism or circuit or subsystem functions within design parameters

9) Step-by-step instructions, types of solvents, cleansers, and lubricants with intervals for lubrication and cleaning of mechanisms to prevent or minimize grime, corrosion, and wear

10) Step-by-step instructions to verify the adjustment of the system, equipment, or circuit which will allow it to operate properly (safely, reliably, and without causing excessive wear) until the next scheduled PMI

11) Step-by-step instructions to verify the integrity of all fasteners, couplings, electrical connections, etc. which may fail or loosen between scheduled maintenance intervals

12) Step-by-step instructions to document the measured condition of the equipment or circuit, to be used for abatement of deterioration, future failure analysis, and in case of catastrophe

13) Step-by-step detailed adjustment instructions for any mechanism or circuit found to be out-of-adjustment.

6. Spare Parts Lists:

a. Recommended spare parts shall be detailed for each DTR. The spare parts shall be sufficient to cover the complete range of DTRs supplied.

b. Unit prices shall be supplied.

c. The list shall include the following:

1) Item identification

2) Recommended spares quantities

3) Base price

7. Certification:

   a. Certified test results for the specified tests on the Remote Terminal Unit or provide certified test reports on identical unit.

   b. Certificates from manufacturers verifying that equipment conforms to the specified

1.5 TRAINING:

A. Engineers and Operation and maintenance training may be required. This shall be required normally for any new DTR products, but may be required for familiarity training as part of a refresher course for both new and existing personnel.

B. The courses shall cover all aspects of the DTR design sufficient for the engineers to configure the DTR and maintainers to troubleshoot and maintain the DTR over its design life. Contents shall include:

   1. DTR operation and data communications protocols

   2. Diagnostic tools provided with the DTR and test equipment to fault find an DTR

   3. Failure modes

   4. Configuration of the DTR

   5. Software

C. Instruction Period: 3 days, 3 sessions. The training courses shall be broken into individual days. The courses may be conducted on single days or multiple days, with multiple days not necessarily being consecutive days.

D. Training course material: Training courses shall be conducted at WMATA. The Supplier shall provide all teaching aids for each attendee for the conduct of the courses, which shall be independent of any other material provided under this Agreement.

PART 2 – PRODUCTS

2.1 GENERAL:

A. DTR CONNECTION POINT REQUIREMENTS: The DTR is connected to the DC systems through current and voltage transducers for analog measurements and to the DC protective relays for disturbance trigger signal.

	TBS DTR CONNECTION POINT COUNTS				
	DC SWITCHGEAR		NEGATIVE		Maximum Required DTR Connections
	BREAKER CURRENTS	BUS VOLTAGES	RETURN CURRENTS	RUNNING RAIL VOLTAGES	
Maximum number of Analog inputs	7	1	NA	NA	8
Maximum number of Digital Inputs from Relays	7	0	NA	NA	8
THE MINIMUM NUMBER OF ANALOG AND DIGITAL INPUTS SHALL BE PROVIDED ON DTR PROVIDED FOR TBS. REFER TO CONTRACT DRAWINGS FOR SITE SPECIFIC CONNECTION COUNTS. ADDITIONAL ANALOG AND DIGITAL INPUT MODULES SHALL BE PROVIDED AS					

B. Typical WMATA Traction Power Systems DC current

shunt ratios: 1. 5000A :50mV

2. 7500A :50mV

3. 10000A :50mV

4. 15000A :50mV

5. 20000A 50mV

C. Digital Trace Recorder Unit

1. Provided in wall mount cabinet

2. Power Source: 125VDC control power.

2.2 DC TRACE RECORDER

A. GENERAL REQUIREMENTS

1. The DTR shall be a High-speed recorder used to capture individual samples of the currents, voltages and harmonics measured by the device with a minimum 10Ks/s per channel sampling frequency to display DC power system faults and transients.
2. Network synchronization method shall be used to allow the DTR’s internal time clock to be synchronized over the substation LAN with the network time-synch master using the methods specified by the protocol.
3. The DTR shall include a Sequence of Event Recorder's (SOE) function to gather and time tag operational data from substation relays, as they react to a system event

4. Storage Methods: DTR shall be designed to store recorded data on a local solid state disk (SSD) storage device to give users adequate time to retrieve the records. Data may need to be stored on the recorder for up to 60 days under limited events situations and a minimum of 7days when the DTR are recording at its maximum sampling rate at each of its connected channel. The DTR's operating system installed on an internal flash disk is desirable.

    a. 64 GB internal flash disk for OS is recommended
    b. 240 GB removable SSD for data storage is recommended as a minimum storage capacity for TBS DTR.

5. All channels from each facility must be recorded and saved as a single file on a single hard drive to allow viewing and analysis of all data on a single screen. Software manipulations to combine DC switchgear data with DC switchboard data is not approved.
    a. DTR module installed on the Negative switchboard shall therefore be connected to the positive switchgear DTR for data recording. Communication cable between the two units must enter the DC switchboard DTR through FRE conduit if it is copper.
    b. For DTR systems that combines all input modules in a single main unit for both the DC switchgear and the DC switchboard, the DTR cabinet can be mounted on the substation wall. The contractor shall identify a new location for the DTR on the submittal drawings.

6. The DTR shall allow complete or partial data retrieval by way of connecting an appropriate device such as a laptop to the DTR while in the substation, or remotely, by using Ethernet access to the DTR from an approved terminal. The DTR shall also allow to setup for auto-data archiving to a central remote data archiving computer; a central server will call the recorder periodically to transfer data. No proprietary software shall be required to download the data files.

7. The DTR configuration and analysis software shall be an application software that combines the functionality of a power analyzer, a data logger, a transient recorder and a FFT harmonic analyzer. The software shall be designed to acquire different signals (analog, digital etc.) simultaneously from multiple sources where not all of them are necessarily sampled at the same sampling rates and store them in one file allowing comprehensive analysis. All records – waveforms, disturbances or trends - shall be saved in a native file format. Software conversion from Excel or other file formats to the proposed software file format to view, and analyze is not acceptable.

8. The DTR be suitable for working on DC electrified area, where the DC switchgear enclosure is ungrounded with +25VDC floating ground voltage.

9. The system shall be capable of working in a traction power facilities' environment where an ambient temperature ranges of -10 deg. C to + 70 deg. C and relative humidity up to 95% at ambient temperature of 40 deg. C Special protection against ingress of dust, moisture etc. shall be provided.

10. The DTR shall interface with the substation Remote Terminal Unit (RTU) for alarm monitoring.

11. Other Specifications: ions ports: One Fiber Optics 100BaseFX, one 100BaseT Ethernet.
    a. Communication ports: One Fiber Optics 100BaeFX, one 100Baset Ethernet
    b. Ethernet Interface for configuration and data output. Protocols: TCP/IP, Modbus TCP/IP or DNP-3, or IEC61850
    c. Configuration & Communication port: USB, EtherCAT
    d. Minimum 24 bit A/D (Preferably arranged as Dual A/D).

12. DTR system shall be provided with all required software for data acquisition. Basic configuration shall be used during factory acceptance tests to verify proper wiring and recording. Final configuration of each unit shall be completed during field tests.

2.3 DTR MODULE INPUTS:

A. Transducers installed in DC switchgear and switchboard provide the analog inputs and the DCprotective relays provide the digital inputs to the DTR
   1. Voltage Transducers Characteristics :
      a. A magnetic amplifier type transducers with the following characteristics are installed by the DC switchgear/switchboard manufacturer to provide complete isolation of the DTR input signal.
         1) Normal Operation Input range: -1000V to +1000 V
         2) Normal Operation Output range: -1mA to +1mA
         3) Disturbance/Fault Input range: -2000V to +2000V
         4) Disturbance/Fault Output range: -2mA to +2mA
         5) Input Impedance: 5000 ohms/Volt
         6) Load Impedance: Any load between 0-10K
         7) Accuracy: ± 0.5% Rated Output @ 25°C
         8) Temperature Range: -10°C to + 70°C
      b. Refer to Tables for point assignments.

   2. Current Transducers Characteristics:

      a. Magnetic amplifier type current transducers with the following characteristics are installed by the DC switchgear/switchboard manufacturer to provide complete isolation of the DTR input signal.
         1) Normal Operation Input range: -100mV to +100 mV
         2) Normal Operation Output range: -2mA to +2mA
         3) Disturbance/Fault Input range: -250mV to +250 mV
         4) Disturbance/Fault Output range: -5mA to +5mA
         5) Input Impedance: 5000 ohms/Volt
         6) Load Impedance: Any load between 0-10K
         7) Accuracy: ± 0.5% Rated Output @ 25°C
         8) Temperature Range: -10°C to + 70°C

b. Refer to Tables for point assignments.

3. Digital Input:
   a. Trigger contact from each breaker relay is connected to the DTR per Tables to trigger the DTR record in event mode.

B. The data acquisition system's analog input modules shall be provided with their own external shunts if mA input modules are not available. These external shunts shall be mounted in the DTR cubicle.

C. Current and voltage transducers can be shared between the DTR and other equipment, however it shall be the responsibility of the DTR equipment supplier to insure the shunts have appropriate ratios and are suitable for the use as designed.

D. Digital Trace Recorder Units are provided to the DC switchgear and Switchboard manufacturers in wall mount cabinets for factory installation on the DC switchgears and switchboards.

2.4 Cabinets

A. DTR Cabinet:
1. Construction: NEMA 12.
2. Power Source: 125V DC control power is provided to the DTR cabinet. It shall be the responsibility of the DTR equipment supplier to provide a reliable power converter if the DTR power source is different.
3. Apply two finish coats, ANSI No. 61, Light Gray, to exterior surface.
4. Paint interior per manufacturer's standard.
5. Fabrication
   a. Cabinet with fixed side, rear and roof panels, front swing, full hinged door with flush latch operable by screw driver, key, hasp and staple for padlock.
   b. Provide protective pocket inside front cover with schematic diagram, connection diagram, operating instructions, and layout drawing of control wiring and components within enclosure.
   c. Cabinet Size:24"h x 20"w x10" d

6. Terminal Blocks:
   a. Terminal blocks located within the DTR cubicle shall define the point of separation between DTR and the substation electrical system.

7. Field Wiring Terminals:
   a. Terminate field wiring to terminal block according the DTR layout drawings.
8. Nameplate:
   a. Black laminated plastic composition with permanent white engraved lettering, and beveled edges.
   b. Fastened to panel using small round-head screws.

c. Installed inside cubicle and cabinets with cement.
d. Submitted for approval.

9. The DTR shall be designed for wall mounting with top cable entry. Kindorf channel shall be used to reinforce switchgear panel where the DTR is mounted.

CAUTION: DATA ACQUISITION SYSTEM SHALL BE SHIPPED SEPARATELY TO AVOID DAMAGES TO THE ELECTRONICS.

2.5 WIRING:

A. Use shielded twisted pair cable for analog inputs and outputs.
B. Use Multimode Fiber jumper cable from DTR to the DC switch patch panel.
C. Use Ethernet fiber cable from DTR to substation network switch.

2.6 SOFTWARE:

Software shall be provided with each DTR system for the configuration of the DTR to measure and record data on internal storage device, to provide remote viewing, used for playback and analysis.

A. DTR Configuration Application:
1. Portable Laptop with the appropriate software shall be used to connect to DTR units after they are installed to configure with initial network parameters. The software used for such initial configuration shall be provided together with its license. .
2. The application shall include as a minimum the following to perform setup and configurations of the DTR's:
a. A startup screen: This shall bring drop down menus to allow operations such as to create, modify current setup/configuration, download new setup or copy recorded file.
b. Fields to assign/change site name, to be stored in the DTR.
c. Fields to assign/change channel name, type, unit, shunt ratio, and scale for channels individually.
d. Fields to create folder for data storage, duration of each recorded file.
e. Fields to change network communication parameters (IP address, subnet mask, gateway).
f. Fields to select and assign color to the desired channel for graph or channel color can be pre-assigned.
g. Fields to configure other communication parameters related to connection to network, NTP, remote viewing, streaming to network.
h. Field to configure each installed modules. Allow unused channels to be turned off. These channels shall not record.
i. Configure trigger points with external trigger.
j. Configure math/calculated channels.
3. DTR Recorded File Format
a. The file format of the recorded DTR file (trace) shall be such that all the relevant information including the configuration information, record start time, record end time, total number of channels in the file, sampling rate

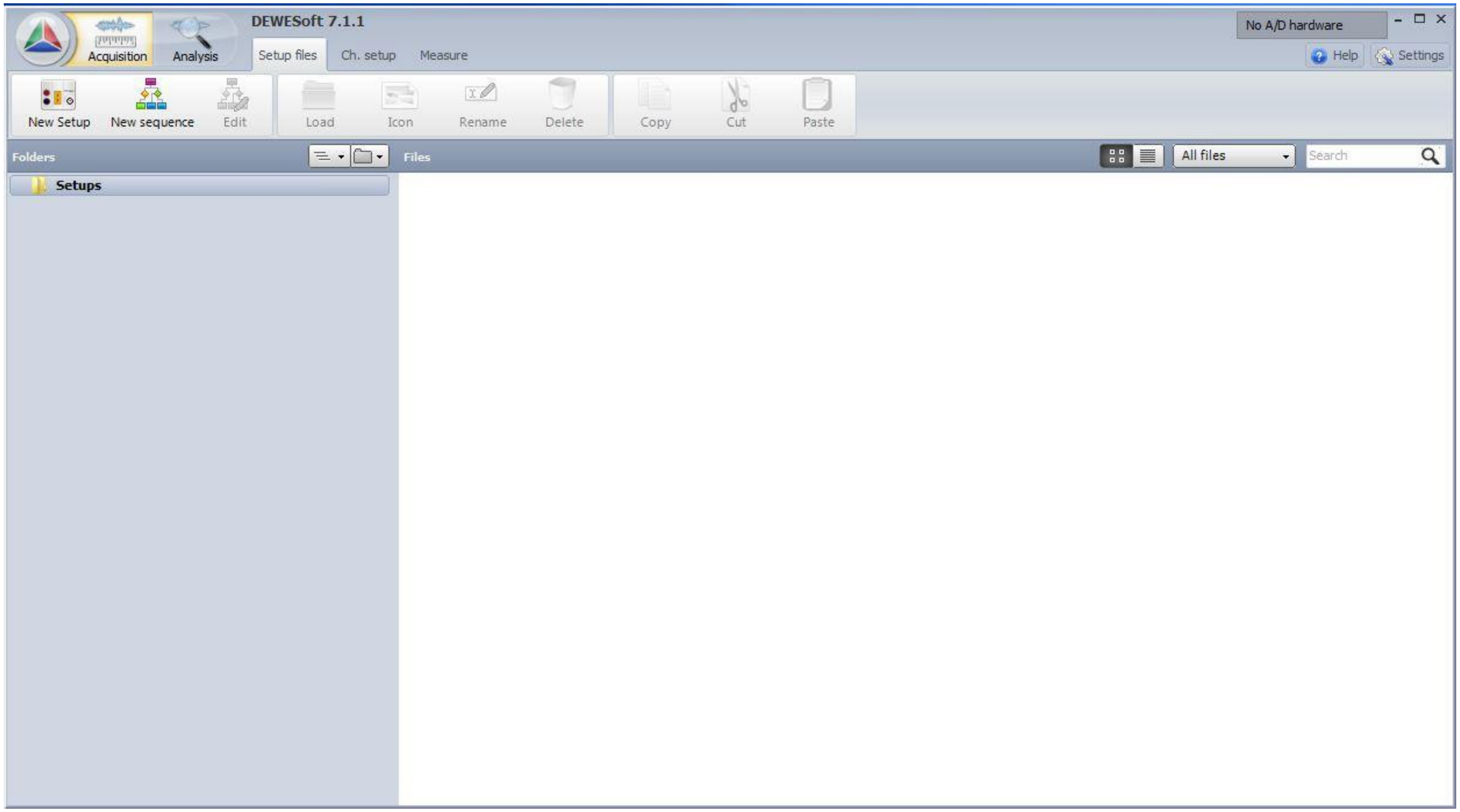
channel at each instant, the DTR name, channel types, units used are all included in a single file. No other information other than this file shall be required to fully reconstruct and view the channels by the viewing software.

b. DTR shall be set to create new data files at 24:00 hours every day. Default file naming shall be in the form LLLLL_YYMMDD_HHMM, where LLLL is location code, YYMMDD is the year, month and date of data collection, and HHMM is recording start time, hours and minutes.

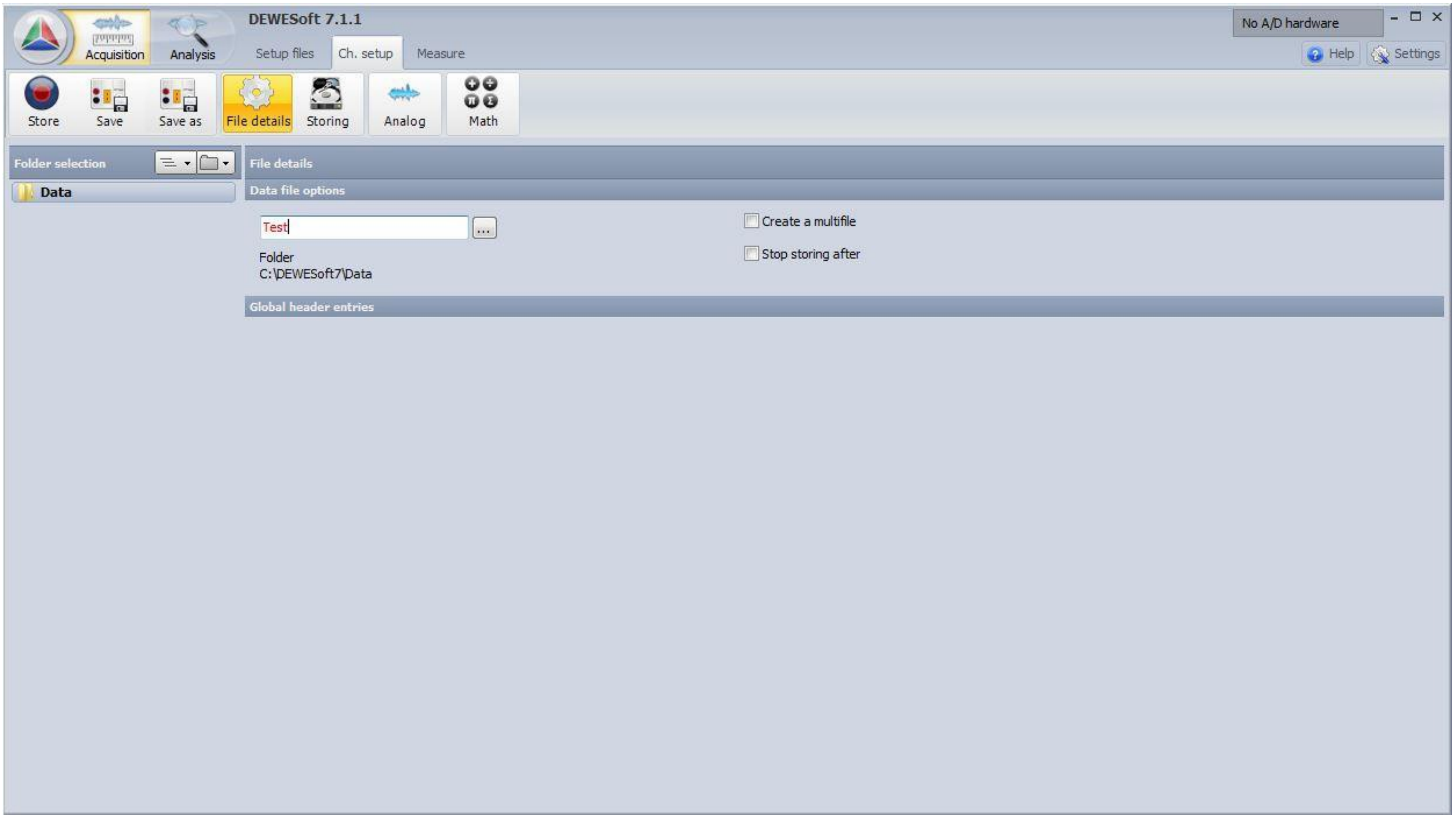
c. The DTR data files shall be stored in equipment software native format capable to be exported into tab delimited text file formats that is acceptable in other software applications.

4. Screen Shots: For information only

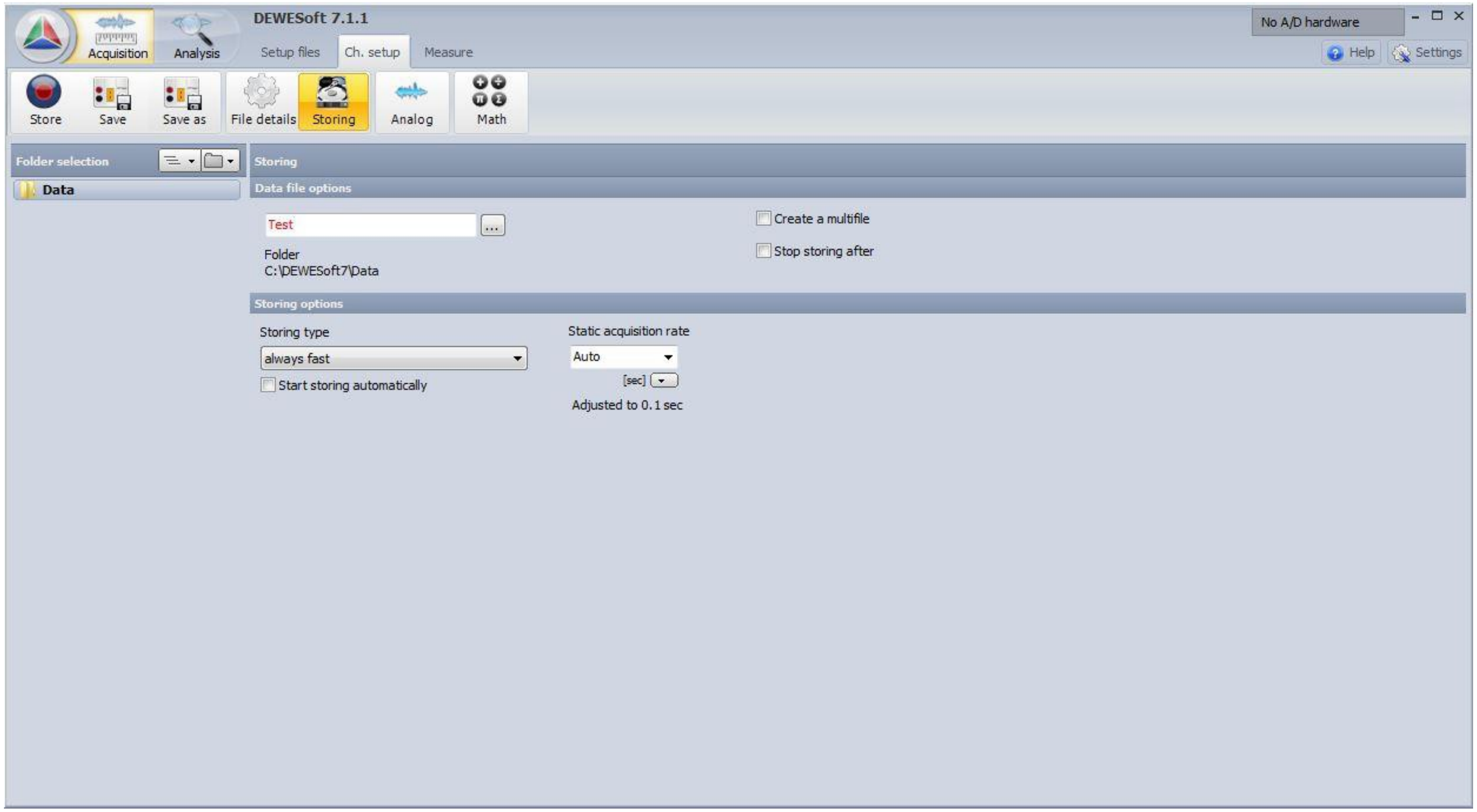
4. Sample Screen Shots



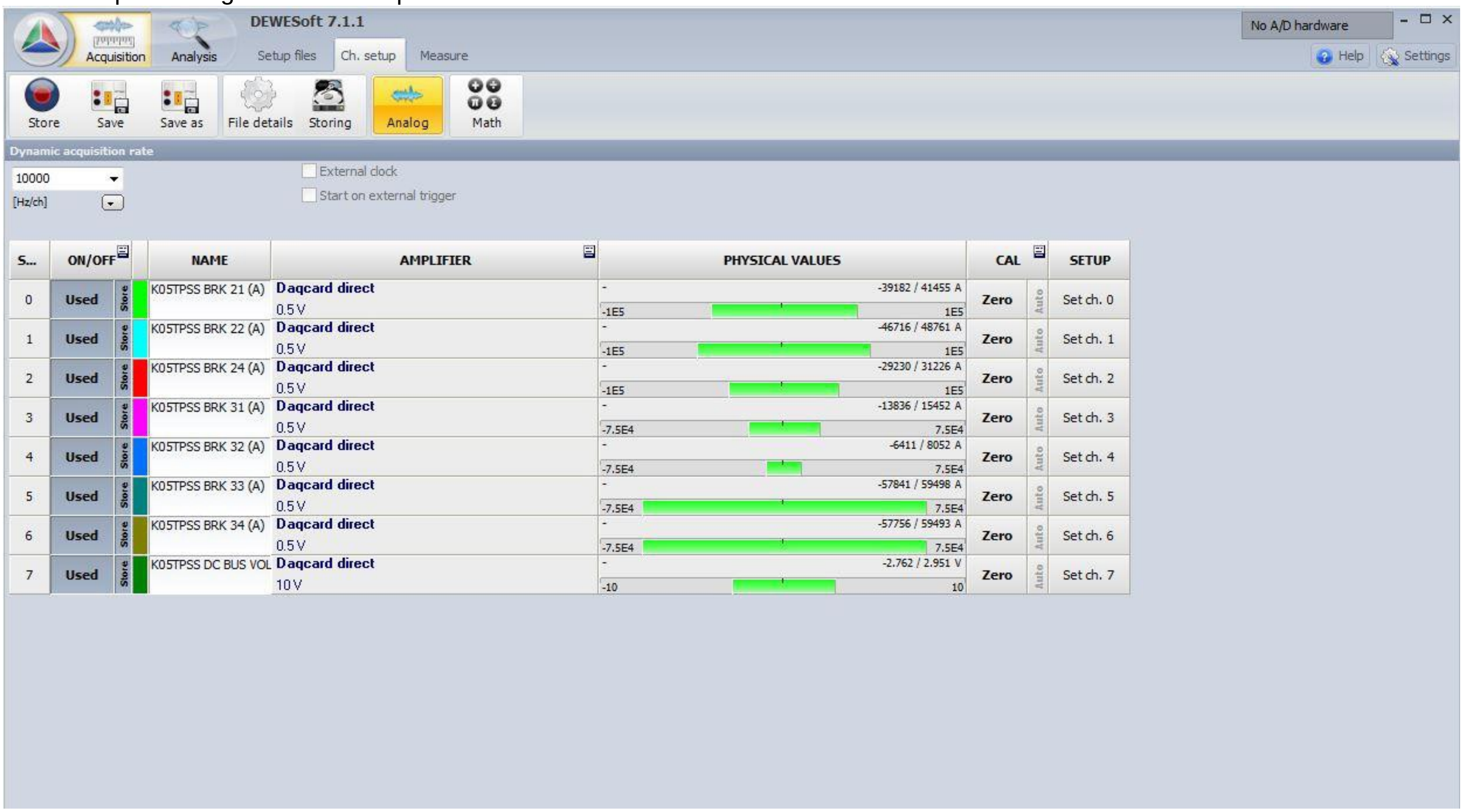
5. Sample File Details Screen



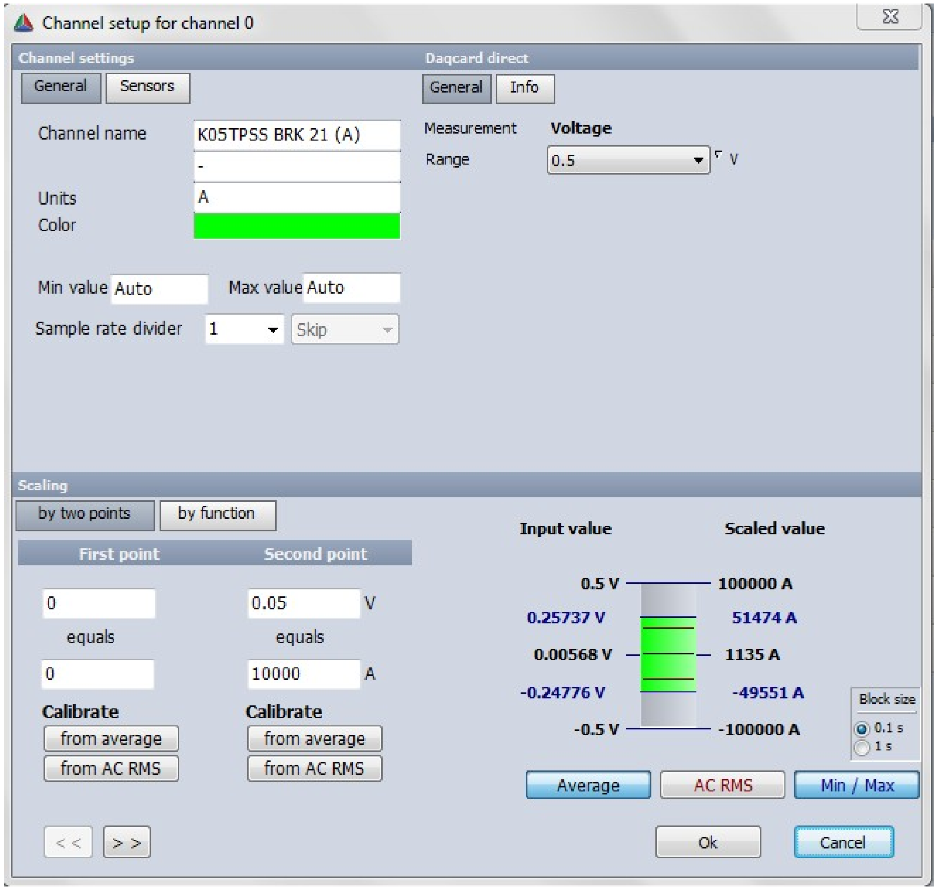
3. Sample File Storage Screen



4. Sample Analog Channel Setup Screen



5. Sample Individual Analog Channel Setup Screen



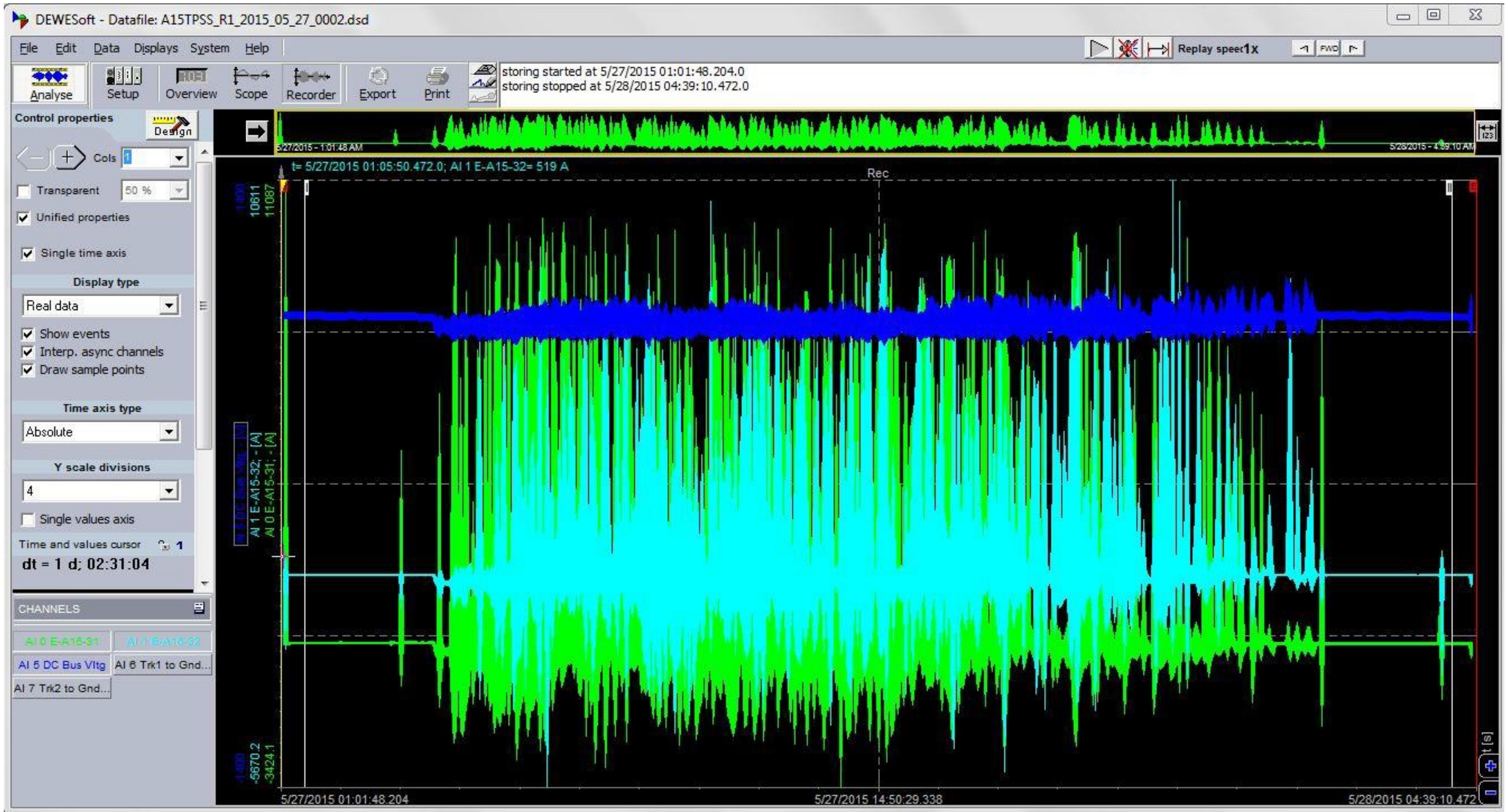
B. Viewing and analysis Application:

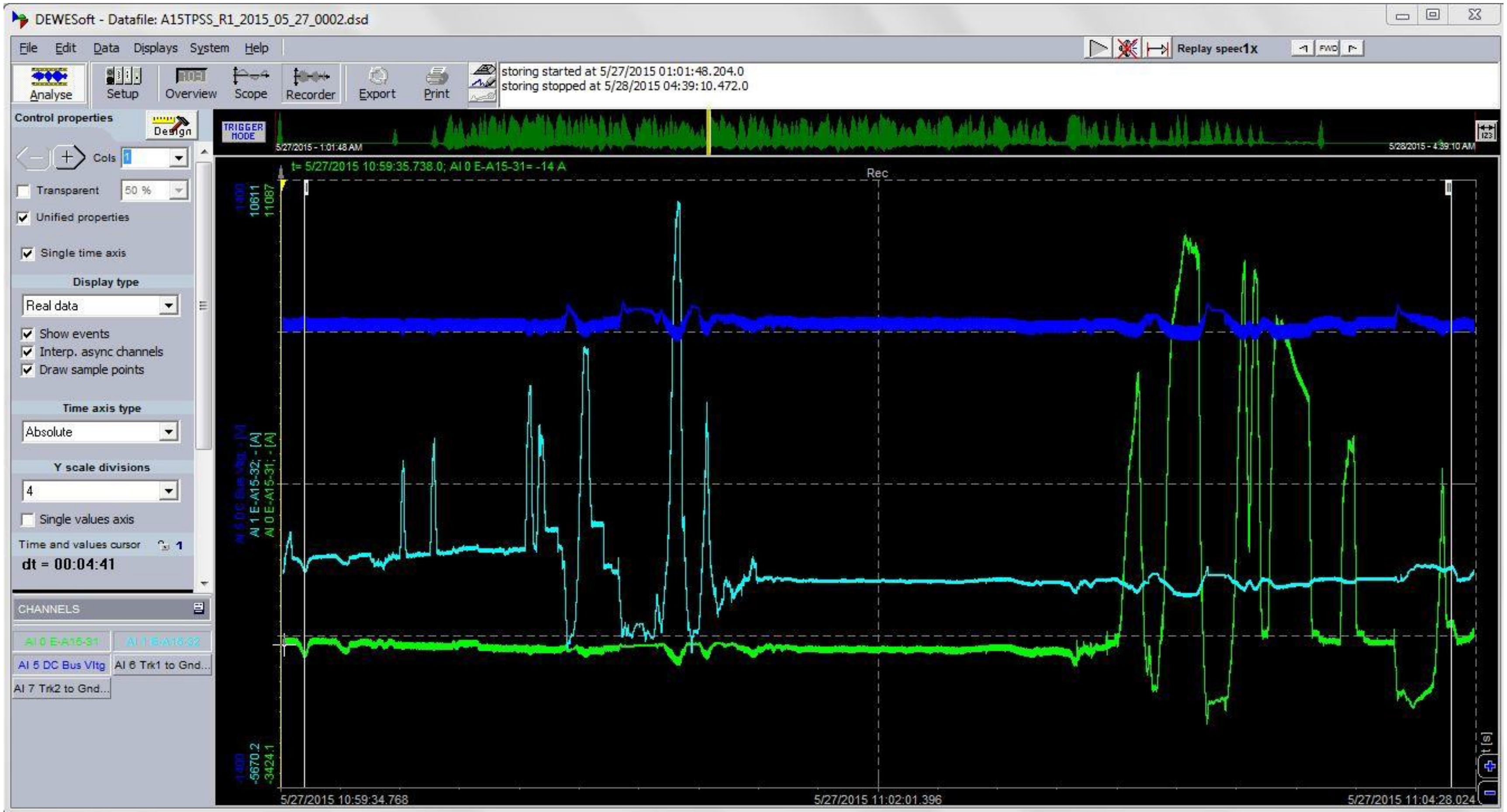
1. Licensed Software shall be provided to view, analyze and document recorded data.
2. The application shall display graphs and trends of the recorded analog data collected from DTRs. At a minimum, the application shall include the following:
   a. Tracing/graphing of the trace file data data into a two dimensional plane (X-Y area) with the time on the X-axis and analog values on the Y-axis. The X-axis shall default to viewing the entire timespan recorded in the file, and shall provide a dropdown list to select time segments from milliseconds to the entire 24hours of recorded data.
   b. By default, all channels shall graph in a single view window with option to select individual channel to display.
   c. The software shall be capable of creating multiple view windows with option to select individual channel to display.
   d. Each windows shall automatically get the label (channel name) used in the DTR channel setup. The Y-axis of each window shall automatically scale consistent with the recorded values and affix labels per the units entered in the DTR channel setup.
   e. It shall also be possible to change the “scaling” of the axes of the individual windows manually irrespective whether or not the graphed data is viewable. Scaling shall mean the numerical distance between any two consecutive units used to mark values on the axes. Selectable X-axis scales shall be Millisecond, Second, Minutes and Hours. Selectable Y- axis scales shall be (1/10$^{th)}$ Unit, (1/5$^{th)}$ Unit, (1/2$^{nd)}$) Unit, Unity, 5 x unit, 10 x unit, 20 x unit, 100 x unit and 1000 x unit. The channel values in the record shall never be altered in the process of scaling. Scaling shall be a separate feature than zooming and shall be accessible via an appropriate drop down menu.
   f. Zooming shall mean fixing a view point within the view window and increasing/decreasing the field of view. Pointing the cursor inside anyone of the windows and left clicking to fix a view point and applying the scroll wheel of the computer mouse shall enable dynamic zooming within the particular window.
   g. It shall be possible to rearrange the order of the vertical arranged windows based on their names and save the particular arrangement to default. This arrangement shall also save the selected scaling applied to the axes.
   h. The default background of each window shall be black and the axes and the labels shall be in white. The application shall have a setup feature where users can select color preferences for the channels that are to be graphed inside the windows by their types.
   i. Standard engineering calculation accompanying report generation for each channel shall include; minimum, maximum average and maximum rate of change along with the plotted graph, These same information shall also be available for view by right clicking the computer mouse inside any of the channel windows and invoking the appropriate software tool.
   j. If displayed data is anything other than all, the application shall add a horizontal scroll bar to scroll left-right.
   k. Provide hot keys for panning and zooming through mouse interaction. Panning shall be left- click and drag.
   l. The software shall enable composite graphing of selected number channels in one window. This feature shall be accessible through appropriate drop down menu where its invoking shall cause the opening up of a new window separate from the default channel windows. To differentiate its composite nature, this window shall have its background white and its axes and labels in black.

The X-axis shall be the time and manually scalable and the Y-axis shall be non-manually scalable real number with no labels so as to accommodate non similar units together such as voltages in Volts and currents in Amperes on the same axis. The Y-axis shall automatically scale such that the channel with largest value in the composite graph is viewable. A second Y-axis with a different range to accommodate for overlaying two different channel types (voltage and current).

m. The software shall be capable of generating virtual channels using any number of recorded channels. For example it shall be possible to graph a composite graph of Traction power substation load by calculation using: ((Cathode 1 current) + (Cathode 2 current)) X Bus Voltage.

Sample Screen Shots: For information only




DEWESoft - Datafile: A15TPSS_R1_2015_05_27_0002.dsd
File Edit Data Displays System Help
Replay speed 1x
Analyse Setup Overview Scope Recorder Export Print
storing started at 5/27/2015 01:01:48.204.0
storing stopped at 5/28/2015 04:39:10.472.0
Control properties
Design
Cols
Transparent
50 %
Unified properties
Single time axis
Display type
Real data
Show events
Interp. async channels
Draw sample points
Time axis type
Absolute
Y scale divisions
4
Single values axis
Time and values cursor
dt = 00:04:41
CHANNELS
AI 5 DC Bus Vltg
AI 6 Trk1 to Gnd...
AI 7 Trk2 to Gnd...
TRIGGER MODE
5/27/2015 - 1:01:48 AM
5/28/2015 - 4:39:10 AM
t= 5/27/2015 10:59:35.738.0; AI 0 E-A15-31= -14 A
Rec
AI 1 E-A15-32; - [A]
AI 0 E-A15-31; - [A]
10611
11087
-5670.2
-3424.1
5/27/2015 10:59:34.768
5/27/2015 11:02:01.396
5/27/2015 11:04:28.024

C. Historical Server Data Storage Application:

1. DTR data shall be made available to all Traction power engineers, SCADA engineers, managers and field maintenance supervisors to enable them to take actions in case of accidents or incidences.
2. Traction power engineers and SCADA engineers shall be able to access raw data of all the stations at any time. For security reasons no engineers or maintenance personnel will be granted access to remotely download files from the DTRs.
3. Servers play vital role in making the DTR data available for multiple groups simultaneously.
4. The SCADA historian Server will connect to the DTRs at predetermined intervals, to download and archive the recorded files to long term storage.
5. Server application software to access and download DTR files is provided by others. However, the DTR shall be capable of such feature and capable of communicating in the file transfer protocol demanded by the server.
6. Default file naming shall be in the form LLLLL_YYMMDD_HHMM, where LLLL is location code, YYMMDD is the year, month and date of data collection, and HHMM is recording start time.
7. The DTR files shall be archived in the historian servers in their native file format.
8. The provided software or Dewesoft shall be used for data retrieval for view and analysis.

D. Failure: DTR shall be monitored by the TBS SCADA system for communication failure as well as DTR failures.

PART 3 - EXECUTION

3.1 INSTALLATION

A. DTRs shall be factory installed in accordance with approved shop drawings for the following facilities:

1. Tie Breaker Stations

B. The Contractor shall terminate all wiring on terminal strips in accordance with approved shop drawings and interconnection diagrams.

C. Perform work in accordance with NEC.

D. Wall mount the DTR cabinet on the side wall of the DC switchgear.

E. Wiring:

1. Use shielded twisted pair cable for analog input and control output signals and multi-conductor cable for all other functions.

2. Install wiring for DTR interface circuits for all points identified.

F. The DTR cabinet shall not be grounded, if mounted on the sidewall of the DC Switchgear.

3.3 FACTORY AND FIELD TESTING:

A. The Contractor shall perform polarity and continuity test on all interconnection wiring.

B. The Contractor shall perform system start-up for each DTR.

C. The Contractor shall label all wiring terminations to reflect the connection points.

D. The Contractor is responsible for testing all DTR input signals to verify correct status and telemetry signal levels mapped to the right channels as specified in the tables in this section and as shown in the contract drawings. A test data sheet shall be developed for each DTR which list all I/O signal points. The data sheet shall be submitted as part of the Contractors test plan. The Contractor shall submit a list of discrepant I/O signal points to the Engineer. I/O equipment supplied under this contract that is not reporting properly shall be corrected and retested. The Contractor shall submit a discrepancy report for all I/O points indicating problems found and required action.

E. DC Positive DTR Test

1. Connect a laptop to the DTR and run the DTR software.
2. Verify DTR firmware.

3. Current Transducers Calibration

   a. Connect test equipment leads to the terminals of the fuse connected to the transducer (Observe correct polarities).

   b. Ensure test leads are not connected to the terminal of the fuse connected to the shunt.

      1) Inject 50mv observe breaker meter is reading full DC shunt ratio scale.
      2) Observe on DTR software that the signal is on the correct DTR channel.
      3) Observe correct reading on Laptop.
      4) Calibrate as necessary using transducer Zero and Gain.
      5) Inject 100mv and 200mv observe breaker meter is reading 2X and 4X full DC shunt ratio scale.
      6) Observe Laptop reading is correct.
      7) Calibrate current transducers for all feeder and cathode breakers.

4. Voltage Transducer Calibration
   a. Identify the correct Voltage Transducer for the DTR.
   b. Connect a variable 1000V DC power supply test leads to the fuse terminals (Observe correct polarities).
   c. Inject 1000v, observe breaker meter is reading 1000V.
   d. Observe on DTR software that the signal is on the correct DTR channel.
   e. Calibrate as necessary using Zero and Gain
   f. Inject 0V, 750V and 1000V DC observe breaker meter reading is correct.
   g. Observe Laptop reading is correct

5. Trigger Configuration
   a. Set DTR trigger as external trigger for each analog current channel.
   b. Set DTR trigger as internal trigger for Voltage channel set at 1000 VDC.
   c. Trigger instantaneous function of each DC protective relay.
   d. Observe current waveform is captured by the DTR.

e. Inject 1100 VDC to DTR
f. Observe current waveform is captured by the DTR.

3.4 DTR SETUP AND CONFIGURATIONS:

A. The Contractor is responsible for the development of the initial site specific DTR configuration files.
B. The Contractor is responsible for the programming and testing of the DTR.

TABLE 1: TBS POSITIVE SWITCHGEAR DTR POINTS FOR CGA DTR			
POINT TYPE	DESCRIPTION	FIELD DEVICE I/O SIGNAL	DTR INPUT PANEL TB
Analog 1	DC Breaker 41 Current	0-2mA from transducers	TB3-1-2
Analog 2	DC Breaker 42 Current	0-2mA from transducers	TB3-4-5
Analog 3	DC Breaker 43 Current	0-2mA from transducers	TB3-7-8
Analog 4	DC Breaker 44 Current	0-2mA from transducers	TB5-1-2
Analog 5	DC Breaker 45 Current	0-2mA from transducers	TB5-4-5
Analog 6	DC Breaker 46 Current	0-2mA from transducers	TB5-7-8
Analog 7	DC Breaker 47 Current	0-2mA from transducers	TB4-1-2
Analog 8	DC Breaker 48 Current	0-2mA from transducers	TB3-4-5
Analog 9	DC Breaker 49 Current	0-2mA from transducers	TB3-7-8
Analog 10	SPARE	0-2mA from transducers	TB6-4-5
Analog 11	DC Bus Voltage	0-2mA from transducers	TB6-1-2
Trigger 1	MPR Relay Trigger Contact Breaker 41	Dry contact from relay	TB2- 5-6
Trigger 2	MPR Relay Trigger Contact Breaker 42	Dry contact from relay	TB2- 7-8
Trigger 3	MPR Relay Trigger Contact Breaker 43	Dry contact from relay	TB2- 9-10
Trigger 4	MPR Relay Trigger Contact Breaker 41	Dry contact from relay	TB2- 11-12
Trigger 5	MPR Relay Trigger Contact Breaker 45	Dry contact from relay	TB2- 13-14
Trigger 6	MPR Relay Trigger Contact Breaker 46	Dry contact from relay	TB3-1-2
Trigger 7	MPR Relay Trigger Contact Breaker 47	Dry contact from relay	TB3-3-4

Trigger 8	MPR Relay Trigger Contact Breaker 48	Dry contact from relay	TB3-5-6
Trigger 9	MPR Relay Trigger Contact Breaker 49	Dry contact from relay	TB3-7-8

END OF SECTION

SECTION 16604

NETWORK SWITCH FOR TBS SCADA AND AUTOMATION SYSTEMS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes requirements for Network Switch to be installed at each Tie Breaker Station (TBS).

B. Network Switches for TBS are furnished and installed by the Authority in the RTU cabinet.

C. Network switch fiber patch panels are furnished and installed by the contractor in the RTU cabinet

D. Power Requirements

1. 125 VDC nominal input voltage

E. General Features

1. Network switch cabinet fiber patch panels and fiber jumper cables shall be provided and installed by the Contractor in the RTU cabinet.

1.2 RELATED SECTIONS

A. Section 16052, BASIC MATERIALS AND METHODS FOR TRACTION POWER

B. Section 16149, WIRE, CABLE, CABLE TRAY, AND TERMINATION PANEL FOR SCADA SYSTEMS.

C. Section 16291A, HUMAN MACHINE INTERFACE (HMI) PANEL FOR TIE BREAKER STATIONS

D. Section 16341, METAL-ENCLOSED DC SWITCHGEAR FOR TIE BREAKER STATIONS

E. Section 16602, REMOTE TERMINAL UNIT (RTU) FOR TIE BREAKER STATIONS

F. Section 16603, DIGITAL TRACE RECORDER (DTR) FOR TIE BREAKER STATIONS

G. Section 16605, DISTRIBUTED I/O (DIO) FOR TIE BREAKER STATIONS

H. Section 16606, SCADA SYSTEM INTEGRATION TIE BREAKER STATION SITE ACCEPTANCE TEST PLAN

1.3 SUBMITTALS

A. Submit the following for approval in accordance with Special Provisions and with the additional requirements as specified for each:

1. Shop Drawings: Show the following as a minimum:

a. Network Switch port assignment charts

b. RTU cabinet installation detail drawings

2. As-Built Documents: Prior to Substantial Completion, develop as-built documents as follows:

a. As-built drawings of the installation: 11-inch by 17-inch composite interconnection wiring diagram showing the entire Network Switch interface system. Provide sufficient copies to be stored in each switchgear cabinet door pocket.

b. Approved copies of each Submittal.

c. Provide As-built drawing in both AutoCAD and PDF formats on CD in sleeves.

1.4 QUALITY ASSURANCE

A. Qualifications:

1. Network Switch: Equipment manufacturer and Model Number:

a. CISCO CGS 2520-16S-8PC

2. Network Switch Patch Panel installer: Installer shall follow current industry standard and Contract Drawings.

3. Network Switch installer: Network Switch will be configured by WMATA IT.

B. Coordination:

1. WMATA IT will furnish, configure and install network switches in the RTU installed by the contractor. It is the contractor responsibility to schedule the installation of the network switches. Two weeks advanced notice is required.

2. TBS Network switches will be installed by WMATA IT only after the approval of the TBS communication cables test reports.

PART 2 - PRODUCTS

2.1 GENERAL

A. Fiber patch panels: As indicated on Contract Drawings.

B. Network Switch (125VDC): Cisco CGS-2520-16PS-8PC

C. Wiring: In accordance with Section 16149, WIRE, CABLE, CABLE TRAY, AND TERMINATION PANEL FOR SCADA SYSTEMS

PART 3 - EXECUTION

3.1 INSTALLATION

A. Network switches will be provided and configured by the Authority.

B. Install 125VDC circuit as shown on the Contract Drawings.

C. Provide and install fiber patch panels in the RTU cabinet for the incoming single-mode fiber from the communication room and multi-mode fiber patch panel for the outgoing fiber cable to DC switchgear and other Intelligent Electronic Devices as shown on the Contract Drawings.

D. Terminate all the outgoing multi-mode fibers from network switches to the equipment within the substation on the patch panels inside the RTU cabinet.

E. Provide and install pre-fabricated fibers jumper cables from the patch panels to the network switch ports in accordance with the approved wiring termination diagram.

3.2 FIELD TESTING

A. Perform polarity and continuity test on all interconnection wiring.

B. Submit all fiber test reports for approval by WMATA IT prior to the system integration tests. All fiber tests shall be conducted in accordance with Section 16149, WIRE, CABLE, CABLE TRAY, AND TERMINATION PANEL FOR SCADA SYSTEMS.

C. The Authority will perform system start-up for each Network Switch in the presence of the Contractor. The Authority will configure and verify correct operation of each Network Switch unit.

D. Perform a complete, end-to-end functional test for each termination and ensure the installation is done as specified and shown in the approved Contract Drawings.

E. Label all wiring terminations to reflect the connection points.

END OF SECTION

SECTION 16605

DISTRIBUTED I/O (DIO) FOR TIE BREAKER STATIONS

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes requirements for Distributed Input Output (DIO) modules installation at each Tie Breaker Station (TBS).

1. Distributed I/O modules will be furnished by the contractor for factory installation and wiring by the manufacturer of the TBS DC switchgear.

2. One DIO is required for each feeder breaker and is installed in the breaker instrument compartment.

3. Refer to Section 16341, METAL ENCLOSED DC SWITCHGEAR FOR TIE BREAKER STATIONS, and Contract Drawings for DIO installation and wiring color requirements.

4. The modules shall receive digital control signals from the RTU and provide relay contact control outputs to the breakers. The module shall also receive dry contact signals from the breakers and send the corresponding digital signals to the RTU.

5. The DIO shall communicate with the station RTU via Network switch using DNP3 protocol over fiber cable.

B. Related Sections:

2. Section 16052- Basic Materials and Methods For Traction Power
3. Section 16053C- Operation and Maintenance Training for Tie Breaker Stations
4. Section 16053D- Operation and Maintenance Training for Supervisory Control and Data
5. Section 16128- Wire and Cable For Traction Power
6. Section 16130 - Raceways, Boxes and Cabinets
7. Section 16145 - Wiring and Control Devices
8. Section 16149 - Wire, Cable and Termination Panel For SCADA
9. System
10. Section 16291A – Human Machine Interface (HMI)
11. Section 16341- Metal-Enclosed DC Switchgear For TBS
12. Section 16602 - RTU for Traction Power systems
13. Section 16604 – Network Switch For SCADA and Automation Systems
14. Section 16606 – SCADA Systems Site Acceptance Test Plan

C. Operating Requirements

Designed for continuous, unattended operation to perform:

1. Analog and digital data acquisition.
   a. Digital control.

D. Power Requirements

1. 125 Volts DC from switchgear control power.

1.2 REFERENCES

A. Code, Regulations, Reference Standards and Specifications
   1. Code and Regulation of jurisdictional authorities
   2. NEC
   3. NEMA 250, ICS-6, WC8, 12
   4. ANSI C37.90, Z55.1, C12
   5. EIA: RS 232.C
   6. ASTM: B138
   7. ASHRAE/ANSI : 135P
   8. ICEA: S-68-516

1.3 QUALITY ASSURANCE

A. Qualifications:
   1. Approved DIO and manufacturer:
      a. DIO series 9100 by CG Automation Solutions (CGA)
      b. SEL -2440 by Schweitzer Engineering Laboratories, Inc.
      c. DDIO by Novatech

   2. DIO installer: DIO is factory installed by the manufacturer of the DC switchgear.

B. Coordination:
   1. DIO shall be installed with the LEDs visible to a maintenance personnel standing in front of the breaker cubicle. The contractor shall coordinate with the DIO manufacturer to order the DIO with the proper mounting hardware..

C. For Code, Regulations, Reference Standards and Specifications, refer to Article 1.02 above.

D. The DC Switchgear equipment manufacturer shall develop factory test procedures and obtain Contracting Officer Representative approval prior to Factory Acceptance Testing (FAT).

E. Factory Testing: DIO factory test shall be an integral part of the DC switchgear Factory Acceptance Test. Allow for witnessing of all tests by the Contracting Officer Representative at the option of the Authority. Witnessing of any portion of the FAT by the Contracting Officer Representative shall not relieve the DC Switchgear equipment manufacturer from responsibility for any portion of follow-on testing. All test discrepancies shall be corrected.

F. End-to-End Test:

1. Demonstrate the proper functioning of the completed DIO system including all components and telemetry between each piece of equipment monitored or controlled by the DIO by using the TBS HMI connected to the RTU/Network Switch in the presence of the Contracting Officer Representative.

2. The DIO must communicate with the station RTU.

3. Simulation of sensors by shorting contacts is to be avoided unless other activation is not possible.

4. Each Intelligent electronic device connected directly to the DIO shall be tested for proper communication.

G. Submit certified test report within ten days after completion of field tests.

1.4 SUBMITTALS:

A. Submit the following for approval in accordance with the General Requirements in accordance with Special Provisions and with the additional requirements as specified for each:

1. Shop Drawings: Show the following as a minimum:

   a. Proposed changes and revised equipment layouts

   b. Electrical wiring diagrams and detail control schematics.

   c. Electrical and mechanical details

   d. Wire and cable schedules, interconnection diagrams, point assignment charts, and connection diagrams

   e. Composite control/status and telemetering sensing equipment schedule.

2. Product Data: Submit annotated product data for each item of equipment and resubmittal for mechanical or electrical equipment which changes as a result of required modification.

3. As-Built Documents: Prior Substantial Completion develop an as-built documents as follows:

   a. As-built drawings of the installation: 11-inch by 17-inch composite interconnection wiring diagram showing the entire DIO interface system. Provide sufficient copies to be stored in each switchgear cabinet door pocket.

   b. Approved copies of each submittal.

   c. Provide As-built drawing in both AutoCAD and PDF formats on CD in sleeves.

4. Operation and maintenance (O & M) manuals:

a. Operation manuals should contain information pertaining to the operation of the facility. The maintenance manual is shall be a compilation of all the technical information related to the maintenance of the facility, equipment, and/or system. Included should be information pertaining to equipment identification, location, data summary, preventive maintenance instruction parts lists, recommended spare parts, wiring diagrams, shop drawings, special tools, test equipment and field test data and reports.

b. Operating and Maintenance Manuals and other supporting documentation shall be provided on a single CD, virus checked, in MS WORD format and PDF format with a Read.me file containing instructions.

c. Preventive Maintenance Instructions shall and other supporting documentation shall be provided on a single folder the CD, virus checked, in MS WORD format and PDF format. All photographs, drawings shall be provided in subfolders in native format (JPEG, DWG etc.).

d. Immediately following the acceptance of the equipment shop drawing, the equipment manufacturer shall submit the associated O&M documentation for review and approval.

e. After approval, the Contractor prepares and delivers the Contract specified number of copies of the O&M manuals for each site.

5. Preventive Maintenance Instructions:

a. The Operations and Maintenance (O&M) Manual provided for contractually furnished or installed equipment shall include a “Preventive Maintenance Instruction” (PMI) section, to ensure the continued safe and reliable operation of the specific system or equipment. Training on these procedures shall be included in the contractor-provided maintainer training curriculum. If a section contains more than one PMI procedure then the section shall begin with a Table of Contents.

6. PMI procedures shall be written in language easily understood by every maintainer skill level of the responsible WMATA maintenance discipline. Prior to acceptance, clarity and effectiveness of each PMI procedure shall be demonstrated in coordination with the maintenance discipline using the recommended minimum number of the lowest skill level maintainers. The maintenance team or individual must be able to understand and successfully perform the draft PMI without coaching from contractors or engineers. Each procedure shall be formatted similar to standard PMI formatting as currently approved by the WMATA maintenance discipline responsible for future maintenance of the equipment, including a standard approval signature cover sheet. Sample PMI’s, as formatting examples, may be obtained from the appropriate maintenance discipline after contract award. Each procedure shall contain:

1) A recommended performance frequency (interval) that is adjusted to the installed environment and expected level of use.

2) The maintenance crew size and average time for performance of the PMI

3) The system-specific and/or equipment-specific objectives of the PMI

4) Lists of:

   a) Prerequisites

   b) Required reference documents

   c) Industry standards or regulations governing the performance of the maintenance action

   d) Necessary tools and test equipment

5) Definitions and graphics, as much as practical to clarify the instructions

6) Warnings, Cautions, and Safety Notices, plentifully and prominently interspersed to prevent injury, damage, or unsafe operating conditions before any procedure step to which they apply

7) Data sheets and checklists, for data collection regarding conditions that are measured and to ensure that important steps are not skipped

8) Step-by-step instructions to verify and document that the tested mechanism or circuit or subsystem functions within design parameters

9) Step-by-step instructions, types of solvents, cleansers, and lubricants with intervals for lubrication and cleaning of mechanisms to prevent or minimize grime, corrosion, and wear

10) Step-by-step instructions to verify the adjustment of the system, equipment, or circuit which will allow it to operate properly (safely, reliably, and without causing excessive wear) until the next scheduled PMI

11) Step-by-step instructions to verify the integrity of all fasteners, couplings, electrical connections, etc. which may fail or loosen between scheduled maintenance intervals

12) Step-by-step instructions to document the measured condition of the equipment or circuit, to be used for abatement of deterioration, future failure analysis, and in case of catastrophe

13) Step-by-step detailed adjustment instructions for any mechanism

or circuit found to be out-of-adjustment

7. Spare Parts Lists: Provide 20% complete control I/O modules.

8. Certification:

   a. Certified test results for the specified tests on the DIO Unit or provide certified test reports on identical unit.

   b. Certificates from manufacturers verifying that equipment conforms to the specified

B. Software: Provide a configuration and testing software with licenses.

1.5 TRAINING OF DIO MAINTAINERS:

A. Training of SCADA System maintainers in the operation and maintenance of DIO may be required. This shall be required normally for any new DIO products, but may be required for familiarity training as part of a refresher course for both new and existing personnel.

B. The courses shall cover aspects of the DIO design sufficient for the maintainers to maintain the DIO over its design life. Contents shall include:

1. DIO operation and data communications protocols
2. Diagnostic tools provided with the DIO and test equipment
3. Troubleshooting.
4. Configuration

C. Instruction Period: The training courses shall be broken into individual days. The courses may be conducted on single days or multiple days, with multiple days not necessarily being consecutive days.

D. Training course material: Training courses shall be conducted at WMATA. The Supplier shall provide all teaching aids for each attendee for the conduct of the courses, which shall be independent of any other material provided under this Agreement.

PART 2 - PRODUCTS

2.1 GENERAL

A. Remote control of the breakers by the Operations Control Center (OCC) and Human Machine Interface (HMI) shall use a Distributed I/O (DIO) technology where required. OCC control commands shall be received by the SCADA RTU through the Wide Area Network (WAN)/Local Area Network (LAN). The RTU shall execute the control through the Distributed I/O Modules using a DNP3 protocol. The RTU shall receive breaker status from the Distributed I/O Modules and transmit the data back to OCC through the WAN/LAN.

B. Distributed I/O Modules shall be provided for each DC breaker. The modules shall receive digital control signals from the RTU or switchgear PLC and provide relay contact control outputs to the breakers through interposing relays. The module shall also receive dry contact signals from the breakers for status indications and send the corresponding digital signals to the RTU or switchgear PLC. The Control I/O Modules shall be power using 125VDC supply at the switchgear.

2.2 DISTRIBUTED I/O (DIO)

A. The I/O modules shall provide status monitoring with 1 millisecond Sequence of Events (SOE) time tagging, and a highly secure select-before-operate controls. The I/O modules installed in DC switchgears shall be in self-contained enclosures with shock mount provisions and suitable for surface mounting, 19” Rack mounting, or DIN rail mounting. The I/O modules shall provide front panel LED indicators for all status inputs, all controls, and all communication port transmit/receive.

2.3 WINDOWS CONFIGURIBILITY

A. The software provided shall run on a standard Windows PC and shall provide drag & drop menus to configure communication ports; status, alarm and control points*;* RTU communication *Servers;* and local calculations and stand alone control algorithms. The module configuration shall required secure login with a user’s ID and pass-word login and shall maintain all attempted log-ins (dated, time-stamped) and all operational and configurable changes to the module database in a log file.

2.4 COMMUNICATIONS

A. I/O modules shall be equipped and easily configured to communicate with a single RTU on a multi-drop line or in a communication loop using RS485, RS232, serial data over multimode fiber optic, 10/100baseTX Ethernet, or 10/100baseFX Ethernet multimode fiber optic. Each I/O module shall be configurable to translate between media by retransmitting data received on any media on any of the other media. As a minimum, the modules shall support communication using DNP3 protocol.

2.5 TIME SYNCRONIZATION

A. The I/O modules shall be equipped to receive NTP time synchronization over the multimode fiber port.

2.6 CONTROLS

A. DIO shall control DC breakers through 125VDC interposing relays. Trip/close relay pairs shall execute controls with secure, multi-step handshaking with a DIO consisting of receiving a point selection message, responding with a “checkback” message, receiving a control execution message, and responding with an execution acknowledgment message. Failsafe control circuits in the I/O module shall ensure that only one relay can be energized at a time, and execute duration shall be configurable per point from 50 milliseconds to 10 seconds. Control relay outputs shall consist of one one form-A contact rated 10-amp “make” at 130 VDC. Termination shall be made to removable terminal blocks secured with screws to the I/O modules.

2.7 STATUS INPUTS

A. Each switchgear Control I/O module shall monitor a minimum of sixteen (16) status inputs with Sequence of Events (SOE) recording accurate to 1 millisecond. The modules shall respond to rapid polls for changes only, and shall retain all changes until the RTU acknowledges receipt of those changes. Each I/O module shall buffer and report a minimum of 7 changes of state occurring between polls for each status point. In addition

the I/O modules shall store up to 25 time-stamped events per-point in files that can be retrieved by a Laptop Test Set. Status inputs shall be optically isolated to meet IEEE Surge Withstand Capability test C37.90.1-2000. Each status inputs shall be configurable for 5 millisecond to 1 second de-bounce, and for 24 or 125VDC keying voltage. Termination shall be made to removable terminal blocks secured with screws to the I/O module.

B. Keying Voltage and Source

a. Keying Voltage: 24VDC or 125VDC

b. Keying Voltage Source:

1) For 24VDC, source comes from an internal DIO 24Vdc isolated power source.

2) For 125VDC, switchgear 125VDC control power shall be used as the external keying voltage source.

2.8 ENVIRONMENTAL

A. -40 to +85 degrees centigrade, 5 to 95% humidity (non-condensing)

B. IEEE Surge Withstand Capability test C37.90.1-2000

C. IEEE Susceptibility C37.90.1, .2, and .3

2.9 WIRING:

A. Status:

1. Status indication wire to DIO with 24VDC keying voltage shall be color coded BLUE to identify the 24VDC voltage level.

2. Status indication wire to DIO with 125VDC keying voltage shall be color coded for ready identification of 125VDC voltage level as specified.

3. Wire size shall be 16AWG for status and the type as specified in the switchgear sections.

4. Wiring identified at each termination, with same number shown on wiring diagram, using suitable plastic sleeve attached within six inches of terminal connections.

B. Control:

1. DC switchgear DIO control wire shall be color-coated for ready identification of 125VDC voltage level.

2. Wire size shall be the size and type specified for DC Switchgear control wire.

3. Wiring identified at each termination, with same number shown on wiring diagram, using suitable plastic sleeve attached within 6 inches of terminal connections.

C. External Wiring: Fiber Optical Jumper cable shall connect each DIO to the station Network Switch Via the DC switchgear fiber patch Panel

PART 3 - EXECUTION

3.1 SOURCE QUALITY CONTROL

A. Design and Production Tests: Perform and submit in accordance with the General Provisions, certified test results for the tests on each unit of DIO supplied under this contract.

3.2 INSTALLATION

A. Factory tested DIO for DC Switchgear is furnished by the contractor for factory installation by the DC switchgear manufacturer.

B. Refer to DC switchgear Section 16341, METAL-ENCLOSED DC SWITCHGEAR FOR TIE BREAKER STATIONS, for additional requirements for DIO installation in the DC switchgear.

C. Factory Installation and Testing:

1. DIO shall be installed with the LEDs visible to a technician standing in front of the cubicle.

2. Perform work in accordance with the NEC.

3. Install wiring for DIO interface circuits for all points identified on the terminal block assignments tables in this Section.

4. DIO device mounted within each physical switchgear cubicle with all required interconnections wiring and interface devices for remote control closing and tripping of each circuit breaker.

5. QEI DIO 9100 specified uses 24Volt DC keying voltage, wire shall be color-coated for ready identification of voltage; <u>blue color</u> shall be used.

6. The DIO module installed in each breaker cubicle shall provide the remote control closing and tripping of the circuit breaker via interposing relays.

7. Refer to Section 16341, METAL-ENCLOSED DC SWITCHGEAR FOR TIE BREAKER STATIONS, for DTS and DIO interposing relays wiring circuits. DIO shall be installed for operation in parallel with the DTS system for the indications and control of the circuit breakers.

8. DIO factory test shall be an integral part of the DC switchgear Factory Acceptance Test witnessed by the Contracting Officer Representative.

D. Field Installation and Testing:

1. Install pre-fabricated fiber jumper cable between the each DIO and the DC switchgear fiber patch panel as shown.

2. The manufacturing representative shall verify correct operation of each DIO prior to scheduling the system integration test.

3. The Contractor is responsible for testing all DIO input signals to verify correct status and telemetry signal levels. A test data sheet shall be developed for each DIO, which list all I/O signal points. The data sheet shall be submitted as part of the Contractors test plan. Submit a list of discrepant I/O signal points to the Contracting Officer Representative. I/O equipment supplied under this Contract that is not reporting properly shall be corrected and retested. Submit a discrepancy report for all I/O points indicating problems found and required action.

TERMINAL BLOCK ASSIGNMENTS TABLE

DIO Terminal Block Assignments For DC Breaker

CONTROL	FUNCTION	DESCRIPTION		
TB2A-1-2	CONTROL TRIP	To energize relay 201 Trip coil		
TB2A-4-5	CONTROL CLOSE	To energize relay 201 Close coil		

STATUS	FUNCTION	DESCRIPTION	OPEN CONTACT WHEN	CLOSED CONTACT WHEN
TB3A-1-2	CLOSED	Breaker status	Bkr Open or Racked out	Bkr Closed
TB3A-3-4	TRIP	Breaker status	Bkr closed or Racked out	Bkr Open
TB3A-5-6	SPARE			
TB3A-7-8	TEST POSITION	Breaker Position	Racked In or Racked Out	Test Pos.
TB3A-9-10	LOCAL POSITION	Local/Remote Switch Position	Remote Position	Local Position
TB3A-11-12	RELAY 201C PICKUP	From 201C relay contact	Normal	Picked Up
TB3B-1-2	RELAY 201T PICKUP	From 201T relay contact	Normal	Picked Up
TB3B-3-4	DC SWG 86 LOCKOUT	Lockout relay status	Lockout	Normal

TB3B-5-6	LOST OF CONTROL POWER (27)	Contact from relay 27	Loss Power	Normal

STATUS	FUNCTION	DESCRIPTION	OPEN CONTACT WHEN	CLOSED CONTACT WHEN
TB3B-7-8	RACKED-IN	Breaker position	Racked out	Racked in
TB3B-9-10	DC SWGR ENERGIZED STRUCTURE (64DX)	Contact from 64 relay	Alarm	Normal
TB3B-11-12	DC MPR Critical Failure	Contact from DC relay	Failure	Normal
TB3C-1-2	BRK CBCM TRIP CKT SUPERVISION FAILURE [1]	CBCM TCS healthy contact	Failure	Normal
TB3C-3-4	BRK CBCM CONTROLLER FAILURE [1]	CBCM Control Healthy contact	Normal	Failure
TB3C-5-6	BRK CBCM OVERLOAD OPERATION[1]	CBCM Overload Operation contact	Normal	Failure
TB3C-7-8	DC SWGR GROUNDED STRUCTURE (64DY)	Contact from 64 relay	Alarm	Normal
TB3C-11	COMMOM WIRE (-) COMMON IS CONNECTED TO EVEN NUMBERS			

NOTES:

1. TB3C 9 & 11 of the DIO are not rated for the 201C and 201T coils control power.
2. Use external control power source for the close and trip coils.
3. For “breaker open” indication a breaker “172/b” contact in series with a breaker TOC “172/a” contact.
4. For “breaker closed” indication, a breaker “172/a” contact in series with a breaker TOC “172/a” contact.
5. (1) is for breaker with microprocessor based controller.

END OF SECTION

SECTION 16606

SCADA SYSTEMS INTEGRATION TIE BREAKER STATION SITE ACCEPTANCE TEST PLAN

PART 1 - GENERAL

1.1 SUMMARY

A. This Section applies to all equipment provided for installation, test, and commissioning. Though the test plan covers all equipment, individual Tie Breaker Station locations may not include all equipment types. The complete plan shall be used at each location, with the equipment tests not applicable to that location marked as N/A.

B. CONTRACTOR shall retain the services of the SCADA RTU manufacturer to be the system integrator, supervise and/or perform check-out and start-up of all system components. As part of these services, the contractor shall include for those equipment items not manufactured by the RTU manufacturer, the services of an authorized manufacturers' representative to check the equipment installation and place the equipment in operation. The manufacturers' representative shall be thoroughly knowledgeable about the installation, operation and maintenance of the equipment.

C. SCADA equipment testing will be scheduled and coordinated and performed by the contractor under the supervision of WMATA SCADA engineer.

D. The system integrator shall develop site specific Remote Terminal Unit (RTU), Human Machine Interface (HMI) and Digital Trace Recorder (DTR) programming files before the SCADA system site acceptance test is scheduled. The configuration of the RTU, HMI and DTR will be scheduled by the contractor as part of the SCADA system site acceptance tests.

E. Related Equipment:

1. The equipment that will be tested as part of the SCADA system site acceptance test includes the following:

a. DC Switchgear Microprocessor Relays

b. DC Circuit Breakers Distributed Input Output Module (DIO)

c. DC Switchgear Digital Trace Recorder (DTR)

d. DC switchgear Cable shield Monitor (as applicable)

e. Battery Monitor (as applicable)

f. UPS/Battery Charger (as applicable)

g. ETS

h. Fire Alarm

i. Unauthorized Entry

j. Room Temperature

k. Human Machine Interface (HMI)

l. Network Switches

m. Remote Terminal Unit (RTU)

n. Fiber Network

1.2 SUBMITTALS

A. Submit the following for approval in accordance with Special Provisions and with the additional requirements as specified for each:

1. Test Procedure: Develop and submit a test procedure for performing the installation acceptance tests of installed SCADA equipment for approval.

2. Fiber Test Report: Singlemode and Multimode fiber test report.

3. SCADA equipment Configuration Files: The System Integrator shall develop and submit site specific RTU, HMI and DTR configuration files two weeks prior to the SCADA system integration tests.

4. As Built documents: All sign-off sheets shall be included in the as-built documents.

1.3 QUALITY ASSURANCE

A. Coordination:

1. The Contracting Officer Representative (SCADA engineer) and the equipment manufacturer technical representative shall be on site to witness and sign test documentations as tests are performed, and shall receive a copy of the completed test reports.

2. Contractor is responsible for the scheduling, coordinating, and simulating all equipment for the site acceptance tests.

3. The contractor system integrator is responsible for the configuring, monitoring, and correcting of RTU, HMI, and DTR related issues during the tests.

4. The following shall be completed prior to scheduling the SCADA system testing and integration:

a. Single Mode Fiber Network (Contractor)

1) Verify that single mode fiber cable has been installed between the facility and the associated communication room.

2) Verify that fiber cable test report has been approved by The Contracting Officer Representative.

b. Multimode Fiber Network (Contractor)

1) Verify that Multimode fiber cables have been installed in the facility.

2) Verify that fiber cables test report has been approved by The Contracting Officer Representative.

PART 2 - PRODUCTS

2.1 RECOMMENDED TEST EQUIPMENT

A. The following test equipment shall be used in the performance of the field tests. Record of test equipment calibration is noted on the last page of the test forms.

1. Variable DC power supply from 0 to 1000 volt D.C.

2. Digital and Analog Multimeters

3. Voltage/current precision calibrator

PART 3 EXECUTION

3.1 FIELD TESTING

A. Day 1

1. Network Switch Configuration (WMATA)

   a. Install network switches

   b. Install Fiber patch cords in accordance with Contract Drawings between network switches and patch panels.

   c. Install Cat6 cables in accordance with Contract Drawings.

   d. Terminate Single mode fibers in the communication room and verify connectivity to WMATA Metronet (If included in the contract).

2. RTU/HMI/DTR Configurations (System Integrator)

   a. RTU Configuration and Setup.

   b. HMI Configuration and Setup.

   c. DTR Configuration and Setup.

   d. Verify HMI properly displays all equipment status and analog values.

   e. Verify communication with DTR and proper scaling.

   f. Verify communication between RTU and all field equipment IEDs.

3. Miscellaneous field verifications (System integrator/WMATA)

a. Verify all IP addresses assigned for each device.

b. Verify version for each DIO Module

c. Verify the DIP switch address for each DIO Module.

d. Verify hard Wire terminations inside RTU.

e. Verify all fiber terminations and connectivity to the Network switch.

B. Day 2

1. DC Switchgear/Switchboard Testing—DC Switchgear Microprocessor Relays

a. Set all overcurrent relays in accordance with the approved setting.

b. Set all overcurrent relays communication mapping in accordance with the approved DNP3 protocol communication mapping.

c. Verify proper target operation for each mapping point

d. Verify proper communication with the SCADA system using the substation HMI.

e. Disconnect Shunt input plug from MPR Isolation amplifier and connect test equipment directly to the MPR Isolation amplifier (Observe correct polarities).

1) Note: When the shunt connection to the isolation amplifier is disconnected, the relay sees fault and protection functions will be activated.

f. Change MPR setting from Feeder type to cathode type

g. Record relay protection as found settings

h. Disable all other functions except the function under test. For functions with long time delay, adjust time to the lowest possible time delay to complete tests faster.

i. Inject 0 mv and reset the relay targets

1) Observe 0 amp of relay

2) Observe 0 amp on HMI display.

j. For each point listed for test, inject 150 mv.

1) Observe full-scale ampere on relay

2) Observe full-scale ampere on HMI display.

3) Observe correct target on relay

4) Observe correct target on HMI

k. At the end of each feeder relay test

1) Reset feeder breaker setting to feeder type

2) Reset relay functions and settings as found

Test Form: Place a check mark on the form as each step is completed.

2. DC Positive DTR Test

Connect a laptop to the DTR and run the DTR software.

a. Current Transducers Calibration

1) Connect test equipment leads to the terminals of the fuse connected to the transducer (Observe correct polarities). Ensure test leads are not connected to the terminal of the fuse connected to the shunt.

2) Inject 50 mv, observe breaker meter is reading full DC shunt ratio scale

3) Observe on DTR software that the signal is on the correct DTR channel.

4) Observe correct reading on HMI

5) Calibrate as necessary using transducer Zero and Gain

6) Inject 100 mv observe breaker meter is reading 2X full DC shunt ratio scale

7) Observe HMI reading is correct

8) Calibrate current transducers for all feeder and cathode breaker

b. Voltage Transducer Calibration

1) Identify the correct Voltage Transducer for the DTR

2) Connect a variable 1000V DC power supply test leads to the fuse terminals (Observe correct polarities)

3) Inject 1000v, observe breaker meter is reading 1000V

4) Observe on DTR software that the signal is on the correct DTR channel.

5) Calibrate as necessary using Zero and Gain

6) Inject 0 V, 750V and 1000V DC observe breaker meter reading is correct

7) Observe HMI reading is correct

Test Form: Place a check mark on the form as each step is completed.

c. DC Relay Fault Trigger Verification

1) Objective: Verification of DTR correct trigger points and fault recording functions.

2) Simulate a DC switchgear fault that will initiate the tripping of the DC breaker by the MPR.

3) Verify and record fault type on DC switchgear.

4) Download the DC fault recorded by the MPR relay.

5) Download and compare the fault recorded by the DTR with the fault recorded by the MPR.

6) Discrepancies between two recorded faults must be addressed by the DTR manufacturer representative.

Test Form: Place a check mark on the form as each step is completed.

3. DC Switchgear Distributed Input Output Module (DIO) Test.

a. Energize control power to the unit(s).

b. Verify DIO communication with RTU

c. Verify breaker status display on HMI

d. Perform a functional check of all control and indication circuitry. Specific functions include tripping, closing, remote operation, rack-out, 86 lockout, local remote switch position, 201C pickup, 201T pickup, 64 energize/ground, AC MPR critical failure, Loss of DC control Power and DIO failure.

Test Form: Place a check mark on the form as each step is completed.

4. HMI Verification and Test

a. Observe all status report by HMI are correct

b. Observe all Annunciator points are on HMI

c. Control all breakers from HMI.

d. Observe active alarm log is correct

e. Observe Alarm History is correct

f. Verify all critical alarms activate the buzzer.

g. Verify buzzer is silenced by the touch screen button.

h. Test Form: Place a check mark on the form as each step is completed.

C. Day 3

1. Room Temperature sensor test

   a. Check and verify temperature sensor reading is correct.

   b. Verify temperature display on HMI is correct.

   Test Form: Place a check mark on the form as each step is completed.

2. Battery Charger Test

   a. Verify connection between battery charger and RTU

   b. Verify connection between the battery charger and DTS

   c. Test by opening AC power input breaker to charger and observe alarm on HMI annunciator panel.

   Test Form: Place a check mark on the form as each step is completed.

3. Philtek Inverter Test (where applicable). This inverter is provided with both Ethernet and hard wire connections. The inverter has only one set of form C contact for Inverter failure and one set for Inverter Transfer switch Abnormal that need to be connected to both the DTS and the HMI. Interposing relays provided in the RTU shall be used by the contractor to provide output to the RTU and DTS.

   a. Hardwire connection Test

      1) Refer to Philtek inverter board form “C” drawing

      2) Verify interposing relays have been installed

      3) Verify contacts are wired to RTU terminals

      4) Verify contacts are wired to DTS terminals

      5) Simulate inverter failure; observe alarm on HMI and DTS

      6) Simulate Inverter transfer switch alarm; observe alarm on HMI and DTS

   b. Ethernet connection Test

      1) Change IP address to 10.18.xxx.181 (Follow manual instructions)

      2) Establish communication

      3) Check webpage (Follow manual instructions)

   Test Form: Place a check mark on the form as each step is completed.

4. UPS (by Contractor): UPS is provided with both RS485 and hard wire connections. UPS may have only one set of form C contact for each Battery charger failure, Inverter failure and Inverter Transfer switch Abnormal that need to be connected to both the DTS and the HMI. Interposing relays provided in the RTU shall be used by the contractor to provide output to the RTU and DTS.

   a. Hardwire connection Test

      1) Refer to UPS communication board drawing

      2) Verify interposing relays have been installed

      3) Verify contacts are wired to RTU terminals

      4) Verify contacts are wired to DTS terminals

      5) Simulate battery charger, inverter, and transfer switch failures; observe alarm on HMI and DTS for each of the failure type.

   b. RS485 connection Test (WMATA)

      1) Verify RS485 connection to RTU terminals.

      2) Verify RTU is polling data from UPS.

      3) Verify HMI is properly displaying UPS information/data points

      4) Refer to table in scope of work for UPS points to validate.

   Test Form: Place a check mark on the form as each step is completed.

5. Battery Cycle Monitor (BCM) (by Contractor) - Objective: Verification of BCM communication and Modbus mapping per WMATA SCADA point assignment chart.

   a. Verify BCM IP address is correct and the BCM is communicating with the substation RTU.

   b. Using a laptop, configure the BCM per WMATA Settings. Using a suitable variable DC Voltage source, simulate low voltage and High Voltage conditions. Using the BCM webpage, verify alarms are generated.

   c. Verify RTU received alarms

   d. Verify HMI for proper display of point tested.

   e. Verify correct voltage is received by HMI

   Test Form: Place a check mark on the form as each step is completed.

6. <u>Fire Alarm</u>

   a. Simulate fire alarm activation (If the fire alarm system wiring is not included in the contract, jumper fire alarm connection terminals in the RTU terminal board to simulate fire alarm activation.)

b. Verify RTU file is updated with the alarm point.

Test Form: Place a check mark on the form as each step is completed.

7. Unauthorized Entry Alarm

a. Simulate unauthorized entry alarm activation (If the unauthorized entry alarm system wiring is not included in the Contract, jumper unauthorized entry alarm connection terminals in the RTU terminal board to simulate unauthorized entry alarm activation.)

b. Verify RTU file is updated with the alarm point.

SCADA Systems Integration—Site Acceptance Test Sign-Off Sheet		
Test Procedure	Date completed (mm/dd/yy)	WMATA Rep. Initials
1. Single Mode Fiber Test Report		
2. Multimode Fiber Network		
a. Fiber Cable Installation		
b. Fiber Cables Test Report Approved		
DAY 1		
1. Network Switch Configuration		
a. Network Switches Installed		
b. Fiber Patch Cord /Cat 6 Cable Installed		
c. Connectivity to WMATA Network		
2. RTU/HMI/DTR Configurations		
a. RTU Configured		
b. HMI Configured		
c. DTR Configured		
d. Verify HMI Display		
e. Verify DTR Communication and Scaling		
f. Verify RTU Communication with Field Devices		
3. IP Address Setting		
a. Verified IP addresses		
b. Verified DIO Version		
c. Verified Connections to RTU		

SCADA Systems Integration—Site Acceptance Test Sign-Off Sheet		
Test Procedure	Date completed (mm/dd/yy)	WMATA Rep. Initials
DAY2		
DC Switchgear/Switchboard Testing		
1. DC Switchgear Microprocessor Relays		
a. Verified Relay Communication with RTU		
b. Completed all SCADA Points Tests		
c. Verified HMI displays		
2. DC Positive & Negative DTR Test		
a. Calibrated Current Transducers		
b. Calibrated Voltage Transducers		
c. Verified HMI displays		
d. Verified DTR Trigger functions		
3. DC Switchgear Distributed Input Output Module Test		
a. Verify DIO communication with RTU		
b. Verify breaker status display on HMI		
c. Completed all SCADA Points Tests		
d. Verified correct displays and alarms points on HMI		
4. HMI Verification and Test		
a. Observed status report by HMI are correct		
b. Observed Annunciator points are on HMI		
c. Tested Breaker Controls by HMI.		
d. Verified active alarm/History are correct		
e. Verified buzzer is properly working		

SCADA Systems Integration—Site Acceptance Test Sign-Off Sheet		
Test Procedure	Date completed (mm/dd/yy)	WMATA Rep. Initials
DAY 3		
1. Room Temperature sensor test		
a. Verified temperature sensor reading is correct		
b. Verified temperature display on HMI is correct.		
2. Battery Charger Test		
a. Verified connection between battery charger and RTU		
b. Verified connection between battery charger and DTS		
c. Completed all SCADA Points Tests		
d. Verified HMI annunciator and alarms		
3. Inverter Test		
a. Hardwire connection Test Completed		
b. Verified Correct IP address		
c. Verified Communication with RTU		
d. Verified Webpage access.		
e. Verified HMI Displays.		
4. UPS		
a. Hardwire connection Test Completed		
b. Verified RS485 communication		
c. Verified Communication with RTU		
d. Verified HMI Displays.		
5. Battery Cycle Monitor Test		
a. Verified Correct IP address		
b. Verified Communication with RTU		
c. Verified Webpage access.		
d. Completed all SCADA Points Tests		
e. Verified HMI for proper display of point tested.		
f. Verified correct voltage is received by HMI		
6. Fire Alarm		
a. Verified Hardwire connection to RTU		
b. Test Completed		
7. Unauthorized Entry Alarm		
a. Verified Hardwire connection to RTU		
b. Test Completed		

END OF SECTION