SECTION 26 11 16

SECONDARY UNIT SUBSTATIONS
02/10, CHG 2: 11/19

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by the basic designation only.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI C12.1	((2014; Errata 2016) Electric Meters - Code for Electricity Metering
ANSI C39.1	(1981; R 1992) Requirements for Electrical Analog Indicating Instruments
ANSI C57.12.13	(1982) Conformance Requirements for Liquid-Filled Transformers

ASTM INTERNATIONAL (ASTM)

ASTM A167	(2011) Standard Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
ASTM D92	(2012a) Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester
ASTM D97	(2017b) Standard Test Method for Pour Point of Petroleum Products
ASTM D709	(2017) Standard Specification for Laminated Thermosetting Materials
ASTM D877/D877M	(2019) Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes
ASTM D1535	(2014; R 2018) Standard Practice for Specifying Color by the Munsell System

FM GLOBAL (FM)

FM APP GUIDE	(updated on-line) Approval Guide http://www.approvalguide.com/

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 100	(2000; Archived) The Authoritative Dictionary of IEEE Standards Terms
IEEE 386	(2016) Separable Insulated Connector

	Systems for Power Distribution Systems Rated 2.5 kV through 35 kV
IEEE C2	(2017; Errata 1-2 2017; INT 1 2017) National Electrical Safety Code
IEEE C37.20.3	(2013) Standard for Metal-Enclosed Interrupter Switchgear
IEEE C37.90.1	(2013) Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus
IEEE C37.121	(2012) American National Standard for Switchgear-Unit Substations - Requirements
IEEE C57.12.00	(2015) General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers
IEEE C57.12.29	(2014) Standard for Pad-Mounted Equipment - Enclosure Integrity for Coastal Environments
IEEE C57.12.80	(2010) Standard Terminology for Power and Distribution Transformers
IEEE C57.12.90	(2015; Corr 2017) Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers
IEEE C57.13	(2016) Requirements for Instrument Transformers
IEEE C57.98	(2011) Guide for Transformer Impulse Tests
IEEE C62.11	(2020) Standard for Metal-Oxide Surge Arresters for Alternating Current Power Circuits (>1kV)

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

NETA ATS	(2017; Errata 2017) Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA ICS 6	(1993; R 2016) Industrial Control and Systems: Enclosures
NEMA LI 1	(1998; R 2011) Industrial Laminating Thermosetting Products
NEMA ST 20	(2014) Dry-Type Transformers for General Applications
NEMA/ANSI C12.10	(2011) Physical Aspects of Watthour Meters

- Safety Standards

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2020; ERTA 20-1 2020; ERTA 20-2 2020; TIA 20-1; TIA 20-2; TIA 20-3; TIA 20-4) National Electrical Code

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD)

OECD Test 203	(1992) Fish Acute Toxicity Test

U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA)

EPA 712-C-98-075	(1998) Fate, Transport and Transformation Test Guidelines - OPPTS 835.3100- "Aerobic Aquatic Biodegradation"
EPA 821-R-02-012	(2002) Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms

UNDERWRITERS LABORATORIES (UL)

UL 467	(2013; Reprint Jun 2017) UL Standard for Safety Grounding and Bonding Equipment

1.2 RELATED REQUIREMENTS

Section 26 08 00 APPARATUS INSPECTION AND TESTING applies to this section, with the additions and modifications specified herein.

1.3 DEFINITIONS

Unless otherwise specified or indicated, electrical and electronics terms used in these specifications, and on the drawings, shall be as defined in IEEE 100.

1.4 SUBMITTALS

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

As an exception to the transformer submittal requirements specified herein, liquid-filled transformers manufactured by ABB in South Boston, VA; by Cooper Power Systems in Waukesha, WI; or by Howard Industries in Laurel, MS need not meet the submittal requirements of this contract. Instead, the following shall be submitted:

a. A certification, from the manufacturer, that the technical requirements of this specification shall be met.

b. An outline drawing of the transformer with devices identified (paragraph entitled "Transformer Drawings," item a).

c. ANSI nameplate data of the transformer (paragraph entitled "Transformer Drawings", item b).

d. Routine and other tests (paragraph entitled "Routine and Other Tests"), shall be conducted by the manufacturer and will be witnessed by the government (paragraph entitled "Source Quality Control"). Provide transformer test schedule required by submittal item "SD-11 Closeout Submittals". Provide certified copies of the tests.

e. Provide acceptance test reports required by submittal item "SD-06 Test Reports".

f. Provide operation and maintenance manuals required by submittal item "SD-10 Operation and Maintenance Data".

1.4.1 Coordinated Submittal Reviews

a. Submit remaining substation component submittals to Engineer of Record for approval. In addition, submit one set of transformer submittals for surveillance and to insure alignment of equipment and coordination for interconnections.

SD-02 Shop Drawings

Unit Substation Drawings; G

Transformer drawings; G

Include wiring diagrams and installation details of equipment indicating proposed location, layout and arrangement, control panels, accessories, piping, ductwork, and other items that must be shown to ensure a coordinated installation. Wiring diagrams shall identify circuit terminals and indicate the internal wiring for each item of equipment and the interconnection between each item of equipment. Drawings shall indicate adequate clearance for operation, maintenance, and replacement of operating equipment devices. Submittals shall include the nameplate data, size, and capacity. Submittals shall also include applicable federal, military, industry, and technical society publication references.

SD-03 Product Data

Fuse curves; G

Secondary unit substation excluding transformer data; G

Unit substation transformer (liquid-filled)); G

Submittal shall include manufacturer's information for each component, device, and accessory provided with the transformer.

SD-06 Test Reports

Acceptance checks and tests; G

SD-07 Certificates

Paint coating system; G

Transformer Losses; G

SD-09 Manufacturer's Field Reports

Unit substation transformer design tests (liquid-filled) (to code CI44074); G

Unit substation transformer routine and other tests (liquid-filled) (to code CI44074); G

SD-10 Operation and Maintenance Data

Unit substations, Data Package 5; G

SD-11 Closeout Submittals

Assembled Operation and Maintenance Manuals; G

Equipment test schedule (to Code CI44 for liquid-filled units); G

1.5 QUALITY ASSURANCE

1.5.1 Drawing Requirements

1.5.1.1 Unit Substation Drawings

Drawings shall include, but are not limited to the following:

a. An outline drawing, with front, top, and side views showing incoming, transformer, and outgoing sections. Include switchgear information from Section 26 23 00 LOW VOLTAGE SWITCHGEAR as part of the total unit substation.

b. One-line diagram showing current transformers, meters, and ampere rating of bus bars.

c. Elementary diagrams and wiring diagrams with terminals identified, and indicating prewired interconnections between items of equipment and the interconnection between the items.

1.5.1.2 Transformer Drawings

Drawings shall include, but are not limited to the following:

a. An outline drawing, with front, top, and side views.

b. ANSI nameplate data.

1.5.2 Paint Coating System

Submit IEEE C57.12.29 coating system performance requirement tests. When interrupter switchgear and transformer are provided by two different manufacturers, each one shall provide certification.

1.5.3 Transformer Losses

Submit certification from the manufacturer indicating conformance with the paragraph entitled "Specified Transformer Losses".

1.5.4 Substation Product Data

Submittal shall include manufacturer's information for each component, device, and accessory provided with the equipment.

1.5.5 Test Reports

Submit report of acceptance test results as specified by paragraph entitled "Field Quality Control."

1.5.6 Regulatory Requirements

In each of the publications referred to herein, consider the advisory provisions to be mandatory, as though the word, "shall" had been substituted for "should" wherever it appears. Interpret references in these publications to the "authority having jurisdiction," or words of similar meaning, to mean the Contracting Officer. Equipment, materials, installation, and workmanship shall be in accordance with the mandatory and advisory provisions of NFPA 70 unless more stringent requirements are specified or indicated.

1.5.7 Standard Products

Provide materials and equipment that are products of manufacturers regularly engaged in the production of such products which are of equal material, design and workmanship. Products shall have been in satisfactory commercial or industrial use for 2 years prior to bid opening. The 2-year period shall include applications of equipment and materials under similar circumstances and of similar size. The product shall have been on sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2-year period. Where two or more items of the same class of equipment are required, these items shall be products of a single manufacturer; however, the component parts of the item need not be the products of the same manufacturer unless stated in this section.

1.5.7.1 Alternative Qualifications

Products having less than a 2-year field service record will be acceptable if a certified record of satisfactory field operation for not less than 6000 hours, exclusive of the manufacturers' factory or laboratory tests, is furnished.

1.5.7.2 Material and Equipment Manufacturing Date

Products manufactured more than 3 years prior to date of delivery to site shall not be used, unless specified otherwise.

1.6 MAINTENANCE

1.6.1 Assembled Operation and Maintenance Manuals

Manuals shall be assembled in durable, hard covered, water resistant binders. The manual shall be assembled and indexed in the order noted in a table of contents. The contents of the assembled operation and maintenance manuals shall be as follows:

a. Manufacturer's O&M information required by the paragraph entitled, "SD-10 Operation and Maintenance Data."

b. Catalog data required by the paragraph entitled, "SD-03 Product Data."

c. Drawing required by the paragraph entitled, "SD-02 Shop Drawings."

d. Price for spare parts and supply list

e. Routine and field acceptance test reports

1.6.2 Operation and Maintenance Data

Submit operation and maintenance data in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA and as specified herein.

1.7 WARRANTY

The equipment items shall be supported by service organizations which are reasonably convenient to the equipment installation in order to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

PART 2 PRODUCTS

2.1 PRODUCT COORDINATION

Products and materials not considered to be secondary unit substations and related accessories are specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION and Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

2.2 SECONDARY UNIT SUBSTATION

Secondary Unit substations shall comply with IEEE C37.121 regardless of the kVA rating specified. Substation shall consist of one incoming section s, one transformer section, and one outgoing section. Substation shall be designed for outdoor service with ventilation openings and gasketing provided to ensure a weatherproof assembly under rain, snow, sleet, and hurricane conditions. Substations shall be subassembled and coordinated by one manufacturer and shall be shipped in complete sections ready for connection at the site. Where practicable, substation shall be shipped as one unit. External doors shall have provisions for padlocking. Provide bird mitigation method for substation.

2.2.1 Incoming Section

The transformer primary overcurrent protection shall be accomplished using a 24VDC microprocessor based feeder relay paried with a resettable vacuum fault interrupter (VFI). The VFI unit is to be used for transformer and loop protection.

2.2.1.1 Incoming Section Enclosure

The incoming section enclosure shall be NEMA ICS 6 Type as indicated. Bases, frames and channels of enclosure shall be corrosion resistant and shall be fabricated of ype 304 or 304L stainless steel. Base shall include any part of enclosure that is within 3 inches of concrete pad. Paint enclosure, including bases, ASTM D1535 light gray No. 61 or No. 49. Paint coating system shall comply with IEEE C57.12.29.

2.2.1.2 Cable Terminations

Provide medium voltage cable terminations as specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION.

a. 600 ampere deadbreak connector ratings: Voltage: 15 kV, 95 kV BIL. Short time rating: 40,000 rms symmetrical amperes. Connectors shall have 200 ampere bushing interface for surge arresters.

2.2.1.3 Surge Arresters

IEEE C62.11, rated 10kV, fully shielded, dead-front, metal-oxide-varistor, elbow type with resistance-graded gap, suitable for plugging into inserts. Arresters shall be distribution class. Arresters shall be equipped with mounting brackets suitable for the indicated installations.

2.2.1.4 Vacuum Fault Interrupters

1. The transformer shall incorporate a vacuum fault interrupter for overcurrent protection, such that the major dielectric media is never contaminated by circuit interruption arc products. The interrupter shall be manually resettable, with no consumable parts (i.e. fuses). The maximum interrupting time from issuance of a trip signal from the electronic control shall be 2 cycles.

2. The vacuum fault interrupter may be tripped via the incorporated relay control by sensing anomalies in the system provided there is adequate sensing equipment also incorporated into the transformer. That is, the VFI may be tripped (opened) in the event of anomalies such as, but not limited to, overcurrent, over/undervoltage, over temperature, over pressure, under frequency, etc. provided the appropriate associated devices are also incorporated into the transformer (i.e. potential transformers, thermometers, pressure relief devices, transducers, etc.) and the appropriate relay control is selected.

3. To maximize safety to the operator, the interrupter shall incorporate a trip-free mechanism to prevent the possibility of holding the interrupter mechanism closed under a faulted circuit condition.

4. The vacuum fault interrupter shall act as a three-phase group operated circuit breaker. The trip mechanisms for each phase shall be mechanically linked and the electronic control shall be set so that an overcurrent condition on any one phase shall simultaneously trip all three phases. A single operating handle shall be provided for manual opening, reset and closing. The operating handle(s) shall be mounted on the front plate of the tank in close relation to the VFI being controlled and shall have three distinct operating positions corresponding to the vacuum fault interrupter positions of closed, open, or tripped. A pointer attached to the handle shall be provided for ready identification of the handle's position. The handle shall be designed for operation with a lineman's hot stick and have a push to close / pull to open / pull to reset operation requiring no more than 75 lbs. of force and 60 degrees of movement for complete operation. Except when equipped with the optional motor operator, when the vacuum fault interrupter is tripped by automatic action of the VFI control, the operating handle shall drop to an intermediate position between its closed and open positions, to provide indication that it is tripped. The operating handle assembly shall include

provisions to padlock the handle in the open position.

2.2.1.4.1 Electronic Trip Control

1. The protective relays for the transformer protection shall be a single multifunction, microprocessor-based relay that incorporates feeder overcurrent protection for the primary or secondary of a two-winding transformer. Relay will have fixed or variable percentage, using one or two settable slopes with adjustable intersection points and minimum pickup.

2. The relay shall be Eaton device type EDR-3000, EDR-5000, or approved equal feeder relay having all, but not limited to, the features and functions herein specified.

3. Relay shall be wired to directly trip the VFI mechanism.

4. The relay shall be a solid-state microprocessor-based multifunctional type that operates from a 5 ampere or 1 ampere secondary output of current transformers. The relay shall provide ANSI 50/51 protective functions, and ANSI 50/51N or 50/51G ground fault protection functions for each winding as shown on the plans or as determined by the coordination study. The relay shall be configurable between true rms or fundamental sensing for each phase and ground. Ground element shall be capable of being utilized in residual, zero sequence, ground source connection schemes, or deactivated.

5. The current transformer ratings being used for percentage overcurrent protection, phase, negative sequence, and ground protection feeding device shall have primary current ratings from 1 through 10,000 amperes. Relay may be programmable for current transformers 1 through 50,000 amperes.

6. Provide phase and ground (as applicable) CT's on transformer primary. CTs will be connected to transformer relay via test switches within control cabinet. CT ratio shall be as appropriate for the full amp output of the given transformer kVA rating.

7. Control cabinet will be equipped with ABB test FT-1 switches as needed for application or approved equal

8. Control cabinet will be supplied with terminal block for customer connections

9. Control cabinet will be supplied with 24V UPS system supplied by 120VAC from internal CPT and 12VDC from cabinet mounted 12V battery capable of 24hour back up (optional: customer supplied power)

10. Control cabinet to include heater

11. Control cabinet will be NEMA 4X, UL listed, 100% stainless steel box

12. The relay shall provide, but is not limited to, the following protection devices:

    a. Phase overcurrent (50/51): Four inverse time and instantaneous overcurrent (50/51-1, 50/51-2, 50/51-3, 50/51-4) functions with adjustable time delay. The element is assigned to either the primary or secondary side of the transformer.

b. Ground overcurrent (50R/51R): One inverse time overcurrent (51R) function and one instantaneous overcurrent (50R) function from calculated values with adjustable time delay. The element can be assigned to either side of the transformer.

c. The phase, negative sequence, and ground protection curves shall be independently field-selectable. Curves shall be selectable from the following:

1) IEEE: Moderately inverse, very inverse, extremely inverse

2) IEC: A, B, C or D

3) Thermal: Flat, lt, I2t, I4t

13. The relay shall have 8 contact outputs that may be programmed for any protection function operation output

14. The relay shall have a front panel display of relay condition, and 7 programmable LEDs that can be used for trip condition or breaker status

15. The relay shall have a LCD display with LED background illumination capable of displaying the following information with metering accuracy of +/- half (0.5) percent of measured value (ln) for ln < 2 ln and +/- one (1) percent of measured value (ln) for ln > 2:

16. Relay will be able to measure the following values from the transformer (*voltage and power measurements require inclusion of PTs and PT inputs):

a. Individual RMS and fundamental phase currents

b. Ground RMS and fundamental current

c. Phase-to-ground and phase-to-phase voltages with phase angles

d. Watts

e. Vars

f. VA

g. Frequency

h. Power factor - apparent and displacement

i. Minimum/maximum values of current, voltage, watts, vars, VA, frequency, apparent pf and displacement pf

j. Phase angles

17. Relay shall have the following features:

a. Trip coil-monitoring and IRIG-B

b. Zone selective interlocking capability

c. Real-time clock for stamping of events, trips and minimum/maximum

values with

d. 1ms time resolution or better

e. User interface for programming and retrieving data from the front of the unit without additional equipment

f. Four (4) contact inputs that are user programmable

g. Continuous self-testing of internal circuitry, self-diagnostic capability.

h. Programmable lockout/self-reset after trip function (86 lockout)

i. Programmable set points for device curve selection

j. Programmable inputs, such as current transformer ratios

k. Relay shall be suitable for operating temperatures from -20 degrees to 60 degrees C. Relay shall be suitable for operating with humidity from 0 to 95% relative humidity

18. Relay shall record information on the last 20 faults including:

    a. Date, time, and currents at the time of fault

    b. Relay shall record 3600 cycles of waveform data for the current

    c. Relay shall record the last 300 events into an event log with date and time stamping

19. Relay shall have the following communications ports available if specified:

    a. Rear communications port(s) that support: IEC61850, Modbus TCP, and DNP3.0 TCP via RJ-45 connector

    b. A USB front communication port for programing and interrogation of the relay via personal or laptop computer

    c. Communication ports shall have the ability to transmit all information contained in the relay such as currents, set points, cause of trip, magnitude of trip current, and open-close trip status over the connected network.

20. Relay trip contacts shall not change state if power is lost or an undervoltage occurs. These contacts shall only cause a trip upon detection of an overcurrent or fault condition based upon programmed settings

21. The relay shall be suitable for operating on control power with a nominal input voltage of 24Vdc

22. The Relay shall be fully programmable through the face of the relay. In addition, a means to be able to program the relay through a communication port needs to be provided.

23. Meet the specified time-current curve immediately upon energization.

24. No "warm-up", initialization, or arming time delays adjustments shall be necessary.

25. No minimum load requirement or battery back-up device shall be necessary to meet the specified time-current characteristics.

2.2.2 Transformer (Liquid-Filled) Section

ANSI C57.12.13. Less-flammable liquid-filled. The entire transformer assembly including, transformer base, the tank, radiators, flanges, base, lifting provisions, and hardware, shall be fabricated of ASTM A167 type 304, 304L, or 316 stainless steel. Transformer base shall include any part of the transformer that is within 3 inches of concrete pad. Paint coating system shall comply with IEEE C57.12.29.

2.2.2.1 Transformer Ratings

a. Cooling Class: ONAN-Liquid-filled, self-cooled.

b. Frequency: 60 Hz.

c. Phases: Three phase.

d. Rated Kilovolt Amperes: As indicated kVA

e. Voltage Rating: As indicated

f. Impedance: Minimum tested impedance shall not be less than 5.32 percent at 85 degrees C.

g. Insulation Level: 95 kV BIL

h. Temperature Rise: 65 degree C average winding temperature rise above a 30 degree ambient.

i. Audible Sound Levels: Audible sound levels shall comply with the following:

kVA Range	DECIBELS (MAX)
225-300	55
1001-1500	60
3001-4000	64

2.2.2.2 Transformer Accessories

The transformer shall have the following accessories:

a. 7.5 percent full capacity taps, such that the transformers can be set up for 450V vessels and 480V vessels.

b. Tap changer, with external, pad-lockable, manual type operating handle, for changing tap setting when transformer is de-energized.

c. Dead-front high-voltage bushings; IEEE 386. 15 kV, 95 kV BIL.

Provide 600 ampere one piece deadbreak apparatus bushings.

d. Parking stands: Provide a parking stand near each dead-front bushing. Provide insulated standoff bushings for parking of energized load-break connectors on each parking stands.

e. Insulated low-voltage neutral bushing with lugs for ground cable and removable ground strap.

f. Ground pads.

g. Liquid-level indicator.

h. Pressure-vacuum gage.

i. Liquid temperature indicator.

j. Drain and filter valves.

k. Pressure relief device, top mounted, Qualitrol series 208.

l. Diagrammatic stainless steel or laser-etched anodized aluminum nameplate in accordance with IEEE C57.12.00 and as modified or supplemented by this section.

m. Transformer base with provisions for jacking and for rolling in either direction.

n. Lifting provisions.

o. Bolted transformer top or welded top with bolted handhole access.

2.2.2.3 Insulating Liquid

a. Less-flammable transformer liquids: NFPA 70 and FM APP GUIDE for less-flammable liquids having a fire point not less than 300 degrees C tested per ASTM D92 and a dielectric strength not less than 33 kV tested per ASTM D877/D877M. Provide identification of transformer as "non-PCB" and "manufacturer's name and type of fluid" on the nameplate.

The fluid shall be a biodegradable electrical insulating and cooling liquid classified by UL and approved by FM as "less flammable" fluids. The fluid shall meet the following fluid properties:

1. Pour point: ASTM D97, less than -15 degree C

2. Aquatic biodegradation: EPA 712-C-98-075, 100 percent

3. Trout toxicity: OECD Test 203, zero mortality of EPA 821-R-02-012, pass

2.2.3 Outgoing Section

The outgoing section shall consist of a secondary transition section for connecting to a low-voltage switchgear section. The switchgear shall be as specified in Section 26 23 00 LOW VOLTAGE SWITCHGEAR 26 24 13 SWITCHBOARDS. Connections between the transformer secondary bushings and the outgoing section transition bus shall be flexible braid bus. The secondary transition section shall have a hinged front panel.

2.2.3.1 Outgoing Section Enclosure

Provide outgoing section enclosure in accordance with the requirements in paragraph entitled, "Incoming Section Enclosure".

2.2.4 Watthour and Digital Meters

2.2.4.1 Electronic Watthour Meter

NEMA/ANSI C12.10. Provide a switchboard style electronic programmable watthour meter, semi-drawout, semi-flush mounted, as indicated. Meter shall either be programmed at the factory or shall be programmed in the field. When field programming is performed, turn field programming device over to the Contracting Officer at completion of project. Meter shall be coordinated to system requirements.

a. Design: Provide meter designed for use with 3 current transformers. Include necessary KYZ pulse initiation hardware for Energy Monitoring and Control System (EMCS) as specified in Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC.

b. Coordination; Provide meter coordinated with ratios of current transformers and transformer secondary voltage.

c. Class 20. Form: 9S. Accuracy: plus or minus 1.0 percent. Finish: Class II.

d. Kilowatt-hour Register: 5 digit electronic programmable type.

e. Demand Register:

    1. Provide solid state.

    2. Meter reading multiplier: Indicate multiplier on the meter face.

    3. Demand interval length: shall be programmed for 15 minutes with rolling demand up to six subintervals per interval.

2.2.4.2 Digital Meters

IEEE C37.90.1 for surge withstand. Provide true rms, plus/minus one percent accuracy, programmable, microprocessor-based meters enclosed in sealed cases with a simultaneous three line display. Meters shall have 0.56 inch, minimum, LED's. The meters shall accept input from standard 5A secondary instrument transformers. Programming shall be via a front panel display and a communication interface with a computer. Password secured programming shall be stored in non-volatile EEPROM memory. Digital communications shall be coordinated with PWD. The meter shall calculate and store average max/min demand values for all readings based on a user selectable sliding window averaging period. The meter shall have programmable hi/low set limits with two Form C dry contact relays when exceeding alarm conditions. Historical trend logging capability shall include ability to store up to 100,000 data points with intervals of 1 second to 180 minutes. The unit shall also store and time stamp up to 100 programmable triggered conditions.

a. Multi-Function Meter: Meter shall simultaneously display a selected phase to neutral voltage, phase to phase voltage, percent phase to

neutral voltage THD, percent phase to phase voltage THD; a selected phase current, neutral current, percent phase current THD, percent neutral current; selected total PF, kW, kVA, kVAR, FREQ, kVAh, kWh. Detected alarm conditions include over/under current, over/under voltage, over/under kVA, over/under frequency, over/under selected PF/kVAR, voltage phase reversal, voltage imbalance, reverse power, over percent THD. The meter shall have a Form C KYZ pulse output relay.

2.2.5 Instruments

ANSI C39.1 for electrical indicating switchboard style instruments, with 2 percent accuracy. The ac ammeters and voltmeters shall be minimum of 2 inches square, with 250 degree scale. Provide single phase indicating instruments with flush-mounted transfer switches for reading three phases.

2.2.6 Control Power Transformers

Transformer shall conform to the requirements of Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

2.2.7 Meter Fusing

Provide a fuse block mounted in the metering compartment containing one fuse per phase to protect the voltage input to voltage sensing meters. Size fuses as recommended by the meter manufacturer.

2.2.8 Heaters

Provide 120-volt heaters in incoming section, and outgoing section. Heaters shall be of sufficient capacity to control moisture condensation in the compartments, shall be 250 watts minimum, and shall be controlled by a thermostat and humidistat located in each section. Thermostat shall be industrial type, high limit, to maintain compartments within the range of 60 to 90 degrees F. Humidistat shall have a range of 30 to 60 percent relative humidity. If heater voltage is different than substation equipment voltage, provide transformer rated to carry 125 percent of heater full load rating. Transformer shall have 220 degrees C insulation system with a temperature rise not exceeding 115 degrees C and shall conform to NEMA ST 20. Energize electric heaters while the equipment is in storage or in place prior to being placed in service. Provide method for easy connection of heater to external power source.

2.2.9 Insulated Barriers

Where insulated barriers are required by reference standards, provide barriers in accordance with NEMA LI 1, Type GPO-3, 0.25 inch minimum thickness.

2.2.10 Terminal Boards

Provide with engraved plastic terminal strips and screw type terminals for external wiring between components and for internal wiring between removable assemblies. Terminal boards associated with current transformers shall be short-circuiting type. Terminate conductors for current transformers with ring-tongue lugs. Terminal board identification shall be identical in similar units. External wiring shall be color coded consistently for similar terminal boards.

2.2.11 Wire Marking

Mark control and metering conductors at each end. Provide factory-installed, white, plastic tubing, heat stamped with black block type letters on factory-installed wiring. On field-installed wiring, provide white, preprinted, polyvinyl chloride (PVC) sleeves, heat stamped with black block type letters. Each sleeve shall contain a single letter or number, shall be elliptically shaped to securely grip the wire, and shall be keyed in such a manner to ensure alignment with adjacent sleeves. Provide specific wire markings using the appropriate combination of individual sleeves. Each wire marker shall indicate the device or equipment, including specific terminal number to which the remote end of the wire is attached.

2.2.12 Grounding and Bonding

Provide as specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION.

2.2.13 Cast-in-Place Concrete

Concrete associated with electrical work for other than encasement of underground ducts shall be 4000 psi minimum 28-day compressive strength unless specified otherwise. All concrete shall conform to the requirements of Section 03 30 00 CAST-IN-PLACE CONCRETE.

2.3 MANUFACTURER'S NAMEPLATES

Each item of equipment shall have a nameplate bearing, as a minimum, the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent will not be acceptable. Include additional information as applicable to fully identify the equipment. Nameplates shall be made of noncorrosive metal. Sectionalizer switch nameplates shall have a schematic with all switch positions shown and labeled. As a minimum, provide nameplates for transformers, circuit breakers, meters, switches, and switchgear.

2.4 FIELD FABRICATED NAMEPLATES

ASTM D709. Provide laminated plastic nameplates for each secondary unit substation, equipment enclosure, relay, switch, and device; as specified in this section or as indicated on the drawings. Each nameplate inscription shall identify the function and, when applicable, the position. Nameplates shall be melamine plastic, 0.125 inch thick, white with black center core. Surface shall be matte finish. Corners shall be square. Accurately align lettering and engrave into the core. Minimum size of nameplates shall be one by 2.5 inches. Lettering shall be a minimum of 0.25 inch high normal block style.

2.5 WARNING SIGNS

Provide warning signs for the enclosures of secondary unit substations having a nominal rating exceeding 600 volts.

a. When the enclosure integrity of such equipment is specified to be in accordance with IEEE C57.12.29, such as for secondary unit substations, provide self-adhesive warning signs on the outside of the high voltage compartment door(s). Sign shall be a decal and shall have nominal dimensions of 7 by 10 inches with the legend "DANGER HIGH

VOLTAGE" printed in two lines of nominal 2 inch high letters. The word "DANGER" shall be in white letters on a red background and the words "HIGH VOLTAGE" shall be in black letters on a white background.

2.6 SOURCE QUALITY CONTROL

2.6.1 Equipment Test Schedule

The Government will witness tests. Provide equipment test schedules for tests to be performed at the manufacturer's test facility. Submit required test schedule and location, and notify the Contracting Officer 30 calendar days before scheduled test date. Notify Contracting Officer 15 calendar days in advance of changes to scheduled date.

Test Instrument Calibration

1. The manufacturer shall have a calibration program which assures that all applicable test instruments are maintained within rated accuracy.

2. The accuracy shall be directly traceable to the National Institute of Standards and Technology.

3. Instrument calibration frequency schedule shall not exceed 12 months for both test floor instruments and leased specialty equipment.

4. Dated calibration labels shall be visible on all test equipment.

5. Calibrating standard shall be of higher accuracy than that of the instrument tested.

6. Keep up-to-date records that indicate dates and test results of instruments calibrated or tested. For instruments calibrated by the manufacturer on a routine basis, in lieu of third party calibration, include the following:

   (a) Maintain up-to-date instrument calibration instructions and procedures for each test instrument.

   (b) Identify the third party/laboratory calibrated instrument to verify that calibrating standard is met.

2.6.2 Transformer Design Tests (Liquid-Filled)

In accordance with IEEE C57.12.00 and IEEE C57.12.90. Additionally, IEEE C57.12.80 section 5.1.2 states that "design tests are made only on representative apparatus of basically the same design." Submit design test reports (complete with test data, explanations, formulas, and results), in the same submittal package as the product data and shop drawings for each of the specified transformers. Design tests shall have been performed prior to the award of this contract.

a. Tests shall be certified and signed by a registered professional engineer.

b. Temperature rise: "Basically the same design" for the temperature rise test means a unit-substation transformer with the same coil construction (such as wire wound primary and sheet wound secondary),

the same kVA, the same cooling type (ONAN), the same temperature rise rating, and the same insulating liquid as the transformer specified.

c. Lightning impulse: "Basically the same design" for the lightning impulse dielectric test means a unit-substation transformer with the same BIL, the same coil construction (such as wire wound primary and sheet wound secondary), and a tap changer, if specified. Design lightning impulse tests shall include both the primary and secondary windings of that transformer.

1. IEEE C57.12.90 paragraph 10.3 entitled "Lightning Impulse Test Procedures," and IEEE C57.98.

2. State test voltage levels.

3. Provide photographs of oscilloscope display waveforms or plots of digitized waveforms with test report.

d. Lifting and moving devices: "Basically the same design" for the lifting and moving devices test means a transformer in the same weight range as the transformer specified.

e. Pressure: "Basically the same design" for the pressure test means a unit-substation transformer with a tank volume within 30 percent of the tank volume of the transformer specified.

2.6.3 Transformer Routine and Other Tests (Liquid-Filled)

In accordance with IEEE C57.12.00 and IEEE C57.12.90. Routine and other tests shall be performed by the manufacturer on each of the actual transformers prepared for this project to ensure that the design performance is maintained in production. Submit test reports, by serial number and receive approval before delivery of equipment to the project site. Required tests and testing sequence shall be as follows:

a. Cold resistance measurements (provide reference temperature)

b. Phase relation

c. Ratio

d. Insulation power-factor by manufacturer's recommended test method.

e. No-load losses (NLL) and excitation current

f. Load losses (LL) and impedance voltage

g. Dielectric

1. Impulse: Per IEEE C57.12.90 paragraph 10.3 entitled "Lightning Impulse Test Procedures," and IEEE C57.98. Test the primary winding only.

(a) State test voltage levels

(b) Provide photographs of oscilloscope display waveforms or plots of digitized waveforms with test reports.

2. Applied voltage

3. Induced voltage

h. Leak

i. Sample insulating liquid. Sample shall be tested for:

1. Dielectric breakdown voltage

2. Acid neutralization number

3. Specific gravity

4. Interfacial tension

5. Color

6. Visual condition

7. Water in insulating liquid

8. Measure dissipation factor or power factor

j. Perform dissolved gas analysis (DGA)

PART 3 EXECUTION

3.1 INSTALLATION

Electrical installations shall conform to IEEE C2, NFPA 70, and to the requirements specified herein.

3.2 GROUNDING

NFPA 70 and IEEE C2, except that grounds and grounding systems shall have a resistance to solid earth ground not exceeding 5 ohms.

3.2.1 Grounding Electrodes

Provide driven ground rods as specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION. Connect ground conductors to the upper end of the ground rods by exothermic weld or compression connector. Provide compression connectors at equipment end of ground conductors.

3.2.2 Substation Grounding

Provide bare copper cable not smaller than No. 4/0 AWG not less than 24 inches below grade interconnecting the indicated ground rods. Surge arrester and neutrals shall be bonded directly to the transformer enclosure and then to the grounding electrode system with bare copper conductors, sized as shown. Lead lengths shall be kept as short as practicable with no kinks or sharp bends. Substation transformer neutral connections shall not be smaller than No. 1/0 AWG. When work in addition to that indicated or specified is directed to obtain the specified ground resistance, the provision of the contract covering "Changes" shall apply.

3.2.3 Connections

Make joints in grounding conductors and loops by exothermic weld or

compression connector. Exothermic welds and compression connectors shall be installed as specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION, paragraph regarding "Grounding".

3.2.4 Grounding and Bonding Equipment

UL 467, except as indicated or specified otherwise.

3.3 INSTALLATION OF EQUIPMENT AND ASSEMBLIES

Install and connect unit substations furnished under this section as indicated on project drawings, the approved shop drawings, and as specified herein.

3.3.1 Interrupter Switchgear

IEEE C37.20.3.

3.3.2 Meters and Instrument Transformers

ANSI C12.1.

3.3.3 Field Applied Painting

Where field applied painting of enclosures is required to correct damage to the manufacturer's factory applied coatings, provide manufacturer's recommended coatings and apply in accordance with manufacturer's instructions.

3.3.4 Field Fabricated Nameplate Mounting

Provide number, location, and letter designation of nameplates as indicated. Fasten nameplates to the device with a minimum of two sheet-metal screws or two rivets.

3.3.5 Warning Sign Mounting

Provide the number of signs required to be readable from each accessible side, but space the signs a maximum of 30 feet apart.

3.4 FOUNDATION FOR EQUIPMENT AND ASSEMBLIES

3.4.1 Exterior Location

Refer to the structural drawings and specification for exterior platform provision.

3.4.2 Interior Location

Mount unit substation on concrete slab. Unless otherwise indicated, the slab shall be at least 4 inches thick. The top of the concrete slab shall be approximately 4 inches above finished floor. Edges above floor shall have 1/2 inch chamfer. The slab shall be of adequate size to project at least 4 inches beyond the equipment. Provide conduit turnups and cable entrance space required by the equipment to be mounted. Seal voids around conduit openings in slab with water- and oil-resistant caulking or sealant. Seals shall be of sufficient strength and durability to protect all energized live parts of the equipment from rodents, insects, or other foreign matter. Cut off and bush conduits 3 inches above slab surface.

3.4.3 Cast-in-Place Concrete

Cast-in-place concrete work shall conform to the requirements of Section 03 30 00 CAST-IN-PLACE CONCRETE.

3.5 FIELD QUALITY CONTROL

3.5.1 Performance of Acceptance Checks and Tests

Perform in accordance with the manufacturer's recommendations and include the following visual and mechanical inspections and electrical tests, performed in accordance with NETA ATS.

3.5.1.1 Transformers (Liquid-Filled)

a. Visual and mechanical inspection

1. Compare equipment nameplate data with specifications and approved shop drawings.

2. Inspect physical and mechanical condition. Check for damaged or cracked insulators and leaks.

4. Verify operation of all alarm, control, and trip circuits from temperature and level indicators, pressure relief device, and fault pressure relay.

5. Inspect all bolted electrical connections for high resistance using low-resistance ohmmeter, verifying tightness of accessible bolted electrical connections by calibrated torque-wrench method, or performing thermographic survey.

6. Verify correct liquid level in transformer tank.

7. Perform specific inspections and mechanical tests as recommended by manufacturer.

8. Verify correct equipment grounding.

9. Verify the presence of transformer surge arresters.

b. Electrical Tests

1. Perform resistance measurements through all bolted connections with low-resistance ohmmeter, if applicable.

2. Perform dissolved gas analysis (DGA).

3. Verify that the tap-changer is set at specified ratio.

4. Verify proper secondary voltage phase-to-phase and phase-to-neutral after energization and prior to loading.

3.5.1.2 Current Transformers

a. Visual and Mechanical Inspection

1. Compare equipment nameplate data with specifications and approved

shop drawings.

2. Inspect physical and mechanical condition.

3. Verify correct connection.

4. Verify that adequate clearances exist between primary and secondary circuit.

5. Inspect all bolted electrical connections for high resistance using low-resistance ohmmeter, verifying tightness of accessible bolted electrical connections by calibrated torque-wrench method, or performing thermographic survey.

6. Verify that all required grounding and shorting connections provide good contact.

b. Electrical Tests

1. Perform resistance measurements through all bolted connections with low-resistance ohmmeter, if applicable.

2. Perform insulation-resistance tests.

3. Perform polarity tests.

4. Perform ratio-verification tests.

3.5.1.3 Metering and Instrumentation

a. Visual and Mechanical Inspection

1. Compare equipment nameplate data with specifications and approved shop drawings.

2. Inspect physical and mechanical condition.

3. Verify tightness of electrical connections.

b. Electrical Tests

1. Verify accuracy of meters at 25, 50, 75, and 100 percent of full scale.

2. Calibrate watthour meters according to manufacturer's published data.

3. Verify all instrument multipliers.

4. Verify that current transformer and voltage transformer secondary circuits are intact.

3.5.1.4 Grounding System

a. Visual and Mechanical Inspection

1. Inspect ground system for compliance with contract plans and specifications.

b. Electrical Tests

1. Perform ground-impedance measurements utilizing the fall-of-potential method. On systems consisting of interconnected ground rods, perform tests after interconnections are complete. On systems consisting of a single ground rod perform tests before any wire is connected. Take measurements in normally dry weather, not less than 48 hours after rainfall. Use a portable ground testing megger in accordance with manufacturer's instructions to test each ground or group of grounds. The instrument shall be equipped with a meter reading directly in ohms or fractions thereof to indicate the ground value of the ground rod or grounding systems under test.

2. Submit the measured ground resistance of each ground rod or grounding system, indicating the location of the rod or grounding system. Include the test method and test setup (i.e., pin location) used to determine ground resistance and soil conditions at the time the measurements were made.

3.5.2 Protective Relays

Protective relays shall be visually and mechanically inspected, adjusted, tested, and calibrated in accordance with the manufacturer's published instructions. Tests shall include pick-up, timing, contact action, restraint, and other aspects necessary to ensure proper calibration and operation. Relay settings shall be implemented as directed by the Contracting Officer. Relay contacts shall be manually or electrically operated to verify that the proper breakers and alarms initiate. Relaying current transformers shall be field tested in accordance with IEEE C57.13.

3.5.3 Pre-Energization Services

Calibration, testing, adjustment, and placing into service of the installation shall be accomplished by a manufacturer's product field service engineer or independent testing company with a minimum of 2 years of current product experience. The following services shall be performed subsequent to testing but prior to the initial energization. The equipment shall be inspected to ensure that installation is in compliance with the recommendations of the manufacturer and as shown on the detail drawings. Terminations of conductors at major equipment shall be inspected to ensure the adequacy of connections. Bare and insulated conductors between such terminations shall be inspected to detect possible damage during installation. If factory tests were not performed on completed assemblies, tests shall be performed after the installation of completed assemblies. Components shall be inspected for damage caused during installation or shipment to ensure packaging materials have been removed. Components capable of being both manually and electrically operated shall be operated manually prior to the first electrical operation. Components capable of being calibrated, adjusted, and tested shall be calibrated, adjusted, and tested in accordance with the instructions of the equipment manufacturer.

3.5.4 Follow-Up Verification

Upon completion of acceptance checks, settings, and tests, the Contractor shall show by demonstration in service that circuits and devices are in

good operating condition and properly performing the intended function. Test shall require each item to perform its function not less than three times. As an exception to requirements stated elsewhere in the contract, the Contracting Officer shall be given 5 working days' advance notice of the dates and times for checks, settings, and tests.

3.6 Special Testing for Seismic-Resisting Equipment

Equipment is required to remain operational after an earthquake will be seismic qualified by shake table testing conforming to ICC ES AC156 Shake Table Test procedures. The manufacturer is to provide a certification by a fully qualified testing agency for the specific equipment and/or components. Prequalified certifications are acceptable unless noted otherwise. Seismic component qualification documentation for each piece of equipment must contain the information required in UFC 3-301-02, Section 2-17.2.5 Component Qualification Documentation. Miscellaneous components that are required to be certified must bear permanent marking or nameplates constructed of a durable heat and water resistant material. Nameplates must be mechanically attached to such nonstructural components and placed on each component for clear identification. The nameplate must not be less than 5 inches by 7 inches with red letters 1-inch in height on a white background stating "Certified Equipment". The following statement must be on the nameplate: "This equipment/component is certified. No modifications are allowed unless authorized in advance and documented in the Equipment Certification Documentation file." The nameplate must also contain the component identification number in accordance with the drawings/specifications and the O&M manuals.

3.7 Special Inspection for Seismic-Resisting Systems and Equipment

Perform special inspections for seismic-resisting systems, equipment and components for structures assigned to Risk Category IV per Section 01 45 35 SPECIAL INSPECTIONS.

-- End of Section --