BID ADDENDUM #1
March 4, 2022

To:
Prospective Bidders/Planholders

ELECTRICAL VAULT RELOCATION
PROJECT NUMBER CSUSTRFP20111
California State University Stanislaus
One University Circle, Turlock, CA 95382

This Addendum forms a part of the contract documents and modifies the original bidding documents. Addendum shall be noted as received and acknowledged on the Bid Proposal Form when submitted as outlined in the Bid Package referenced above.

The following corrections, additions, deletions, and/or modifications to the above package, by this reference, shall be incorporated therein:

Addition:

• Drawing E1.2: Incorporated changes for fiber optic cabling into corporation building, see changes in Delta #1 revision cloud.
• Drawing E2.12: Incorporated changes for pathway and fiber optic cabling into corporation building, see changes in Delta #1 revision cloud.
• Section 01 11 11, incorporate paragraph 1.01.A.2:

  2. The new 12kV network shall maintain consistent phasing throughout the system as such that both existing vacuum breakers and all looped switched are closed to fail over and isolation faults. Phase rotation will need to be addressed at the existing distribution transformers throughout the campus. For the purposes of this scope the ethernet network shall be fully configured with all relays and device configured and addressed on the network, however no communication between the relays will be required.

• Section 26 13 13, revise paragraph 2.02.D in its entirely as follows:

  D. **SCADA ready** configuration, in addition to the base configuration above provide the following Add electrically operated vacuum switches on the (2) non-fused switched ways at 120Vac.

    1. Single PT transformer for control new SCADA relays and UPS on the main bus.
    2. For each motorized switch, provide control via a SEL-751 relay with SEL-RPM (or equal) supply.
    3. The SEL-751 shall have the following features:

      a. Reclosing, Directional, and Arc Sense
      b. 2X16 LCD with (8) Pushbuttons
      c. 110-250Vdc power supply
d. 125Vdc/Vac digital input voltaje

e. Dual 100B-FX MM LC Ethernet Ports

f. IEC 61850 Protocol enabled

g. Ethernet/IP Protocol enabled

h. (2x) 4DO/4D1 Form A relays at 125Vdc/Vac

4. Incorporate 120Vac distribution to (2) motorized switches for manual/automatic control.

5. Relay and related controls to reside on the end of the switchgear to accommodate a new relay and UPS cabinet.

6. SEL SEL-2740S (Part #2740S#C8DH with 8 100BASE-FX MM fiber ports) or equal network switch

   a. Modular Hardware. Modular hardware design shall permit repair or reconfiguration of the switch through the use of hot-swappable, field-replaceable modules

   b. SNMP. The front and back ports of the switch shall support SNMP v2c and SNMPv3.


   d. OpenFlow Support. The switch shall support OpenFlow 1.3.

   e. Reduction of Complexity. The switch shall not support traditional networking; this allows for a reduction of the code base, resulting in less overhead for patch management and administrative configuration.


   g. Activity Indications. The switch shall support local indications of traffic activity.

   h. Self-Discovery and Topology Management. The switch shall support self-discovery of the flow controller and shall be able to bind with the controller without local commissioning steps.

   i. Flow Table and Group Support. The switch shall support 8,000 flow entries and 256 group entries.

   j. Secure Flow Controller Communications. The switch shall only support secure communications with the flow controller.

   k. Flow Retention Through Power Cycles. The switch shall maintain all flows, groups, and meters through a power cycle without the need for the flow controller to be online.

   l. Secure Firmware Upgrading. The switch shall support authentication of firmware through digital signatures.

   m. Network Time Protocol (NTP) Time Synchronization and Distribution. The switch shall be able to perform as an NTP client.


   o. Dual Power Supply. The switch shall have a redundant power supply option.

   p. Logging. The switch shall log events locally and forward them to both the flow controller and remote syslog servers with the ability to send logs through acknowledged and secure transport.
q. Reliability. The vendor shall supply the actual measured mean time between failures (MTBF) for the switch upon request.

r. Service. The switch shall include no-cost technical support for the life of the product.

s. Manufacturer. The switch shall be manufactured in the U.S.A.

t. Conformal Coating. The switch shall have optional conformal coating to protect the circuit boards from harsh environments.

u. Warranty Return. The vendor will endeavor to support a 72-hour turnaround on all warranty repairs.

v. Warranty. The switch shall include a ten-year warranty for all material and workmanship defects

7. Provide an APC SUA500PDR APC DIN Rail - Panel Mount UPS with High Temperature Batteries or equal. UPS to have relay outputs for AC power fail and battery fault/failure. The UPS will power the network switch as well as supply a source on the SEL-RPM

8. Provide the following functionality
   a. Each SEL-751 relay to operate each switch as follows:
      1) Open upon detection of a fault.
      2) Remote command from future SCADA
   b. For each fused switch way series, parallel the (3) SEL-ARDs onto a single discrete input to monitor via future SCADA.
   c. One SEL-751 discrete input to monitor network switch status
   d. Two SEL-751 discrete inputs to monitor network switch UPS AC power and battery fail.

Please also see three new attachments.
   • 2022 03 02 440 CSUS 12kv Switchgear Replacement at Various – Addendum-01.pdf
   • 26 05 53 Electrical Identification
   • 26 08 00 Electrical Testing

End of Addenda No. 1
SECTION 26 05 53

ELECTRICAL IDENTIFICATION

PART 1 GENERAL

1.01 SUMMARY

A. Section includes requirements for:
   1. Identifying electrical, instrumentation, and process equipment and components.

B. Related Sections:
   1. Contract Documents are a single integrated document, and as such all Divisions and Sections apply. It is the responsibility of the CONTRACTOR and its subcontractors to review all sections to ensure a complete and coordinated project.

1.02 REFERENCES

A. Refer to Section 26 05 00.

1.03 DEFINITIONS

A. Refer to Section 26 05 00.

1.04 SYSTEM DESCRIPTION

A. Nameplates:
   1. Provide a nameplate for each control device or major item of electrical equipment, either located in the field or within panels.
   2. Provide all nameplates of identical style, color, and material throughout the facility.
   3. Device nameplates information:
      a. Designations as indicated on the Drawings and identified on the Process and Instrumentation Drawings.
      b. Device tag and loop number ID (e.g. EDV-60.0101.01).
      c. Circuit ID (e.g. LPA-11).
      d. Area served (e.g. Lighting Chemical Building).

B. Wire Numbers:
   1. Coordinate the wire numbering system with all vendors of equipment so that every field wire has a unique number associated with it for the entire system:
      a. Wire numbers shall correspond to the wire numbers on the control drawings or the panel and circuit numbers for receptacles and lighting.
      b. Wire numbers shall correspond to the terminal block number to which they are attached in the control panel.
      c. Internal panel wires on a common terminal shall have the same wire number.
d. All instrumentation cables shall be identified at pull points as described above.

2. Provide the following wiring numbering schemes throughout the project for field wires between Process Control Module, (PCM), Vendor Control Panels, (VCP), Motor Control Centers, (MCC), field starters, field instruments, etc.

\[
\text{WHERE:} \\
\text{ORIGIN LOC.} = \text{Designation for originating panel or device} \\
\text{ORIGIN TERM.} = \text{Terminal designation at originating panel or device} \\
\text{DEST. LOC.} = \text{Designation for destination panel or device} \\
\text{DEST. TERM.} = \text{Terminal designation at destination panel or device or PLC I/O address at destination panel}
\]

a. Identify equipment and field instruments as the origin.
b. PCM's are always identified as the destination.
c. Location is the panel designation for VCP, LCP, or PCM. For connections to MCC's, location is the specific starter tag and loop number. Location is the tag and loop number for motor starters, field instruments and equipment. Any hyphen in the panel designation or tag and loop number shall be omitted.
d. Terminal designation is the actual number on the terminal block where the conductor terminates at field devices and vendor control panels. For multiconductor cables, all terminal numbers shall be shown, separated by commas.
e. Terminal designations at motor leads shall be the motor manufacturer's standard terminal designation (e.g. T1, T2, T3, etc.).
f. Terminal designations at PCM's where the field conductor connects to a PLC input or output shall be the PLC address (Note: the following PLC I/O numbering scheme is typical for Allen Bradley, the numbering scheme should be modified to match that of the actual PLC manufacturer used for the project):

1) Discrete Point: \text{W:X:Y/Z} \\
2) Analog Point: \text{W:X:Y.Z}

Where:
\text{W} = I \text{ for input, O for output} \\
\text{X} = \text{PLC number (1, 2, 3...)} \\
\text{Y} = \text{Slot number (01, 02, 03...)} \\
\text{Z} = \text{Terminal number (00,01,02...) for a discrete point or a word number for an analog point (1,2,3...)}
g. Terminal designations at PCM's where the conductor does not connect
to a PLC I/O point shall be the terminal number with a “C” prefix (e.g. 010). For common power after a fuse or neutrals after a switch, the subsequent points shall have an capital letter suffix starting with “A” (e.g., C0010A).

3. **Case 1**: Vendor Control Panel (VCP) to Process Control Module (PCM):
   Field Wire Number/Label: A-B/C-D
   - A = Vendor Control Panel number without hyphen (VCP60.0101.01)
   - B = Terminal number within VCP (manufacturer’s or vendor’s standard terminal number)
   - C = Process Control Module number without hyphen (PCM60.0101)
   - D = Either the PLC address if the field terminal is connected directly to a PLC input or output point or the terminal number with a “C” prefix if not connected directly to a PLC I/O point (C0010)

   Examples: VCP60.0101.01-10/PCM60.0101-I:1:01/01
               VCP60.0101.01-10/PCM60.0101-O:1:10/07
               VCP60.0101.01-10/PCM60.0101-C0100

4. **Case 2**: Field Instrument to Process Control Module (PCM):
   Field Wire Number/Label: E-F/C-D
   - C = Process Control Module number without hyphen (PCM60.0101)
   - D = Either the PLC address if the field terminal is connected directly to a PLC input or output point or the terminal number with a “C” prefix if not connected directly to a PLC I/O point (C0010)
   - E = Field mounted instrument tag and loop numbers without hyphen (EDV60.0101.01)
   - F = Manufacturer’s standard terminal number within instrument. Use both terminal numbers for analog points separated by a comma

   Examples: TIT60.0101.01-2,3/PCM60.0101-I:1:01.1
               TSH60.0101-1/PCM60.0101-I:2:01/00

5. **Case 3**: Motor Control Center (MCC) to Process Control Module (PCM):
   Field Wire Number/Label: G-B/C-D
   - B = Terminal number within Motor Control Center (manufacturer’s or vendor’s standard terminal number)
   - C = Process Control Module number without hyphen (PCM60.0101)
   - D = Either the PLC address if the field terminal is connected directly to a PLC input or output point or the terminal number with a “C” prefix if not connected directly to a PLC I/O point (C0010)
   - G = Actual starter designation in the Motor Control Center without hyphen (MMS60.0101)

   Examples: MMS60.0101-10/PCM60.0101-I:1:01/01
               MMS60.0101-10/PCM60.0101-O:1:10/07
               MMS60.0101-10/PCM60.0101-C0100

6. **Case 4**: Motor Control Center (MCC) to Vendor Control Panel (VCP):
   Field Wire Number/Label: G-B/A-B
   - A = Vendor Control Panel number without hyphen (VCP60.0101.01)
B = Terminal number within motor control center or vendor control panel (manufacturer's or vendors standard terminal number)

G = Actual starter designation in the Motor Control Center without hyphen (MMS60.0101)

Example: MMS60.0101-X2/VCP60.0101.01-10

7. **Case 5**: Motor leads to a Motor Control Center (MCC): Field Wire Number/Label: H-I/G-B

    B = Terminal number within motor control center (manufacturer's standard terminal number)
    G = Actual starter designation in the Motor Control Center without hyphen (MMS60.0101)
    H = Equipment tag and loop number without hyphen (PMP60.0101.01)
    I = Motor manufacturer's standard motor lead identification (e.g., T1, T2, T3, etc.)

Example: PMP-60.0101.01-T3/MMS60.0101.01-T3

8. **Case 6**: Remote or separately mounted starter or Variable Frequency Drive (VFD) to Process Control Module (PCM): Field Wire Number/Label: J-B/C-D

    B = Terminal number within starter or Variable Frequency Drive (manufacturer's standard terminal number)
    C = Process Control Module number without hyphen (VCP60.0101.01)
    D = Either the PLC address if the field terminal is connected directly to a PLC input or output point or the terminal number with a “C” prefix if not connected directly to a PLC I/O point (C0010)
    J = Starter or Variable Frequency Drive tag and loop number without hyphen (MMS60.0101)

Examples: MMS60.0101-10/PCM60.0101.01-I:1:01/01
          MMS60.0101-10/PCM60.0101.01-O:2:10/07
          MMS60.0101-10/PCM60.0101.01-C0010

9. Terminate all spare conductors on terminal blocks and identify as required for other field wires with an “S” prefix:

Example: S MMS60.0101-10/PCM60.0101.01-C011

1.05 **SUBMITTALS**

A. Furnish submittals in accordance with Sections 01 33 00 and 26 05 00.

B. Product Data:

1. **Nameplates**:
   a. Color.
   b. Size:
      1) Outside dimensions.
      2) Lettering.
   c. Material.
   d. Mounting means.

2. **Nameplate Schedule**:
Project Number: 20-357

Project Name: ELECTRICAL VAULT RELOCATION

a. Show exact wording for each nameplate.
b. Include nameplate and letter sizes.
3. Wire Numbers:
   a. Manufacturer's catalog data for wire labels and label printer.

C. Record Documents:
   1. Update the conduit schedule to reflect the exact quantity of wire numbers including spares and destination points for all wires.

1.06 QUALITY ASSURANCE

A. Schedule a pre-installation conference in accordance with Sections 01 43 00 and 26 05 00 in order to clearly define the requirements specified for equipment identification:
   1. Representatives of the CONTRACTOR, OWNER, and ENGINEER shall convene before any major purchases of cable or conductors and before the installation or termination of any cables or conductors.

1.07 DELIVERY, STORAGE, AND HANDLING

A. Refer to Section 26 05 00.

1.08 WARRANTY

A. Refer to Section 26 05 00.

1.09 SYSTEM START UP

A. Refer to Section 26 05 00.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Nameplates and Signs:
   1. One of the following or equal:
      a. Brady.
      b. Seton.

B. Conductor and Cable Markers:
   1. Heat-shrinkable tubing:
      a. One of the following or equal:
         1) Raychem.
         2) Brady.
         3) Thomas & Betts.
         4) Kroy.

C. Conduit and Raceway Markers:
   1. One of the following or equal:
      b. Lapp Group: Maxi System
D. Medium Voltage Raceway Voltage Labels:
   1. One of the following or equal:
      a. Brady.
      b. Seton.

2.02 MATERIALS

A. Nameplates:
   1. Fabricated from white-center and red or black face laminated plastic engraving stock:
      a. 3/32-inch thick material.
      b. Two-ply.
      c. With chamfered edges.
      d. Block style engraved characters of adequate size to be read easily from a distance of 6 feet:
         1) No characters smaller than 1/8-inch in height.

B. Signs:
   1. Automatic equipment and high voltage signs:
      a. Suitable for exterior use.
      b. In accordance with OSHA regulations.

C. Conductor and Cable Markers:
   1. Machine printed black characters on white tubing.
   2. Ten point type or larger.

D. Conduit and Raceway Markers:
   1. UV resistant holder and letters.
   2. Black letters on yellow background.
   3. Minimum 1/2-inch high letters.

E. Medium Voltage Circuit Raceway Labels:
   1. Vinyl plastic.
   2. Minimum 1-inch high letters.

2.03 SOURCE QUALITY CONTROL

A. Nameplates:
   1. Provide all nameplates for control panel operator devices (e.g. pushbuttons, selector switches, pilot lights, etc.):
      a. Same material and same color and appearance as the device nameplates, in order to achieve an aesthetically consistent and coordinated system.

PART 3 EXECUTION

3.01 INSTALLATION

A. Refer to Section 26 05 00.
B. Nameplates:
1. Attach nameplates to equipment with rivets, bolts or sheet metal screws, approved waterproof epoxy-based cement or install in metal holders welded to the equipment.
2. On NEMA 4 or NEMA 4X enclosures, use epoxy-based cement to attach nameplates.
3. Nameplates shall be aligned and level or plumb to within 1/64 inch over the entire length:
   a. Misaligned or crooked nameplates shall be remounted, or provide new enclosures at the discretion of the ENGINEER.

C. Conductor and Cable Markers:
1. Apply all conductor and cable markers before termination.
2. Heat-shrinkable tubing:
   a. Tubing shall be shrunk using a heat gun that produces low temperature heated air.
   b. Tubing shall be tight on the wire after it has been heated.
   c. Characters shall face the open panel and shall read from left to right or top to bottom.
   d. Marker shall start within 1/32 inch of the end of the stripped insulation point.

D. Conduit Markers:
1. Furnish and install conduit markers for every conduit in the electrical system that is identified in the conduit schedule or part of the process system:
   a. Conduit markings shall match the conduit schedule; refer to Section 26 05 53.
2. Mark conduits at the following locations:
   a. Each end of conduits that are greater than 10 feet in length.
   b. Where the conduit penetrates a wall or structure.
   c. Where the conduit emerges from the ground, slab, etc.
   d. The middle of conduits that are 10 feet or less in length.
3. Mark conduits after the conduits have been fully painted.
4. Position conduit markers so that they are easily read from the floor.
5. Secure all conduit markers with nylon cable ties:
   a. Provide with ultraviolet resistant cable ties for conduit markers exposed to direct sunlight.
   b. Adhesive labels are not acceptable.
6. Mark conduits before construction review by ENGINEER for punch list purposes.

E. Medium Voltage Raceway Labels:
1. Apply at 50 foot intervals stating the voltage level contained within the raceway.

F. Signs and Labeling:
1. Furnish and install permanent warning signs at mechanical equipment that may be started automatically or from remote locations:
   a. Fasten warning signs with round head stainless steel screws or bolts.
   b. Locate and mount in a manner to be clearly legible to operations personnel.
2. Furnish and install permanent and conspicuous warning signs on equipment (front and back), doorways to equipment rooms, pull boxes, manholes, etc. where the voltage exceeds 600 volts.

3. Furnish and install warning signs on equipment that has more than one source of power.
   a. Warning signs to identify every panel and circuit number of the disconnecting means of all external power sources.

4. Place warning signs on equipment that has 120 VAC control voltage source used for interlocking.
   a. Identify panel and circuit number or conductor tag for control voltage source disconnecting means.

3.02 FIELD QUALITY CONTROL

A. Replace any nameplates, signs, conductor markers, cable markers, or raceway labels that in the sole opinion of the ENGINEER do not meet the ENGINEER’s aesthetic requirements.

END OF SECTION
MAINTENANCE AND TESTING OF ELECTRICAL SYSTEMS

PART 1 — GENERAL

1.01 SUMMARY

A. Section includes

1. Provide all labor, materials and equipment necessary to complete the installation required for the items specified under this Section, including but not limited to electrical system testing and maintenance.

B. Related sections

1. Where items specified in other Division 26 sections conflict with the requirements of this Section, the most stringent requirement shall govern.

2. The requirements of this Section apply to all Division 16 work, as applicable.

3. Consult all other sections, determine the extent and character of related work and properly coordinate work specified herein with that specified elsewhere to produce a complete installation.

1.02 REFERENCES

A. Comply with the latest edition of the following applicable specifications and standards except as otherwise shown or specified:

1. ASTM International – ASTM
   a. ASTM D 92; Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester
   b. ASTM D 445; Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (the Calculation of Dynamic Viscosity)
   c. ASTM D 664; Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration
   d. ASTM D 877; Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids using Disk Electrodes
   e. ASTM D 923; Standard Practices for Sampling Electrical Insulating Liquids
   f. ASTM D 924; Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids
   g. ASTM D 971; Standard Test Method for Interfacial Tension of Oil against Water by the Ring Method
h. ASTM D 974; Standard Test Method for Acid and Base Number by Color-Indicator Titration

i. ASTM D 1298; Standard Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method

j. ASTM D 1500; Standard Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)

k. ASTM D 1524; Standard Test Method for Visual Examination of Used Electrical Insulating Oils of Petroleum Origin in the Field

l. ASTM D 1533; Standard Test Methods for Water in Insulating Liquids by Coulometric Karl Fischer Titration

m. ASTM D 1816; Standard Test Method for Dielectric Breakdown Voltage of Insulating Oils of Petroleum Origin Using VDE Electrodes

n. ASTM D 2029; Standard Test Methods for Water Vapor Content of Electrical Insulating Gases by Measurement of Dew Point

o. ASTM D 2129; Standard Test Method for Color of Clear Electrical Insulating Liquids (Platinum-Cobalt Scale)

p. ASTM D 2284; Standard Test Method of Acidity of Sulfur Hexafluoride

q. ASTM D 2285; Standard Test Method for Interfacial Tension of Electrical Insulating Oils of Petroleum Origin against Water by the Drop-Weight Method

r. ASTM D 2477; Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Insulating Gases at Commercial Power Frequencies

s. ASTM D 2685; Standard Test Method for Air and Carbon Tetrafluoride in Sulfur Hexafluoride by Gas Chromatography

t. ASTM D 2759; Standard Practice for Sampling Gas from a Transformer under Positive Pressure

u. ASTM D 3284; Standard Test Method for Combustible Gases in the Gas Space of Electrical Apparatus Using Portable Meters

v. ASTM D 3612; Standard Test Method for Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography

w. ASTM D 3613; Standard Practice for Sampling Electrical Insulating Oils for Gas Analysis and Determination of Water Content

2. Electrical Apparatus Service Association – EASA
   a. ANSI/EASA AR100; Recommended Practice for the Repair of Rotating Electrical Apparatus

3. Institute of Electrical and Electronic Engineers – IEEE
   a. ANSI/IEEE C2; National Electrical Safety Code
   b. ANSI/IEEE C37 Compilation; Guides and Standards for Circuit Breakers, Switchgear, Relays, Substations, and Fuses
c. ANSI/IEEE C57 Compilation; Distribution, Power, and Regulating Transformers

d. ANSI/IEEE C62 Compilation; Surge Protection

e. ANSI/IEEE 43; IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery

f. ANSI/IEEE 48; IEEE Standard Test Procedures and Requirements for Alternating-Current Cable Terminations 2.5 kV through 765 kV

g. IEEE 81; IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System Part I: Normal Measurements

h. ANSI/IEEE 81.2; IEEE Guide for Measurement of Impedance and Safety Characteristics of Large, Extended or Interconnected Grounding Systems

i. ANSI/IEEE 95; IEEE Recommended Practice for Insulation Testing of Large AC Rotating Machinery with High Direct Voltage

j. IEEE 100; The Authoritative Dictionary of IEEE Standards Terms

k. IEEE 141; IEEE Recommended Practice for Electrical Power Distribution for Industrial Plants (Red Book)

l. ANSI/IEEE 142; IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (Green Book)

m. ANSI/IEEE 241; IEEE Recommended Practice for Electric Power Systems in Commercial Buildings (Gray Book)

n. ANSI/IEEE 242; IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (Buff Book)

o. IEEE 386; IEEE Standard for Separable Insulated Connectors System for Power Distribution Systems above 600 V

p. ANSI/IEEE 399; IEEE Recommended Practice for Power Systems Analysis (Brown Book)

q. IEEE 400; IEEE Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems

r. ANSI/IEEE 421.3; IEEE Standard for High-Potential-Test Requirements for Excitation Systems for Synchronous Machines

s. ANSI/IEEE 446; IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (Orange Book)

t. ANSI/IEEE 450; IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications

u. ANSI/IEEE 493; IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (Gold Book)
v. ANSI/IEEE 519; IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
w. ANSI/IEEE 602; IEEE Recommended Practice for Electric Systems in Health Care Facilities (White Book)
x. ANSI/IEEE 637; IEEE Guide for the Reclamation of Insulating Oil and Criteria for Its Use
y. IEEE 644; Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines
z. ANSI/IEEE 739; IEEE Recommended Practice for Energy Management in Commercial and Industrial Facilities (Bronze Book)
bb. IEEE 1015; IEEE Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems (Blue Book)
c. IEEE 1100; IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (Emerald Book)
dd. ANSI/IEEE 1106; IEEE Recommended Practice for Maintenance, Testing, and Replacement of Nickel-Cadmium Batteries for Stationary Applications
e. ANSI/IEEE 1159; IEEE Recommended Practice on Monitoring Electrical Power Quality
ff. ANSI/IEEE 1188; IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications

4. Insulated Cable Engineers Association – ICEA
   a. ANSI/ICEA S-93-639/NEMA WC 74
   b. 5-46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy
c. ANSI/ICEA S-94-649
d. Standard for Concentric Neutral Cables Rated 5,000 – 46,000 Volts
e. ANSI/ICEA S-97-682

5. InterNational Electrical Testing Association – NETA
   a. ANSI/NETA ETT; Standard for Certification of Electrical Testing Technicians
   b. ANSI/NETA ATS; Acceptance Testing Specifications for Electrical Power Equipment and Systems

6. National Electrical Manufacturers Association – NEMA
   a. NEMA AB4; Guidelines for Inspection and Preventive Maintenance of Molded-Case Circuit Breakers Used in Commercial and Industrial Applications
b. ANSI/NEMA C84.1; Electrical Power Systems and Equipment Voltage Ratings (60 Hz)

c. NEMA MG1; Motors and Generators


a. ANSI/NFPA 70; National Electrical Code

b. ANSI/NFPA 70B; Recommended Practice for Electrical Equipment Maintenance

c. ANSI/NFPA 70E; Standard for Electrical Safety in the Workplace

d. ANSI/NFPA 99; Standard for Healthcare Facilities

e. ANSI/NFPA 101; Life Safety Code

f. ANSI/NFPA 110; Emergency and Standby Power Systems

g. ANSI/NFPA 780; Installation of Lightning Protection Systems

1.03 SYSTEM DESCRIPTION

A. These specifications cover the suggested field tests and inspections that are available to assess the suitability for continued service and reliability of electrical power distribution equipment and systems.

B. The purpose of these specifications is to assure that tested electrical equipment and systems are operational, are within applicable standards and manufacturer’s tolerances, and are suitable for continued service.

C. The work specified in these specifications may involve hazardous voltages, materials, operations, and equipment. These specifications do not purport to address all of the safety problems associated with their use. It is the responsibility of the user to review all applicable regulatory limitations prior to the use of these specifications.

1.04 QUALIFICATIONS

A. While technicians performing tests and inspections on new equipment deal with finite test values, those working with service-aged equipment must form recommendations based on judgment.

B. Technicians performing these electrical tests and inspections shall be trained and experienced concerning the apparatus and systems being evaluated. These individuals shall be capable of conducting the tests in a safe manner and with complete knowledge of the hazards involved. They must be able to evaluate the test data and make a judgment on the continued serviceability or non-serviceability of the specific equipment.

C. Test technicians shall have knowledge of and experience with the specific device under test. Additional personnel qualifications are as follows:

1. Testing Company/Organization: The company shall have an on-site crew leader shall hold a current certification, Level III or higher, in electrical testing. This certification shall be in accordance with ANSI/NETA ETT-2010, Standard for Certification of Electrical Testing Personnel.
2. Manufacturers’ Service Personnel: Field service personnel of the manufacturer of the equipment being evaluated shall be certified by the manufacturer to perform these electrical tests and inspections. The manufacturer shall provide sufficient documentation to satisfy the owner that its service personnel are trained and qualified to perform these electrical tests and inspections.

1.05 SUBMITTALS

A. A written test report shall be submitted to the County after completion of tests. The test report shall be written in accordance with the test report section of NETA MTS. In addition, the test report shall include:

1. All the fields noted in NFPA 70B – Low-voltage circuit breaker five year test form plus additional fields as required to document all the test results.
2. Manufacturer and model of the test equipment used and the date the test equipment was last calibrated.

1.06 RESPONSIBILITIES

A. Owner’s

1. The Owner shall be responsible for all power switching of equipment and for providing equipment in a ready-to-test condition. The Owner shall provide the testing organization with the following:

   a. A short-circuit analysis, a coordination study, an arc-flash hazard analysis, and a protective device setting sheet if applicable.
   b. If available, the most current set of electrical drawings and instruction manuals applicable to the scope of work relative to the equipment under test.
   c. An itemized description of equipment to be inspected and tested.
   d. A determination of who shall provide a suitable and stable source of electrical power to each test site.
   e. Notification of when equipment becomes available for maintenance tests. Work shall be coordinated to expedite project scheduling.
   f. Site-specific hazard notification and safety training.

B. Contractor/Testing Organization

1. The testing organization shall provide the following:

   a. All field technical services, tooling, equipment, instrumentation, and technical supervision to perform such tests and inspections.
   b. Specific power requirements for test equipment.
   c. Notification to the owner’s representative prior to commencement of any testing.
   d. A timely notification of any system, material, or workmanship which is found deficient on the basis of maintenance tests.
1.07 GENERAL

A. Safety and Precautions

1. All parties involved must be cognizant of industry-standard safety procedures. This document does not include any procedures, including specific safety procedures. It is recognized that an overwhelming majority of the tests and inspections recommended in these specifications are potentially hazardous. Individuals performing these tests shall be capable of conducting the tests in a safe manner and with complete knowledge of the hazards involved.

a. Safety practices shall include, but are not limited to, the following requirements:

1) All applicable provisions of the Occupational Safety and Health Act, particularly OSHA 29CFR 1910.

2) ANSI/NFPA 70E, Standard for Electrical Safety in the Workplace


4) Applicable state and local safety operating procedures.

5) Owner’s safety practices.

b. A safety lead person shall be identified prior to commencement of work.

c. A safety briefing shall be conducted prior to the commencement of work.

d. All tests shall be performed with the apparatus de-energized and grounded except where otherwise specifically required to be ungrounded or energized for certain tests.

e. The testing organization shall have a designated safety representative on the project to supervise operations with respect to safety.

B. Suitability of Test Equipment

1. All test equipment shall meet the requirements below and be in good mechanical and electrical condition.

2. Field test metering used to check power system meter calibration must be more accurate than the instrument being tested.

3. Accuracy of metering in test equipment shall be appropriate for the test being performed.

4. Waveshape and frequency of test equipment output waveforms shall be appropriate for the test and the tested equipment.

C. Test Instrument Calibration
1. The testing organization shall have a calibration program which assures that all applicable test instruments are maintained within rated accuracy for each test instrument calibrated.

2. The firm providing calibration service shall maintain up-to-date instrument calibration instructions and procedures for each test instrument calibrated.

3. The accuracy shall be directly traceable to the National Institute of Standards and Technology (NIST).

4. Instruments shall be calibrated in accordance with the following frequency schedule:
   a. Field instruments: Analog and digital, 12 months maximum.
   b. Laboratory instruments: 12 months maximum.
   c. Leased specialty equipment: 12 months maximum.

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

6. Records, which show date and results of instruments calibrated or tested, must be kept up-to-date.

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

D. Test Report

1. The test report shall include the following:
   a. Summary of project.
   b. Description of equipment tested.
   c. Description of tests.
   d. Test data.
   e. Analysis and recommendations.

2. Test data records shall include the following minimum requirements:
   a. Identification of the testing organization.
   b. Equipment identification.
   c. Humidity, temperature, and other conditions that may affect the results of the tests/calibrations.
   d. Date of inspections, tests, maintenance, and/or calibrations.
   e. Identification of the testing technician.
   f. Indication of inspections, tests, maintenance, and/or calibrations to be performed and recorded.
   g. Indication of expected results when calibrations are to be performed.
   h. Indication of “as-found” and “as-left” results, as applicable.
   i. Sufficient spaces to allow all results and comments to be indicated.
3. The testing organization shall furnish a copy or copies of the complete report as specified in the maintenance testing contract.

PART 2 — PRODUCTS


PART 3 — EXECUTION

3.01 ELECTRICAL EQUIPMENT & COMPONENTS

A. Switchgear and Switchboard Assemblies

1. Visual and Mechanical Inspection
   a. Inspect physical, electrical, and mechanical condition including evidence of moisture or corona.
   b. Inspect anchorage, alignment, grounding, and required area clearances.
   c. Prior to cleaning the unit, perform as-found tests, if required.
   d. Clean the unit.
   e. Verify that fuse and/or circuit breaker sizes and types correspond to drawings and coordination study as well as to the circuit breaker’s address for microprocessor-communication packages.
   f. Verify that current and voltage transformer ratios correspond to drawings.
   g. Inspect bolted electrical connections for high resistance using one or more of the following methods:
      1) Use of a low-resistance ohmmeter in accordance with 3.01.A.2. below.
      2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.
      3) Perform a thermographic survey in accordance with Section 3.03.
   h. Confirm correct operation and sequencing of electrical and mechanical interlock systems.
      2) Make key exchange with all devices included in the interlock scheme as applicable.
   i. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
   j. Verify correct barrier and shutter installation and operation.
   k. Exercise all active components.
l. Inspect mechanical indicating devices for correct operation.

m. Verify that filters are in place and/or vents are clear.

n. Perform visual and mechanical inspection of instrument transformers in accordance with Section 3.01.M.

o. Inspect control power transformers.
   1) Inspect for physical damage, cracked insulation, broken leads, tightness of connections, defective wiring, and overall general condition.
   2) Verify that primary and secondary fuse ratings or circuit breakers match drawings.
   3) Verify correct functioning of draw-out disconnecting and grounding contacts and interlocks.

p. Perform as-left tests.

2. Electrical Tests

a. Perform resistance measurements through bolted electrical connections with a low-resistance ohmmeter in accordance with Section 3.01.A.1, if applicable.

b. Perform insulation–resistance tests for one minute on each bus section, phase-to-phase and phase-to-ground. Apply voltage in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.1.

c. Perform electrical tests on instrument transformers in accordance with Section 3.01.M.

d. Perform ground–resistance tests in accordance with Section 3.01.N.

e. Control Power Transformers
   1) Perform insulation-resistance tests. Perform measurements from winding-to-winding and each winding-to-ground. Test voltages shall be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.1.

   2) Verify correct function of control transfer relays located in switchgear with multiple power sources.

f. Verify operation of switchgear/switchboard heaters and their controller, if applicable.

g. Perform system function tests in accordance with Section 3.02.

3. Test Values – Visual and Mechanical

a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

b. Bolt-torque levels should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12.
c. Results of the thermographic survey shall be in accordance with Section 3.03.

4. Test Values – Electrical
   a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
   b. Insulation-resistance values of bus insulation should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer’s recommendations should be investigated. Dielectric withstand voltage tests should not proceed until insulation-resistance levels are raised above minimum values.
   c. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the test, the test dielectric withstand voltage specimen is considered to have passed the test.
   d. Minimum insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
   e. Results of electrical tests on instrument transformers should be in accordance with Section 3.01.M.
   f. Results of ground resistance tests should be in accordance with Section 3.01.N.
   g. Control Power Transformers
      1) Insulation-resistance values of control power transformers should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer’s recommendations should be investigated.
      2) Control transfer relays should perform as designed.
   h. Heaters should be operational.
   i. Results of system function tests shall be in accordance with Section 3.02.

B. Panelboards and Loadcenters
   1. Visual and Mechanical Inspection
      a. Inspect physical, electrical, and mechanical condition including evidence of moisture or corona.
      b. Inspect anchorage, alignment, grounding, and required area clearances.
      c. Prior to cleaning the unit, perform as-found tests, if required.
      d. Clean the unit.
e. Inspect bolted electrical connections for high resistance using one or more of the following methods:

1) Use of a low-resistance ohmmeter in accordance with 3.01.B.2. below.

2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.

3) Perform a thermographic survey in accordance with Section 3.03.

f. Confirm correct operation and sequencing of electrical and mechanical interlock systems.


2) Make key exchange with all devices included in the interlock scheme as applicable.

g. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.

h. Verify correct barrier and shutter installation and operation.

i. Exercise all active components.

j. Inspect mechanical indicating devices for correct operation.

k. Perform visual and mechanical inspection of instrument transformers in accordance with Section 3.01.M.

l. Perform as-left tests.

2. Electrical Tests

a. Perform resistance measurements through bolted electrical connections with a low-resistance ohmmeter in accordance with Section 3.01.B.1, if applicable.

b. Perform insulation–resistance tests for one minute on each bus section, phase-to-phase and phase-to-ground. Apply voltage in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.1.

c. Perform ground–resistance tests in accordance with Section 3.01.N.

d. Verify operation of switchgear/switchboard heaters and their controller, if applicable.

e. Perform system function tests in accordance with Section 3.02.

3. Test Values – Visual and Mechanical

a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

b. Bolt-torque levels should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12.
c. Results of the thermographic survey shall be in accordance with Section 3.03.

4. Test Values – Electrical

a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

b. Insulation-resistance values of bus insulation should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer’s recommendations should be investigated. Dielectric withstand voltage tests should not proceed until insulation-resistance levels are raised above minimum values.

c. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the test, the test dielectric withstand voltage specimen is considered to have passed the test.

d. Results of ground resistance tests should be in accordance with Section 3.01.N.

e. Results of system function tests shall be in accordance with Section 3.02.

C. Transformers, Dry Type, Air-Cooled, Low-Voltage, Small (< 600V, and > 167 kVA single-phase or 500 kVA three-phase)

1. Visual and Mechanical Inspection.

a. Inspect physical and mechanical condition.

b. Inspect anchorage, alignment, and grounding.

c. Prior to cleaning the unit, perform as-found tests, if required.

d. Clean the unit.

e. Inspect bolted electrical connections for high resistance using one or more of the following methods:

   1) Use a of low-resistance ohmmeter in accordance with Section 3.01.C.2.

   2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.

   3) Perform a thermographic survey in accordance with Section 3.03.

f. Perform as-left tests.

g. Verify that as-left tap connections are as specified.

2. Electrical Tests

a. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 3.01.C.1.
b. Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Apply voltage in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.5. Calculate the dielectric absorption ratio or polarization index.

c. Test Values – Visual and Mechanical

1) Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

2) Bolt-torque levels should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12.

3) Results of the thermographic survey shall be in accordance with Section 3.03.

4) Tap connections are left as found unless otherwise specified.

d. Test Values – Electrical

1) Compare bolted electrical connection resistances to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

2) Minimum insulation-resistance values of transformer insulation should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer’s recommendations should be investigated. The dielectric absorption ratio or polarization index shall be compared to previously obtained results and should not be less than 1.0.

3) Turns-ratio test results should not deviate more than one-half percent from either the adjacent coils or the calculated ratio.

D. Transformers, Dry Type, Air-Cooled, Large (> 600V; and low voltage transformer ≤ 600V, and > 167 kVA single-phase or 500 kVA three-phase)

1. Visual and Mechanical Inspection

a. Inspect physical and mechanical condition including evidence of moisture and corona.

b. Inspect anchorage, alignment, and grounding.

c. Prior to cleaning the unit, perform as-found tests, if required.

d. Clean the unit.

e. Verify that cooling fans operate correctly.

f. Inspect bolted electrical connections for high resistance using one or more of the following methods:
1) Use of a low-resistance ohmmeter in accordance with Section 3.01.D.2.

2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.

g. Perform a thermographic survey in accordance with Section 3.03.

h. Perform specific inspections and mechanical tests as recommended by the manufacturer.

i. Perform as-left tests.

j. Verify that as-left tap connections are as specified.

k. Verify the presence of surge arresters.

2. Electrical Tests

a. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 3.01.D.1.

b. Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Apply voltage in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.5. Calculate polarization index.

c. Perform insulation power-factor or dissipation-factor tests on all windings in accordance with the test equipment manufacturer’s published data.

d. Perform turns-ratio tests at the designated tap position.

e. Perform an excitation-current test on each phase.

f. Measure core insulation resistance at 500 volts dc if the core is insulated and if the core ground strap is removable.

g. Verify correct secondary voltage phase-to-phase and phase-to-neutral after energization and prior to loading.

h. Test surge arresters in accordance with Section 3.01.Q.

3. Test Values – Visual and Mechanical

a. Control and alarm settings on temperature indicators should operate within manufacturer’s recommendations for specified settings.

b. Cooling fans should operate.

c. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

d. Bolt-torque levels should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12.

e. Results of the thermographic survey shall be in accordance with Section 3.03.
f. Tap connections shall be left as found unless otherwise specified.

4. Test Values – Electrical
   a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
   b. Minimum insulation-resistance values of transformer insulation should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer’s recommendations should be investigated. The polarization index shall be compared to previously obtained results and should not be less than 1.0.
   c. CH and CL power-factor or dissipation-factor values will vary due to support insulators and bus work utilized on dry transformers. The following should be expected on CHL power factors:
      1) Power transformers: 2.0 percent or less Distribution transformers: 5.0 percent or less
      2) Consult transformer manufacturer’s or test equipment manufacturer’s data for additional information.
   d. Power-factor or dissipation-factor tip-up exceeding 1.0 percent should be investigated.
   e. Turns-ratio test results should not deviate more than one-half percent from either the adjacent coils or the calculated ratio.
   f. The typical excitation current test data pattern for a three-legged core transformer is two similar current readings and one lower current reading.
   g. Temperature-corrected winding-resistance values should compare within one percent of previously-obtained results.
   h. Core insulation-resistance values should be comparable to previously-obtained results but not less than one megohm at 500 volts dc.
   i. AC dielectric withstand test voltage shall not exceed 65 percent of factory test voltage for one minute duration. DC dielectric withstand test voltage shall not exceed 100 percent of the ac rms test voltage specified in ANSI C57.12.91, Section 10.2 for one minute duration. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.
   j. Phase-to-phase and phase-to-neutral secondary voltages should be in agreement with nameplate data.
   k. Test results for surge arresters shall be in accordance with Section 3.01.Q.

E. Transformers, Liquid-Filled
   1. Visual and Mechanical Inspection
a. Inspect physical and mechanical condition.
b. Inspect anchorage, alignment, and grounding.
c. Verify the presence of PCB labeling, if applicable.
d. Prior to cleaning the unit, perform as-found tests, if required.
e. Clean bushings and control cabinets.
f. Verify operation of alarm, control, and trip circuits from temperature and level indicators, pressure relief device, and fault pressure relay, if applicable.
g. Verify that cooling fans and/or pumps operate correctly.
h. Inspect bolted electrical connections for high resistance using one or more of the following methods:
   1) Use of a low-resistance ohmmeter in accordance with Section 3.01.E.2.
   2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.
   3) Perform a thermographic survey in accordance with Section 3.03.
i. Verify correct liquid level in tanks and bushings.
j. Verify that positive pressure is maintained on gas-blanketed transformers.
k. Perform inspections and mechanical tests as recommended by the manufacturer.
l. Verify the presence of transformer surge arresters.
m. Perform as-left tests.
n. Verify de-energized tap-changer position is left as specified.

2. Electrical Tests
   a. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 3.01.E.1.
   b. Perform insulation-resistance tests, winding-to-winding and each winding-to-ground. Apply voltage in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.5. Calculate polarization index.
   c. Perform turns-ratio tests at the designated tap position.
   d. Perform insulation power-factor or dissipation-factor tests on all windings in accordance with test equipment manufacturer’s published data.
   e. Perform power-factor or dissipation-factor tests on each bushing.
   f. Perform excitation-current tests in accordance with the test equipment manufacturer’s published data.
g. Measure the resistance of each winding at the designated tap position.

h. Remove a sample of insulating liquid in accordance with ASTM D 923. The sample shall be tested for the following.
   1) Dielectric breakdown voltage: ASTM D 877 and/or ASTM D 1816
   2) Acid neutralization number: ANSI/ASTM D 974
   3) Specific gravity: ANSI/ASTM D 1298
   4) Interfacial tension: ANSI/ASTM D 971 or ANSI/ASTM D 2285
   5) Color: ANSI/ASTM D 1500
   6) Visual Condition: ASTM D 1524

i. Remove a sample of insulating liquid in accordance with ASTM D 3613 and perform dissolved-gas analysis (DGA) in accordance with ANSI/IEEE C57.104 or ASTM D3612.

j. Test the instrument transformers in accordance with Section 3.01.M.

k. Test the surge arresters in accordance with Section 3.01.Q.

l. Test the transformer neutral grounding impedance devices, if applicable.

3. Test Values – Visual and Mechanical
   a. Alarm, control, and trip circuits from temperature and level indicators as well as pressure relief device and fault pressure relay should operate within manufacturer’s recommendations for their specified settings.

   b. Cooling fans and/or pumps should operate.

   c. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

   d. Bolt-torque levels should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12.

   e. Results of the thermographic survey shall be in accordance with Section 3.03.

   f. Liquid levels in the transformer tanks and bushings should be within indicated tolerances.

   g. Positive pressure should be indicated on pressure gauge for gas-blanketed transformers.

4. Test Values – Electrical
   a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
b. Minimum insulation-resistance values of transformer insulation should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer’s recommendations should be investigated. The polarization index shall be compared to previously obtained results and should not be less than 1.0.

c. Turns-ratio test results should not deviate by more than one-half percent from either the adjacent coils or the calculated ratio.

d. Maximum power-factor/dissipation-factor values of liquid-filled transformers corrected to 20° C should be in accordance with the transformer manufacturer’s published data. Representative values are indicated in Table 100.3.

e. Investigate bushing power-factor and capacitance values that vary from nameplate values by more than ten percent. Hot-collar tests are evaluated on a milliampere/milliwatt loss basis, and the results should be compared to values of similar bushings.

f. Typical excitation-current test data pattern for a three-legged core transformer is two similar current readings and one lower current reading.

g. Temperature corrected winding-resistance values should compare within one percent of previously obtained results.

h. Core insulation values should be comparable to previously obtained results but not less than one megohm at 500 volts dc.

i. Investigate the presence of oxygen in the nitrogen gas blanket.

j. Insulating liquid values should be in accordance with Table 100.4.

k. Evaluate results of dissolved-gas analysis in accordance with ANSI/IEEE Standard C57.104.

l. Results of electrical tests on instrument transformers shall be in accordance with Section 3.01.M.

m. Results of surge arrester tests shall be in accordance with Section 3.01.Q.

n. Compare grounding impedance device values to previously obtained results. In the absence of previously obtained values, compare obtained values to manufacturer’s published data.

F. Cables, Low-Voltage, 600-Volt Maximum

1. Visual and Mechanical Inspection

   a. Inspect exposed sections of cables for physical damage and evidence of overheating.

   b. Inspect bolted electrical connections for high resistance using one or more of the following methods:

      1) Use of a low-resistance ohmmeter in accordance with Section 3.01.F.2.
2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.

3) Perform a thermographic survey in accordance with Section 3.03.

c. Inspect compression-applied connectors for correct cable match and indentation.

2. Electrical Tests

a. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 3.01.F.1.

b. Perform an insulation-resistance test on each conductor with respect to ground and adjacent conductors. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. The test duration shall be one minute.

c. Verify uniform resistance of parallel conductors.

3. Test Values – Visual and Mechanical

a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

b. Bolt-torque levels should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12.

c. Results of the thermographic survey shall be in accordance with Section 3.03.

4. Test Values – Electrical

a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

b. Insulation-resistance values should be comparable to previously obtained results and similar circuits but not less than two megohms.

c. Deviations in resistance between parallel conductors shall be investigated.

G. Cables, Medium- and High-Voltage

1. Visual and Mechanical Inspection

a. Inspect exposed sections of cables for physical damage and evidence of overheating and corona.

b. Inspect terminations and splices for physical damage, evidence of overheating, and corona.

c. Inspect bolted electrical connections for high resistance using one or more of the following methods:
1) Use of a low-resistance ohmmeter in accordance with Section 3.01.G.2.

2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.

3) Perform a thermographic survey in accordance with Section 3.03.

d. Inspect compression-applied connectors for correct cable match and indentation.

e. Inspect shield grounding and cable support.

f. Verify that visible cable bends meet or exceed ICEA and/or manufacturer’s minimum allowable bending radius.

g. If cables are terminated through window-type current transformers, inspect to verify that neutral and ground conductors are correctly placed and that shields are correctly terminated for operation of protective devices.

2. Electrical Tests

a. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 3.01.G.1.

b. Perform an insulation-resistance test individually on each conductor with all other conductors and shields grounded. Apply voltage in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.1.

c. Perform a shield-continuity test on each power cable by ohmmeter method.

3. Test Values – Visual and Mechanical

a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

b. Bolt-torque levels should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12.

c. Results of the thermographic survey shall be in accordance with Section 3.03.

d. The minimum bend radius to which insulated cables may be bent for permanent training shall be in accordance with Table 100.22.

4. Test Values – Electrical

a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

b. Insulation-resistance values should be in accordance with manufacturer’s published data. In the absence of manufacturer’s
published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer’s recommendations should be investigated.

c. Shielding shall exhibit continuity. Investigate resistance values in excess of ten ohms per 1000 feet of cable.

d. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the test, the test specimen is considered to have passed the test.

e. Based on the test methodology chosen, refer to applicable standards or manufacturer’s literature for acceptable values.

H. Switches, Air, Low-Voltage

1. Visual and Mechanical Inspection
   a. Inspect physical and mechanical condition.
   b. Inspect anchorage, alignment, grounding, and required clearances.
   c. Prior to cleaning the unit, perform as-found tests, if required.
   d. Clean the unit.
   e. Verify correct blade alignment, blade penetration, travel stops, and mechanical operation.
   f. Verify that fuse sizes and types are in accordance with drawings, short-circuit study, and coordination study.
   g. Verify that each fuse has adequate mechanical support and contact integrity.
   h. Inspect bolted electrical connections for high resistance using one or more of the following methods:
      1) Use of a low-resistance ohmmeter in accordance with Section 3.01.H.2.
      2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.
      3) Perform a thermographic survey in accordance with Section 3.03.
   i. Verify operation and sequencing of interlocking systems.
   j. Verify phase-barrier mounting is intact.
   k. Verify correct operation of indicating and control devices.
   l. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
   m. Perform as-left tests.

2. Electrical Tests
   a. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 3.01.H.1.
b. Measure contact resistance across each switchblade and fuseholder.

c. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with switch closed and across each open pole. Apply voltage in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.1.

d. Measure fuse resistance.

e. Verify cubicle space heater operation.

f. Perform a ground-fault test in accordance with Section 3.01.O, if applicable.

g. Perform tests on other protective devices in accordance with Section 3.01.K, if applicable.

3. Test Values – Visual and Mechanical

a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

b. Bolt-torque levels should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12.

c. Results of the thermographic survey shall be in accordance with Section 3.03.

4. Test Values – Electrical

a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

b. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer’s published data. If manufacturer’s data is not available, investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

c. Insulation-resistance values should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer’s recommendations should be investigated.

d. Investigate fuse-resistance values that deviate from each other by more than 15 percent.

e. Heaters should be operational.

f. Ground fault tests should be in accordance with Section 3.01.O.

g. Results of protective device tests should be in accordance with Section 3.01.K.

I. Switches, Air, Medium-Voltage, Metal-Enclosed
1. Visual and Mechanical Inspection  
   a. Inspect physical and mechanical condition.  
   b. Inspect anchorage, alignment, grounding, and required clearances.  
   c. Prior to cleaning the unit, perform as-found tests, if required.  
   d. Clean the unit.  
   e. Verify correct blade alignment, blade penetration, travel stops, arc interrupter operation, and mechanical operation.  
   f. Verify that fuse sizes and types are in accordance with drawings, short-circuit studies, and coordination study.  
   g. Verify that expulsion-limiting devices are in place on all fuses having expulsion-type elements.  
   h. Verify that each fuseholder has adequate mechanical support and contact integrity.  
   i. Inspect bolted electrical connections for high resistance using one or more of the following methods:  
      1) Use of a low-resistance ohmmeter in accordance with Section 3.01.I.2.  
      2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.  
      3) Perform a thermographic survey in accordance with Section 3.03.  
   j. Verify operation and sequencing of interlocking systems.  
   k. Verify that phase-barrier mounting is intact.  
   l. Verify correct operation of all indicating and control devices.  
   m. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.  
   n. Perform as-left tests.  

2. Electrical Tests  
   a. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 3.01.I.1.  
   b. Measure contact resistance across each switchblade assembly and fuseholder.  
   c. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with switch closed and across each open pole. Apply voltage in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.1.  
   d. Perform a dielectric withstand voltage test on each pole with switch closed. Test each pole-to-ground with all other poles grounded. Test
voltage shall be in accordance with manufacturer’s published data or Table 100.2.

e. Measure fuse resistance.

f. Verify cubicle space heater operation.

3. Test Values – Visual and Mechanical

a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

b. Bolt-torque levels should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12.

c. Results of the thermographic survey shall be in accordance with Section 3.03.

4. Test Values – Electrical

a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

b. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer’s published data. If manufacturer’s data is not available, investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

c. Insulation-resistance values should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer’s recommendations should be investigated. Dielectric withstand voltage tests shall not proceed until insulation-resistance levels are raised above minimum values.

d. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.

e. Investigate fuse resistance values that deviate from each other by more than 15 percent.

f. Heaters should be operational.

J. Switches, Vacuum, Medium-Voltage

1. Visual and Mechanical Inspection

a. Inspect physical and mechanical condition.

b. Inspect anchorage, alignment, grounding, and required clearances.

c. Prior to cleaning the unit, perform as-found tests, if required.

d. Clean the unit.
e. Perform mechanical operator tests in accordance with manufacturer’s published data, if applicable.

f. Verify correct operation and adjustment of motor operator limit switches and mechanical interlocks, if applicable.

g. Measure critical distances on operating mechanism as recommended by the manufacturer.

h. Inspect bolted electrical connections for high resistance using one or more of the following methods:
   1) Use of a low-resistance ohmmeter. See Section 3.01.J.2.
   2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.
   3) Perform a thermographic survey in accordance with Section 3.03.

i. Inspect insulating assemblies for evidence of physical damage or contaminated surfaces.

j. Verify that each fuseholder has adequate support and contact integrity.

k. Verify that fuse sizes and types are in accordance with drawings, short-circuit studies, and coordination study.

l. Test all electrical and mechanical interlock systems for correct operation and sequencing.

m. Verify that insulating oil level is correct, if applicable.

n. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.

o. Perform as-left tests.

p. Record as-found and as-left operation counter readings, if applicable.

2. Electrical Tests

a. Perform resistance measurements through bolted electrical connections with a low-resistance ohmmeter, if applicable. See Section 3.01.J.1.

b. Perform a contact/pole-resistance test.

c. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with switch closed, and across each open pole. Apply voltage in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.1.

d. Perform a vacuum bottle integrity (dielectric withstand voltage) test across each vacuum bottle with the switch in the open position in strict accordance with manufacturer’s published data.
e. Remove a sample of insulating liquid, if applicable, in accordance with ASTM D 923. The sample shall be tested in accordance with the referenced standard.

1) Dielectric breakdown voltage: ASTM D 877
2) Color: ASTM D 1500
3) Visual condition: ASTM D 1524

f. Verify open and close operation from control devices, if applicable.

3. Test Values – Visual and Mechanical

a. Critical distances of operating mechanism should be in accordance with manufacturer’s published data.

b. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

c. Bolt-torque levels should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12.

d. Results of the thermographic survey shall be in accordance with Section 3.03.

e. Operation counter should advance one digit per close-open cycle.

4. Test Values – Electrical

a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

b. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer’s published data. If manufacturer’s data is not available, investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

c. Insulation-resistance values should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer’s recommendations should be investigated. Dielectric withstand voltage tests should not proceed until insulation-resistance levels are raised above minimum values.

d. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the vacuum bottle integrity test, the test specimen is considered to have passed the test.

e. Insulating liquid test results should be in accordance with Table 100.4.

f. Insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
g. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.

h. Results of open and close operation from control devices should be in accordance with system design.

K. Protective Relays, Electromechanical and Solid-State

1. Visual and Mechanical Inspection
   a. Inspect relays and cases for physical damage.
   b. Prior to cleaning the unit, perform as-found tests, if required.
   c. Clean the unit.
   d. Relay Case
      1) Tighten case connections.
      2) Inspect cover for correct gasket seal.
      3) Clean cover glass. Inspect shorting hardware, connection paddles, and/or knife switches.
   e. Remove any foreign material from the case.
   f. Verify target reset
   g. Relay
      1) Inspect relay for foreign material, particularly in disk slots of the damping and electromagnets.
      2) Verify disk clearance. Verify contact clearance and spring bias.
      3) Inspect spiral spring convolutions. Inspect disk and contacts for freedom of movement and correct travel. Verify tightness of mounting hardware and connections. Burnish contacts. Inspect bearings and/or pivots.
   h. Verify that all settings are in accordance with coordination study or setting sheet supplied by owner.
   i. Perform as-left tests.

2. Electrical Tests
   a. Perform insulation-resistance test on each circuit-to-frame. Procedures for performing insulation-resistance tests on solid-state relays should be determined from the relay manufacturer’s published data.
   b. Inspect targets and indicators.
      1) Determine pickup and dropout of electromechanical targets.
      2) Verify operation of all light-emitting diode indicators.
      3) Set contrast for liquid-crystal display readouts.

3. Functional Operation
a. 2/62 Timing Relay
   1) Determine time delay.
   2) Verify operation of instantaneous contacts.

b. 21 Distance Relay
   1) Determine maximum reach.
   2) Determine maximum torque angle.
   3) Determine offset.

c. 24 Volts/Hertz Relay
   1) Determine pickup frequency at rated voltage.
   2) Determine pickup frequency at a second voltage level.
   3) Determine time delay.

d. 25 Sync Check Relay
   1) Determine closing zone at rated voltage.
   2) Determine maximum voltage differential that permits closing at zero degrees.
   3) Determine live line, live bus, dead line, and dead bus set points.
   4) Determine time delay.
   5) Verify dead bus/live line, dead line/live bus and dead bus/dead line control functions.

e. 27 Undervoltage Relay
   1) Determine dropout voltage.
   2) Determine time delay.
   3) Determine the time delay at a second point on the timing curve for inverse time relays.

f. 32 Directional Power Relay
   1) Determine minimum pickup at maximum torque angle.
   2) Determine closing zone.
   3) Determine maximum torque angle.
   4) Determine time delay.
   5) Verify the time delay at a second point on the timing curve for inverse time relays.

g. 40 Loss of Field (Impedance) Relay
   1) Determine maximum reach.
   2) Determine maximum torque angle.
   3) Determine offset.

h. 46 Current Balance Relay
1) Determine pickup of each unit.
2) Determine percent slope.
3) Determine time delay.

i. 46N Negative Sequence Current Relay
1) Determine negative sequence alarm level.
2) Determine negative sequence minimum trip level.
3) Determine maximum time delay.
4) Verify two points on the (I2)t curve.

j. 47 Phase Sequence or Phase Balance Voltage Relay
1) Determine positive sequence voltage to close the normally open contact.
2) Determine positive sequence voltage to open the normally closed contact (undervoltage trip).
3) Verify negative sequence trip.
4) Determine time delay to close the normally open contact with sudden application of 120 percent of pickup.
5) Determine time delay to close the normally closed contact upon removal of voltage when previously set to rated system voltage.

k. 49R Thermal Replica Relay
1) Determine time delay at 300 percent of setting.
2) Determine a second point on the operating curve.

l. 49T Temperature (RTD) Relay
1) Determine trip resistance.
2) Determine reset resistance.

m. 50 Instantaneous Overcurrent Relay
1) Determine pickup.
2) Determine dropout.

n. 51 Time Overcurrent
1) Determine minimum pickup.
2) Determine time delay at two points on the time current curve.

o. 55 Power Factor Relay
1) Determine tripping angle.
2) Determine time delay.

p. 59 Overvoltage Relay
1) Determine overvoltage pickup.
2) Determine time delay to close the contact with sudden application of 120 percent of pickup.

q. 60 Voltage Balance Relay
   1) Determine voltage difference to close the contacts with one source at rated voltage.

r. 63 Transformer Sudden Pressure Relay
   1) Determine rate-of-rise or the pickup level of suddenly applied pressure in accordance with manufacturer’s published data.
   2) Verify operation of the 63 FPX seal-in circuit.
   3) Verify trip circuit to remote operating device.

s. 64 Ground Detector Relay
   1) Determine maximum impedance to ground causing relay pickup.

t. 67 Directional Overcurrent Relay
   1) Determine directional unit minimum pickup at maximum torque angle.
   2) Determine closing zone.
   3) Determine overcurrent unit pickup.
   4) Determine overcurrent unit time delay at two points on the time current curve.

u. 79 Reclosing Relay
   1) Determine time delay for each programmed reclosing interval.
   2) Verify lockout for unsuccessful reclosing.
   3) Determine reset time.
   4) Verify instantaneous overcurrent lockout.

v. 81 Frequency Relay
   1) Verify frequency set points.
   2) Determine time delay.
   3) Determine undervoltage cutoff.

w. 85 Pilot Wire Monitor
   1) Determine overcurrent pickup.
   2) Determine undercurrent pickup.
   3) Determine pilot wire ground pickup level.

x. 87 Differential
   1) Determine operating unit pickup.
   2) Determine the operation of each restraint unit.
   3) Determine slope.
4) Determine harmonic restraint.
5) Determine instantaneous pickup.

4. Control Verification
   a. Verify that each of the relay contacts performs its intended function in the control scheme including breaker trip tests, close inhibit tests, 86 lockout tests, and alarm functions.

5. Test Values
   a. When not otherwise specified, use manufacturer’s recommended tolerances.
   b. When critical test points are specified, the relay should be calibrated to those specified points even though other test points may be out of tolerance.

L. Protective Relays, Microprocessor-Based
1. Visual and Mechanical Inspection
   a. Record model number, style number, serial number, firmware revision, software revision, and rated control voltage.
   b. Download all events from the event recorder in filtered and unfiltered mode before performing any tests on the relay. Download the sequence-of-events recorder prior to testing the relay.
   c. Verify operation of light-emitting diodes, display, and targets.
   d. Record passwords for all access levels.
   e. Clean the front panel and remove foreign material from the case.
   f. Check tightness of connections.
   g. Verify that the frame is grounded in accordance with manufacturer’s instructions.
   h. Download settings from the relay. Print a copy of the settings for the report and compare the settings to those specified in the coordination study.

2. Electrical Tests
   a. Perform insulation-resistance tests from each circuit to the grounded frame in accordance with manufacturer’s published data.
   b. Apply voltage or current to all analog inputs and verify correct registration of the relay meter functions.
   c. Control Verification
      1) Check operation of all active digital inputs.
      2) Check all output contacts or SCRs, preferably by operating the controlled device such as circuit breaker, auxiliary relay, or alarm.
      3) For pilot schemes, perform a loop-back test to check the receive and transmit communication circuits.
4) For pilot schemes with direct transfer trip (DTT), perform transmit and received DTT at each terminal.

5) Upon completion of testing reset all min/max recorders, fault counters, sequence of events recorder, and all event records.

M. Instrument Transformers

1. Visual and Mechanical Inspection
   a. Inspect physical and mechanical condition.
   b. Prior to cleaning the unit, perform as-found tests, if required.
   c. Clean the unit.
   d. Inspect bolted electrical connections for high resistance using one or more of the following methods:
      1) Use of a low-resistance ohmmeter in accordance with Section 3.01.M.2 and 3.01.M.3.
      2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
      3) Perform a thermographic survey in accordance with Section 3.03.
   e. Verify that all required grounding and shorting connections provide contact.
   f. Verify correct operation of transformer withdrawal mechanism and grounding operation, if applicable.
   g. Verify correct primary and secondary fuse sizes for voltage transformers.
   h. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
   i. Perform as-left tests.

2. Electrical Tests – Current Transformers
   a. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 3.01.M.1.
   b. Perform insulation-resistance test of each current transformer and wiring-to-ground at 1000 volts dc for one minute. For units with solid-state components that cannot tolerate the applied voltage, follow manufacturer's recommendations.
   c. When applicable, perform insulation-resistance tests on the primary winding with the secondary grounded. Test voltages shall be in accordance with Table 100.5.
   d. When applicable, perform dielectric withstand voltage tests on the primary winding with the secondary grounded. Test voltages shall be in accordance with Table 100.9 respectively.
e. Verify that current circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3.

3. Electrical Tests – Voltage Transformers
   a. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 3.01.M.1.
   b. Perform insulation-resistance tests for one minute winding-to-winding and each winding-to-ground. Test voltages shall be applied in accordance with Table 100.5. For units with solid-state components that cannot tolerate the applied voltage, follow manufacturer’s recommendations.
   c. Perform a turns-ratio test on all tap positions, if applicable.
   d. Verify that potential circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3.

4. Electrical Tests – Coupling-Capacitor Voltage Transformers
   a. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 3.01.M.1.
   b. Perform insulation-resistance tests for one minute, winding-to-winding and each winding-to-ground. Test voltages shall be applied in accordance with Table 100.5. For units with solid-state components that cannot tolerate the applied voltage, follow manufacturer’s recommendations.
   c. Perform a turns ratio test on the as-found tap position, if applicable.
   d. Measure capacitance of capacitor sections.
   e. Measure insulation power factor or dissipation factor in accordance with test equipment manufacturer’s published data
   f. Verify that potential circuits are grounded and have only one grounding point in accordance with ANSI/IEEE C57.13.3.

5. Test Values – Visual and Mechanical
   a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
   b. Bolt-torque levels should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12.
   c. Results of the thermographic survey shall be in accordance with Section 3.03.

6. Test Values – Current Transformers – Electrical
   a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
b. Insulation-resistance values of instrument transformers should not be less than values shown in Table 100.5.

c. Polarity results should agree with transformer markings.

d. Ratio errors should not be greater than values shown in Table 100.21.

e. Excitation results should match the curve supplied by the manufacturer or be in accordance with ANSI C57.13.1.

f. Compare measured burdens to instrument transformer ratings.

g. Insulation-resistance values of instrument transformers should not be less than values shown in Table 100.5.

h. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the primary windings are considered to have passed the test.

i. Power-factor or dissipation-factor values shall be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use test equipment manufacturer’s published data.

j. Test results should indicate that the circuits have only one grounding point.

7. Test Values – Voltage Transformers – Electrical

   a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

   b. Insulation-resistance values of instrument transformers should not be less than values shown in Table 100.5.

   c. Polarity results should agree with transformer markings.

   d. In accordance with IEEE C57.13; 8.1.1 the ratio error should be as follows:

      1) Revenue metering applications: equal to or less than ±0.1 percent for ratio and ±0.9 mrad (three minutes) for phase angle.

      2) Other applications: equal to or less than ±1.2 percent for ratio and ±17.5 mrad (one degree) for phase angle.

   e. Compare measured burdens to instrument transformer ratings.

   f. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the primary windings are considered to have passed the test.

   g. Power-factor or dissipation-factor values shall be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use test equipment manufacturer’s published data.

   h. Test results should indicate that the circuits have only one grounding point.
8. Test Values – Coupling Capacitor Voltage Transformers
   a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
   b. Insulation-resistance values of instrument transformers should not be less than values shown in Table 100.5.
   c. Polarity results should agree with transformer markings.
   d. In accordance with IEEE C57.13; 8.1.1 the ratio error should be as follows:
      1) Revenue metering applications: equal to or less than ±0.1 percent for ratio and ±0.9 mrad (three minutes) for phase angle.
      2) Other applications: equal to or less than ±1.2 percent for ratio and ±17.5 mrad (one degree) for phase angle.
   e. Compare measured burdens to instrument transformer ratings.
   f. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand voltage test, the test specimen is considered to have passed the test.
   g. Capacitance of capacitor sections of coupling-capacitance voltage transformers should be in accordance with manufacturer’s published data.
   h. Power-factor or dissipation-factor values shall be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use test equipment manufacturer’s published data.
   i. Test results should indicate that the circuits have only one grounding point.

N. Grounding Systems
   1. Visual and Mechanical Inspection
      a. Verify ground system is in compliance with ANSI/NFPA 70, National Electrical Code, Article 250.
      b. Inspect physical and mechanical condition.
      c. Inspect bolted electrical connections for high resistance using one or more of the following methods:
         1) Use of low-resistance ohmmeter in accordance with Section 3.01.N.2.
         2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.
      d. Inspect anchorage.
   2. Electrical Tests
a. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 3.01.N.1.

b. Perform fall-of-potential or alternative test in accordance with IEEE Standard 81 on the main grounding electrode or system.

c. Perform point-to-point tests to determine the resistance between the main grounding system and all major electrical equipment frames, system neutral, and/or derived neutral points.

3. Test Values – Visual and Mechanical

a. Grounding system electrical and mechanical connections should be free of corrosion.

b. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

c. Bolt-torque levels should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12.

4. Test Values – Electrical

a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

b. The resistance between the main grounding electrode and ground should be no greater than five ohms for large commercial or industrial systems and 1.0 ohm or less for generating or transmission station grounds unless otherwise specified by the owner. (Reference ANSI/IEEE Standard 142)

c. Investigate point-to-point resistance values which exceed 0.5 ohm.

O. Ground-Fault Protection Systems, Low-Voltage

1. Visual and Mechanical Inspection

a. Inspect the components for damage and errors in polarity or conductor routing.

   1) Verify that the ground connection is made on the source side of the neutral disconnect link and also on the source side of any ground fault sensor.

   2) Verify that the neutral sensors are connected with correct polarity on both primary and secondary.

   3) Verify that all phase conductors and the neutral pass through the sensor in the same direction for zero sequence systems.

   4) Verify that grounding conductors do not pass through zero sequence sensors.

   5) Verify that the grounded conductor is solidly grounded.

b. Prior to cleaning the unit, perform as-found tests.
c. Clean the unit.

d. Inspect bolted electrical connections for high resistance using one or more of the following methods:
   1) Use of a low-resistance ohmmeter in accordance with Section 3.01.O.2.
   2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12.

e. Verify correct operation of all functions of the self-test panel, if applicable.

f. Verify pickup and time-delay settings in accordance with the settings provided in the owner’s specifications. Record appropriate operation and test sequences as required by ANSI/NFPA 70 National Electrical Code, Article 230.95.

g. Perform as-left tests.

2. Electrical Tests

   a. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 3.01.O.1.

   b. Measure the system neutral-to-ground insulation resistance with the neutral disconnect link temporarily removed. Replace neutral disconnect link after testing.

   c. Perform ground fault protective device pickup tests using primary current injection.

   d. For summation type systems utilizing phase and neutral current transformers, verify correct polarities by applying current to each phase-neutral current transformer pair. This test also applies to molded-case breakers utilizing an external neutral current transformer.

   e. Measure time delay of the ground fault protective device at a value equal to or greater than 150 percent of the pickup value.

   f. Verify that reduced control voltage tripping capability is 55 percent for ac systems and 80 percent for dc systems.

   g. Verify blocking capability of zone interlock systems.

3. Test Values – Visual and Mechanical

   a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

   b. Bolt-torque levels should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12.
4. Test Values – Electrical
   a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
   b. System neutral-to-ground insulation resistance should be a minimum of one megohm.
   c. Insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
   d. Results of pickup test should be greater than 90 percent of the ground fault protection device pickup setting and less than 1200 amperes or 125 percent of the pickup setting, whichever is smaller.
   e. The ground fault protective device should operate when current direction is the same relative to polarity marks in the two current transformers. The ground fault protective device should not operate when current direction is opposite relative to polarity marks in the two current transformers.
   f. Relay timing should be in accordance with manufacturer’s specifications but must be no longer than one second at 3000 amperes in accordance with ANSI/NFPA 70, National Electrical Code, Article 230.95.
   g. The circuit interrupting device should operate when control voltage is 55 percent of nominal voltage for ac circuits and 80 percent of nominal voltage for dc circuits.
   h. Results of zone-blocking tests should be in accordance with manufacturer’s published data and/or design specifications.

P. Surge Arresters, Low-Voltage Surge Protection Devices

1. Visual and Mechanical Inspection
   a. Inspect physical and mechanical condition.
   b. Inspect anchorage, alignment, and grounding.
   c. Prior to cleaning the unit, perform as-found tests.
   d. Clean the unit.
   e. Inspect bolted electrical connections for high resistance using one or more of the following methods:
      1) Use of a low-resistance ohmmeter in accordance with Section 3.01.P.2.
      2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.
   f. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.
   g. Perform as-left tests.
2. Electrical Tests
   a. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 3.01.P.1.
   b. Perform insulation-resistance test on each arrester, from the phase terminal to ground. Apply voltage in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.1.
   c. Test grounding connection in accordance with Section 3.01.N.

3. Test Values – Visual and Mechanical
   a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
   b. Bolt-torque levels should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12

4. Test Values – Electrical
   a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
   b. Insulation-resistance values should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer’s recommendations should be investigated.
   c. Resistance between the arrester ground terminal and the ground system should be less than 0.5 ohm and in accordance with Section 3.01.N.

Q. Surge Arresters, Medium- and High-Voltage Surge Protection Devices

1. Visual and Mechanical Inspection
   a. Inspect physical and mechanical condition.
   b. Inspect anchorage, alignment, and grounding.
   c. Prior to cleaning the unit, perform as-found tests.
   d. Clean the unit.
   e. Inspect bolted electrical connections for high resistance using one or more of the following methods:
      1) Use of a low-resistance ohmmeter in accordance with Section 3.01.Q.2.
      2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.
f. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.

g. Verify that stroke counter, if present, is correctly mounted and electrically connected.

h. Perform as-left tests.

2. Electrical Tests
a. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 3.01.Q.1.

b. Perform insulation-resistance tests from phase terminals(s) to case for one minute. Test voltage and minimum resistance shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, refer to Table 100.1.

c. Test the grounding connection in accordance with Section 3.01.N.

3. Test Values – Visual and Mechanical
a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

b. Bolt-torque levels should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12.

4. Test Values – Electrical
a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

b. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.

c. Resistance between the arrester ground terminal and the ground system should be less than 0.5 ohm and in accordance with Section 3.01.N.

d. Watts loss values are evaluated on a comparison basis with similar units and test equipment manufacturer’s published data.

R. Emergency Systems, Engine Generator
1. Visual and Mechanical Inspection
a. Inspect physical and mechanical condition.

b. Inspect anchorage, alignment, and grounding.

c. Prior to cleaning the unit, perform as-found tests.

d. Clean the unit.
e. Perform as-left tests.

2. Electrical and Mechanical Tests


b. Test protective relay devices in accordance with Section 3.01.K.

c. Functionally test engine shutdown for low oil pressure, overtemperature, overspeed, and other protection features as applicable.

d. Conduct performance test in accordance with ANSI/NFPA Standard 110.

e. Verify correct functioning of governor and regulator.

3. Test Values – Visual and Mechanical

a. Anchorage, alignment, and grounding should be in accordance with manufacturer’s published data and system design.

4. Test Values – Electrical

a. Insulation resistance values should be in accordance with ANSI/IEEE Standard 43.

b. The dielectric absorption ratio or polarization shall be compared to previously obtained results and should not be less than 1.0. The recommended minimum insulation resistance (IR 1 min) test results in megohms should be corrected to 40° C and read as follows:

1) IR 1 min = kV + 1 for most windings made before 1970, all field windings, and others not described in 2.2 and 2.3. (kV is the rated machine terminal-to-terminal voltage, in rms kV)

2) IR 1 min = 100 megohms for most dc armature and ac windings built after 1970 (form-wound coils).

3) IR 1 min = 5 megohms for most machines and random-wound stator coils and form-wound coils rated below 1 kV. NOTE: Dielectric withstand voltage high-potential, and surge comparison tests shall not be performed on machines having values lower than those indicated above.

c. Protective relay device test results shall be in accordance with Section 3.01.K.

d. Low oil pressure, overtemperature, overspeed, and other protection features should operate in accordance with manufacturer’s and system design requirements.

e. Vibration levels should be in accordance with manufacturer’s published data and shall be compared to baseline data.

f. Performance tests should conform to manufacturer’s published data and ANSI/NFPA Standard 110.
g. Governor and regulator should operate in accordance with manufacturer’s and system design requirements.

S. Emergency Systems, Uninterruptible Power Systems

1. Visual and Mechanical Inspection
   a. Inspect physical and mechanical condition.
   b. Check for anchorage, alignment, grounding, and required clearances.
   c. Verify that fuse sizes and types correspond to drawings.
   d. Prior to cleaning the unit, perform as-found tests, if required.
   e. Clean the unit.
   f. Test all electrical and mechanical interlock systems for correct operation and sequencing.
   g. Inspect bolted electrical connections for high resistance using one or more of the following methods:
      1) Use of a low-resistance ohmmeter in accordance with Section 3.01.S.2.
      2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.
      3) Perform a thermographic survey in accordance with Section 3.03.
   h. Perform as-left tests.
   i. Check operation of forced ventilation.
   j. Verify that filters are in place and/or vents are clear.

2. Electrical Tests
   a. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 3.01.S.1.
   b. Test static transfer from inverter to bypass and back. Use normal load, if possible.
   c. Set free running frequency of oscillator.
   d. Test dc undervoltage trip level on inverter input breaker. Set according to manufacturer’s published data.
   e. Test alarm circuits.
   f. Verify sync indicators for static switch and bypass switches.
   g. Perform electrical tests for UPS system breakers in accordance with Section 3.01.U.
   h. Perform electrical tests for UPS system automatic transfer switches in accordance with Section 3.01.T.

3. Test Values – Visual and Mechanical
a. Electrical and mechanical interlock systems should operate in accordance with system design requirements.

b. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

c. Bolt-torque levels should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12.

d. Results of the thermographic survey shall be in accordance with Section 3.03.

4. Test Values – Electrical

a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.

b. Static transfer should function in accordance with manufacturer’s published data.

c. Oscillator free running frequency should be within manufacturer’s recommended tolerances.

d. DC undervoltage should trip inverter input breaker.

e. Alarm circuits should operate in accordance with design requirements.

f. Sync indicators should operate in accordance with design requirements.

g. Breaker performance shall be in accordance with Section 3.01.U

h. Automatic transfer switch performance shall be in accordance with Section 3.01.T.

T. Emergency Systems, Automatic Transfer Switches

1. Visual and Mechanical Inspection

a. Inspect physical and mechanical condition.

b. Inspect anchorage, alignment, grounding, and required clearances.

c. Prior to cleaning the unit, perform as-found tests.

d. Clean the unit.

e. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.

f. Verify that manual transfer warnings are attached and visible.

g. Verify tightness of all control connections.

h. Inspect bolted electrical connections for high resistance using one or more of the following methods:

1) Use of a low-resistance ohmmeter in accordance with Section 3.01.T.2.
2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.

3) Perform a thermographic survey in accordance with Section 3.03.
   i. Perform manual transfer operation.
   j. Verify positive mechanical interlocking between normal and alternate sources.
   k. Perform as-left tests.

2. Electrical Tests
   a. 1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 3.01.T.1.
   b. Perform a contact/pole-resistance test.
   c. Verify settings and operation of control devices.
   d. Calibrate and set all relays and timers in accordance with Section 3.01.K.
   e. Perform automatic transfer tests:
      1) Simulate loss of normal power.
      2) Return to normal power.
      3) Simulate loss of emergency power.
      4) Simulate all forms of single-phase conditions.
   f. Verify correct operation and timing of the following functions:
      1) Normal source voltage-sensing and frequency sensing relays.
      2) Engine start sequence.
      3) Time delay upon transfer.
      4) Alternate source voltage-sensing and frequency sensing relays.
      5) Automatic transfer operation.
      6) Interlocks and limit switch function.
      7) Time delay and retransfer upon normal power restoration.
      8) Engine cool down and shutdown feature.

3. Test Values – Visual and Mechanical
   a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
   b. Bolt-torque levels should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12.
c. Results of the thermographic survey shall be in accordance with Section 3.03.

4. Test Values – Electrical
   a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
   b. Insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
   c. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer’s published data. If manufacturer’s data is not available, investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.
   d. Control devices should operate in accordance with manufacturer’s published data.
   e. Relay test results shall be in accordance with Section 3.01.K.
   f. Automatic transfers should operate in accordance with manufacturer’s design.
   g. Operation and timing should be in accordance with manufacturer’s and/or system design requirements.

U. Circuit Breakers, Air, Insulated-Case/Molded-Case
   1. Visual and Mechanical Inspection
      a. Inspect physical and mechanical condition.
      b. Inspect anchorage and alignment.
      c. Prior to cleaning the unit, perform as-found tests, if required.
      d. Clean the unit.
      e. Operate the circuit breaker to insure smooth operation.
      f. Inspect bolted electrical connections for high resistance using one or more of the following methods:
         1) Use of a low-resistance ohmmeter in accordance with Section 3.01.U.2
         2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.
         3) Perform a thermographic survey in accordance with Section 3.03.
      g. Inspect operating mechanism, contacts, and arc chutes in unsealed units.
      h. Perform adjustments for final protective device settings in accordance with coordination study provided by end user.
      i. Perform as-left tests.
2. Electrical Tests
   a. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 3.01.U.1.
   b. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with the circuit breaker closed, and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
   c. Perform a contact/pole-resistance test.
   d. Determine long-time pickup and delay by primary current injection.
   e. Determine short-time pickup and delay by primary current injection.
   f. Determine ground-fault pickup delay by primary current injection.
   g. Determine instantaneous pickup current by primary injection.
   h. Perform minimum pickup voltage test on shunt trip and close coils in accordance with Table 100.20.
   i. Verify correct operation of auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free, antipump function, and trip unit battery condition.
   j. Reset all trip logs and indicators.
   k. Verify operation of charging mechanism.

3. Test Values – Visual and Mechanical
   a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
   b. Bolt-torque levels should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12.
   c. Results of the thermographic survey shall be in accordance with Section 3.03.
   d. Settings shall comply with coordination study recommendations.

4. Test Values – Electrical
   a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
   b. Insulation-resistance values should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer’s recommendations should be investigated.
c. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer’s published data. If manufacturer’s data is not available, investigate values that deviate from adjacent poles or similar breakers by more than 50 percent of the lowest value.

d. Insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.

e. Long-time pickup values should be as specified, and the trip characteristic should not exceed manufacturer’s published time-current characteristic tolerance band, including adjustment factors. If manufacturer’s curves are not available, trip times should not exceed the value shown in Table 100.7.

f. Short-time pickup values should be as specified, and the trip characteristic should not exceed manufacturer’s published time-current tolerance band.

g. Ground fault pickup values should be as specified, and the trip characteristic should not exceed manufacturer’s published time-current tolerance band.

h. Instantaneous pickup values of molded-case circuit breakers should fall within manufacturer’s published tolerances and/or Table 100.8.

i. Pickup values and trip characteristics should be within manufacturer’s published tolerances.

j. Minimum pickup voltage on shunt trip and close coils should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, refer to Table 100.20.

k. Breaker open, close, trip, trip-free, anti-pump, and auxiliary features should function as designed.

l. Trip logs and indicators are reset.

m. The charging mechanism should operate in accordance with manufacturer’s published data.

V. Circuit Breakers, Air, Low-Voltage Power

1. Visual and Mechanical Inspection

a. Inspect physical and mechanical condition.

b. Inspect anchorage, alignment, and grounding.

c. Verify that all maintenance devices are available for servicing and operating the breaker.

d. Prior to cleaning the unit, perform as-found tests, if required.

e. Clean the unit.

f. Inspect arc chutes.

g. Inspect moving and stationary contacts for condition, wear, and alignment.
h. Verify that primary and secondary contact wipe and other dimensions vital to satisfactory operation of the breaker are correct.

i. Perform all mechanical operator and contact alignment tests on both the breaker and its operating mechanism in accordance with manufacturer’s published data.

j. Inspect bolted electrical connections for high resistance using one or more of the following methods:

1) Use of a low-resistance ohmmeter in accordance with Section 3.01.V.2.

2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or Table 100.12.

3) Perform a thermographic survey in accordance with Section 3.03.

k. Verify cell fit and element alignment.

l. Verify racking mechanism operation.

m. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.

n. Perform adjustments for final protective device settings in accordance with coordination study provided by end user.

o. Perform as-left tests.

p. Record as-found and as-left operation counter readings, if applicable.

2. Electrical Tests

a. 1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 3.01.V.1.

b. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with the circuit breaker closed, and across each open pole. Apply voltage in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.1.

c. Perform a contact/pole-resistance test.

d. Determine long-time pickup and delay by primary current injection.

e. Determine short-time pickup and delay by primary current injection.

f. Determine ground-fault pickup and delay by primary current injection.

g. Determine instantaneous pickup current by primary current injection.

h. Perform minimum pickup voltage test on shunt trip and close coils in accordance with Table 100.20.

i. Verify correct operation of auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free, antipump function, and trip unit battery condition.
j. Reset all trip logs and indicators.
k. Verify operation of charging mechanism.

3. Test Values – Visual and Mechanical
   a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
   b. Bolt-torque levels should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.12.
   c. Results of the thermographic survey shall be in accordance with Section 9.
   d. Settings shall comply with coordination study recommendations.
   e. Operations counter should advance one digit per close-open cycle.

4. Test Values – Electrical
   a. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
   b. Insulation-resistance values of breakers should be in accordance with manufacturer’s published data. In the absence of manufacturer’s published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer’s recommendations should be investigated.
   c. Microhm or dc millivolt drop values should not exceed the high levels of the normal range as indicated in the manufacturer’s published data. If manufacturer’s data is not available, investigate values that deviate from adjacent poles or similar breakers by more than 50 percent of the lowest value.
   d. Insulation-resistance values of control wiring should be comparable to previously obtained results but not less than two megohms.
   e. Long-time pickup values should be as specified, and the trip characteristic shall not exceed manufacturer’s published time-current characteristic tolerance band.
   f. Short-time pickup values should be as specified, and the trip characteristic should not exceed manufacturer’s published time-current tolerance band.
   g. Ground fault pickup values should be as specified, and the trip characteristic should not exceed manufacturer’s published time-current tolerance band.
   h. Instantaneous pickup values should be within the tolerances of manufacturer’s published data.
   i. Pickup values and trip characteristic should be as specified and within manufacturer’s published tolerances.
j. Minimum pickup voltage on shunt trip and close coils should be in accordance with manufacturer’s published data. In the absence of manufacturer's published data, refer to Table 100.20.

k. Auxiliary features should operate in accordance with manufacturer’s published data.

l. Trip logs and indicators are reset.

m. The charging mechanism should operate in accordance with manufacturer’s published data.

3.02 SYSTEM FUNCTION TESTS

A. It is the purpose of system function tests to prove the correct interaction of all sensing, processing, and action devices. Perform system function tests upon completion of the maintenance tests defined, as system conditions allow.

B. Develop test parameters and perform tests for the purpose of evaluating performance of all integral components and their functioning as a complete unit within design requirements and manufacturer's published data.

C. Verify the correct operation of all interlock safety devices for fail-safe functions in addition to design function.

D. Verify the correct operation of all sensing devices, alarms, and indicating devices.

3.03 THERMOGRAPHIC SURVEY

A. Visual and Mechanical Inspection
   1. Inspect physical and mechanical condition.
   2. Remove panel covers or view the equipment through viewing ports designed to transmit applicable signals being measured.

B. Thermographic Survey Report
   1. Description of equipment to be tested.
   2. Discrepancies.
   3. Temperature difference between the area of concern and the reference area.
   4. Probable cause of temperature difference.
   5. Areas inspected. Identify inaccessible and/or unobservable areas and/or equipment.
   6. Identify load conditions at time of inspection.
   7. Provide photographs and/or thermograms of the deficient area.
   8. Provide recommended action for repair.

C. Test Parameters
   1. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1° C at 30° C.
2. Equipment shall detect emitted radiation and convert detected radiation to visual signal.

3. Thermographic surveys should be performed during periods of maximum possible loading. Refer to ANSI/NFPA 70B 2006 edition, Section 21.17

D. Test Results

1. Suggested actions based on temperature rise can be found in Table 100.18.

END OF SECTION