SECTION 26 08 00

ELECTRICAL EQUIPMENT SITE ACCEPTANCE TESTING

PART 1 GENERAL

1.01 SCOPE

A. The Contractor shall engage the service group of a major electrical equipment manufacturer which maintains division-wide recognized specialized testing capabilities for the purpose of performing site acceptance tests as herein specified.

1.02 RELATED SECTIONS

Note to Spec. Writer:
Refer to all specification sections covering equipment for which site acceptance testing is required.

1.03 APPLICABLE CODES, STANDARDS AND REFERENCES

A. All inspections and tests shall be in accordance with the following applicable codes and standards except as provided otherwise herein.

1. National Electrical Manufacturer's Association – NEMA
2. American National Standards Institute – ANSI
3. Institute of Electrical and Electronic Engineers – IEEE
4. National Electrical Code – NEC
5. National Fire Protection Association – NFPA
6. American Society for Testing and Materials – ASTM
7. Insulated Power Cable Engineers Association – IPCEA
8. Association of Edison Illuminating Companies – AEIC
9. Occupational Safety and Health Administration – OSHA
10. State and local codes and ordinances

B. All inspections and tests shall utilize the following references:

1. Project design specifications
2. Project design drawings
3. NFPA 70B - 2013
4. Manufacturer's instruction manuals applicable to each particular apparatus.

1.04 QUALIFICATIONS OF SITE ACCEPTANCE TESTING COMPANY

A. The testing company shall be an independent division of a major electrical equipment manufacturer.

B. The testing company site lead engineer or project manager shall be a degreed engineer, who is a full-time employee, with at least 10 years of experience testing electrical apparatus. All other employees working on this project shall have had specific factory and/or

field training in accordance with the equipment they are testing.

C. To ensure compliance with quality control standards, the testing company shall conduct periodic audits of test procedures and test record forms to ensure compliance with industry standards. A Quality Assurance Manager, not reporting to the operation center of the testing company, must complete such audits.

D. Tools, equipment and personal protective equipment utilized by the testing company shall comply with the requirements of OSHA Standard 29 CFR 1910, Subpart I, and NFPA 70E.

E. Should repairs be required, the testing company shall maintain dedicated locations that perform remanufacturing and reconditioning of electrical equipment. All repairs shall be conducted under the direction of a quality control and reconditioning standard pursuant to ISO9001 compliance. A quality certificate, computer database and final test records shall document the progress of each piece of electrical equipment through the repair or reconditioning process.

F. The instruments and test equipment utilized by the testing company shall be calibrated by an accredited ISO/IEC 17025 laboratory. This laboratory shall be audited regularly by the National Voluntary Laboratory Accreditation Program (NVLAP).

1. The accuracy shall be traceable to the National Bureau of Standards in an unbroken chain.

2. Instruments shall be calibrated in accordance with the following frequency schedule:
   a. Field instruments – six to twelve months
   b. Laboratory instruments – twelve months

3. Dated calibration labels shall be visible on all instruments and test equipment.

1.05 SUBMITTALS

A. The test report shall include the following:

1. Summary of project
2. Description of equipment tested
3. Description of test
4. Test results
5. Conclusions and recommendations
6. Appendix, including appropriate test forms
7. List of test equipment used and calibration date
8. Conditions for future access to secured computer database of all Test Data.

B. Furnish three copies of the completed report to the project engineer no later than 30 days after completion of the project, unless directed otherwise.

1.06 SAFETY AND PRECAUTIONS

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

1. Occupational Safety and Health Act of 1970 – OSHA 29CFR 1910.269

2. National Fire Protection Association – NFPA 70E

3. Applicable state and local safety operating procedures.

B. All tests shall be performed with apparatus de-energized except where otherwise specified.

C. The testing company's lead test engineer for the project shall be a designated safety representative and shall be present on the project and supervise testing operations and safety requirements.

D. Power circuits shall have conductors shorted to ground by a hotline grounded device approved for the purpose in accordance with the appropriate test procedures.

E. In all cases, work shall not proceed until the safety representative has determined that it is safe to do so.

F. The testing company shall have available sufficient protective barriers and warning signs, where necessary, to conduct specified tests safely.

G. The owner's safety procedures shall be reviewed and understood by the testing company personnel.

1.07 EQUIPMENT EVALUATION PREPARATION

A. The electrical contractor shall torque down all accessible bolts; perform continuity checks on all branch and control wiring; and perform rotational tests for all motors prior to and in addition to tests performed by the testing company, specified herein. Contractor shall thoroughly clean and vacuum equipment before testing or energizing electrical equipment.

B. The electrical contractor shall supply a suitable and stable source of test power for testing at each test site. The testing company shall specify requirements.

C. The electrical contractor shall notify the testing company when equipment becomes available for electrical tests. Work shall be coordinated to expedite project scheduling.

D. The customer designated project engineer or consultant will supply a complete set of as-built electrical plans, specifications and any pertinent change orders to the testing company prior to commencement of testing.

E. The testing company shall notify the project engineer prior to commencement of any testing.

F. The testing company shall be responsible for implementing all final settings and adjustments on protective devices and electrical equipment in accordance with the project engineer's specified values or a coordination study performed by the engineer of record or the testing group's licensed professional engineer.

G. Any system, material or workmanship which is found defective on the basis of electrical tests shall be reported directly to the project engineer.

H. The testing company shall maintain a written record of all tests and upon completion of the project, assemble and certify a final test report.

I. All test records shall be recorded onto standardized test forms. All data shall be uploaded to a central computer in a data-secured environment; therefore ensuring no changes can be incorporated into the final test records. These records shall be retrievable

for a period of not less than five years, based on a mutually agreed periodic maintenance plan, separate from this contract.

PART 2 PRODUCTS

Not Used.

PART 3 EXECUTION

3.01 GENERAL REQUIREMENTS

A. The field engineering service group shall provide all material, equipment, labor and technical supervision to perform electrical equipment tests and inspections as listed in the applicable section below. The field engineering service division of the equipment manufacturer shall administer all site acceptance and power system studies, as referenced in other specification sections.

B. Equipment warranty shall be extended to two years from date of shipment when service representatives employed by the equipment manufacturer perform testing.

C. The intent of these tests is to assure that all electrical equipment is operational within industry standards and manufacturer's tolerances and that equipment is installed and functioning in the system in the manner intended by the engineer.

D. Upon completion of the tests and inspections noted in these specifications, a label shall be attached to all serviced devices. These labels will indicate date serviced and the testing company responsible.

E. The tests and inspections shall determine suitability for initial continued reliable operation and provide a baseline for future maintenance testing.

3.02 AC INDUCTION GENERATOR

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the generator, generator breaker, and control unit for:
   a. Shipped loose and shipped short components
   b. Shipping damage
   c. Loose or obviously damaged components
   d. Proper identification
   e. Physical damage from installation
   f. Remove temporary heater wiring and shipping braces
   g. Doors, panels, and sections for alignment, dents, scratches, fit, and missing hardware
   h. Maintenance accessories for servicing and operating all devices
2. Inspect:
   a. All grounding connections
   b. Insulators for evidence of physical damage or contaminated surfaces

c. Surge Arrestor and/or Surge Suppression size, type, installation and connection to determine if they are in accordance with the drawings

d. Generator breaker for physical condition and cleanliness

e. Wiring for damaged insulation, broken leads, tightness of connections, proper crimping, and overall general condition

3. Verify generator enclosure, cables and bus assembly for:

a. Anchorage (per local codes, wind and seismic considerations)

b. Required area clearances, correct alignment and cleanliness.

c. That the grounding electrode conductor is properly sized and connected

d. That conductors are properly identified

e. Cable and control wire termination tightness

f. That all cables have been properly installed, routed and supported

g. That conduits and conduit bushings are correctly installed

h. Unused openings have been properly closed and secured

i. Tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturers published data

j. That blocks or other temporary holding means used for shipment have been removed from all component devices in the enclosure interior

B. ELECTRICAL TESTS

1. Perform an insulation resistance test and calculate the polarization index of the generator windings

3.03 AC INDUCTION MOTOR

A. MECHANICAL AND VISUAL INSPECTION

1. Examine motor for:

a. Shipped loose and shipped short components

b. Shipping damage

c. Loose or obviously damaged

1. Frame
2. Termination box
3. Shaft
4. Tachometer
5. Brake
6. Zero speed switch
7. Mounting feet or flange

d. Proper motor lubrication

e. Coupling alignment and lubrication

f. Proper identification

g. Compliance to drawings

h. Customer field connections and signals

i. Remove temporary heater wiring and shipping braces

2. Inspect:

a. All grounding connections
b. Insulators for evidence of physical damage or contaminated surfaces
c. Surge Arrestor and/or Surge Suppression size, type, installation and connection to determine if they are in accordance with the drawings (Refer to NEC Article 280)
d. Wiring for damaged insulation, broken leads, tightness of connections, proper crimping, and overall general condition

3. Verify structure, grounding, cables and bus assembly for:
a. Anchorage (per local codes, wind and seismic considerations)
b. Required area clearances, correct alignment and cleanliness.
c. That the grounding electrode conductor is properly sized.
d. That conductors are properly identified
e. Cable and control wire termination tightness
f. That all cables have been properly installed, routed and supported
g. That conduits and conduit bushings are correctly installed
h. Unused openings have been properly closed and secured
i. Tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturers published data
j. That blocks or other temporary holding means used for shipment have been removed from the motor
k. That filters are in place and/or vents are clear from obstructions

4. Inspect and test the motor stator circuit:
a. Prior to disconnecting motor leads, verify, note, and mark the motor’s direction of rotation
b. Mark and disconnect the motor stator leads
c. Perform an insulation resistance test
d. Reconnect all leads removed during this check

B. ELECTRICAL TESTS

1. Perform an insulation resistance test on the motor leads to ground at 1000 VDC and calculate the polarization index of the motor windings

3.04 ACTIVE HARMONIC CORRECTION UNIT

A. MECHANICAL AND VISUAL INSPECTION

1. Inspect enclosure for structural integrity.
2. Verify proper door latching and interlocking.
3. Inspect for loose, broken or missing hardware or components.
4. Inspect components for evidence of overheating, burning, discoloration, etc.
5. Inspect the discharge resistors fitted integral to the terminals. Check for secured and snug fit, discoloration, cracked or chapped modules.
6. If reactor is present inspect the reactor for any signs of discoloration and overheating.
7. Inspect and ensure the thermal switch wiring and the switches are securely in place into the hotspot region of the reactor winding.

8. Inspect the electrical connections and perform a pull test on all customer and factory connections by giving a firm tug on all the connections.

9. Check tightness of bolted connections.

10. Inspect control wiring connections for tightness.

11. Inspect power cable for tightness (if accessible), insulation fraying and clearances.

12. Thoroughly clean interior of compartments.

13. Verify proper location and configuration of current transformers.

14. Record Control PCB temperature from the digital interface module

B. ELECTRICAL TESTS

1. Test the IGBTs using a DMM diode test

2. Perform the following tests on current transformers
   a. Ratio
   b. Polarity

3. Check the integrity of:
   a. Pre-charge contactor K1
   b. DC Bus
   c. MOV Block Fuses
   d. Inrush Resistor

C. INITIAL ENEGIZATION

1. Verify proper operation of pre-charge contactor.

2. Configure all set-up parameters.

3. Place the unit into harmonic mode or power factor mode as required.

4. Diagnose any “fault” messages as required.

3.05 ADJUSTABLE FREQUENCY DRIVE – LOW VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the adjustable frequency drive installation
   a. Shipped loose and shipped short components
   b. Shipping damage
   c. Loose or obviously damaged components
   d. Proper identification
   e. Physical damage from installation

2. Inspect:
   a. Inspect grounding connections
   b. Insulators for evidence of physical damage or contaminated surfaces.
   c. Wiring for damaged insulation, broken leads, proper crimping, and overall general condition

3. Review the AFD sizing with the motor sizing and application requirements.

4. Review automation system to be used (as applicable) with AFD

5. Perform safety inspection of the AFD installation and its associated equipment.
   a. Tag and lock out all power sources to the AFD according to the end users and commissioners policies until the commissioner is prepared to energize the AFD.
   b. Perform a walk around of the application and equipment to determine level of preparedness for operation.
   c. Survey the installation environment to ensure it is safe and is within AFD ambient specifications for operation.
   d. Establish whether AFD testing will be performed with or without its load attached.
   e. Have end user representative prepare equipment if necessary.
6. Review AFD and its connected load for proper installation.
   a. Incoming power, outgoing motor, and control wiring are each in their own conduit.
   b. All wiring has been accomplished to manufacturer's specifications for the size of the AFD and its connected load.
   c. The AFD is clean and free of installation debris, equipment, or tools.

B. INITIAL ENEGIZATION

1. Perform Pre-Power meter checks.
   a. Confirm all power sources are tagged and locked and are de-energized.
   b. With motor leads disconnected from AFD perform insulation resistance testing on motor leads
   c. Perform static checks in accordance with manufacturer's model-specific instructions
      1. Perform diode checks of converter rectifiers
      2. Perform diode checks of inverter IGBTs
      3. Measure resistance to ground of positive and negative bus using a digital multi-meter
      4. Measure and record insulation resistance of motor leads.
      5. Measure and record impedance and insulation resistance of line reactor (if applicable), compare to nameplate.
      6. Measure and record insulation resistance of input isolation transformer (if applicable).
2. Perform initial power on safety checks.
   a. Confirm that all power is still tagged and locked out to the AFD.
   b. If disconnected, reconnect the line and/or motor leads.
   c. Ensure all appropriate control wiring has been reconnected.
   d. Conduct a walk around of the AFD and its connected load.
   e. Remove tags and locks from the disconnect supplying power to the AFD disconnect.
   f. When safe, energize the disconnect device that is supplying power to the AFD disconnect.
   g. Using a DMM measure the AC line voltage at the supply side of the AFD disconnect device.
   h. Record phase to phase voltage and phase to ground voltage

i. Phase to phase are balanced within < 2%
j. Phase to ground are balanced within < 2%
k. Measure and record DC bus voltage

3. Setting the AFD Parameters

a. Program AFD parameters as specified by the customer and in accordance manufacturer's model-specific instructions

b. Typical parameters would include

1. Motor name plate information
2. Accel/Decel times
3. Min/Max speeds
4. AFD controls
5. Motor protections

4. Check motor direction of rotation

a. Have customer representative confirm that the motor is ready to rotate.

b. Bump the motor to check it's direction of rotation in the following order:

1. Check rotation from the AFD.
2. After checking AFD rotation if a bypass is used, check rotation from the bypass.

5. Operation of the Drive and Motor

a. It is preferred that the testing from this point on be done with the motor coupled to the normal operating load.

b. Testing of an unload application or just a motor is valid but should be noted in the commissioning documentation.

c. Perform operational checks in accordance with manufacturer's model-specific instructions

6. Typical operational checks include

a. Measure and record motor voltage and compare to AFD display
b. Measure and record motor current and compare to AFD display
c. Measure and record line voltage and line current
d. Measure and record clean power rectifier lead voltages (CPX/CFX AFD's)
e. Perform full power motor run
f. Confirm control systems function

3.06 ADJUSTABLE FREQUENCY DRIVE – MEDIUM VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the adjustable frequency drive installation

a. Shipped loose and shipped short components
b. Shipping damage
c. Proper identification
d. Physical damage from installation
e. Proper Mounting of enclosure
f. Verify all system units are installed and wired including: motors, pump valves, PC's, etc.

2. Inspect:
   a. Inspect grounding connections
   b. Insulators for evidence of physical damage or contaminated surfaces.
   c. Wiring for damaged insulation, broken leads, proper crimping, and overall general condition
3. Review the AFD sizing with the motor sizing and application requirements.
4. Review automation system to be used (as applicable) with AFD
5. Perform safety inspection of the AFD installation and its associated equipment.
   a. Tag and lock out all power sources to the AFD according to the end users and commissioners policies until the commissioner is prepared to energize the AFD.
   b. Perform a walk around of the application and equipment to determine level of preparedness for operation.
   c. Survey the installation environment to ensure it is safe and is within AFD ambient specifications for operation.
   d. Establish whether AFD testing will be performed with or without its load attached.
   e. Have end user representative prepare equipment if necessary.
6. Review AFD and its connected load for proper installation.
   a. Incoming power, outgoing motor, and control wiring are each in their own conduit.
   b. All wiring has been accomplished to manufacturer's specifications for the size of the AFD and its connected load.
   c. The AFD is clean and free of installation debris, equipment, or tools.

B. POWER-OFF CHECKS
1. Verify all Kirk-Key interlocks and functionality
2. Isolate the motor and obtain readings.
3. Perform continuity test on all power and control fuses.
4. Verify proper phase rotation.
5. Perform diode checks of converter rectifiers
6. Perform diode checks of inverter IGBTs.
7. Perform the following checks on control assembly items:
   a. Remove MCR pilot relay to insure the main contactor does not close.
   b. Verify SPX drive, Truck IO and DSP board's powers up with maintenance power applied.
   c. View the keypad display; verify the DC pre-charge operates to approx. 6KV.
   d. Insure the correct MV software is installed in the drive and record.
   e. Force blowers function in the SPX program & insure blower operation.
   f. Force all output lights on the panel with Truck IO and insure proper operation.
   g. Program motor data, start/stop etc. in the SPX drive program.
   h. Ensure all e-stop functions are working properly.
   i. Remove the external control power in preparation for line power-up testing.

C. INITIAL ENEGIZATION

1. Perform Pre-Power meter checks.
   a. Confirm all power sources are tagged and locked and are de-energized.
   b. With motor leads disconnected from AFD perform insulation resistance testing on motor leads
2. Perform initial power and safety checks.
   a. Confirm all power is still tagged and locked out to the AFD.
   b. If disconnected, reconnect the line and/or motor leads.
   c. Ensure all appropriate control wiring has been reconnected.
   d. Conduct a walk around of the AFD and its connected load.
   e. Remove tags and locks from the disconnect device supplying power to the AFD disconnect.
   f. When safe, energize the disconnect device suppling power to the AFD disconnect.
   g. Remove all spare kirk keys and destroy or give to proper customer representative
   h. Confirm kirk keys left in AFD are the only ones necessary for proper operation of interlock scheme.
   i. Force blower function and insure blower operation.
   j. Re-install MCR pilot relay for proper main contactor operation.
   k. Perform Auto-Tune
   l. Charge DC Bus
3. Setting the AFD Parameters
   a. Program AFD parameters as specified by the customer and in accordance manufacturer’s model-specific instructions
   b. Typical parameters would include
      1. Motor name plate information
      2. Accel/Decel times
      3. Min/Max frequency
      4. AFD controls
      5. Motor protections
4. Check motor direction of rotation
   a. Have customer representative confirm that the motor is ready to rotate.
   b. Bump the motor to check it’s direction of rotation in the following order:
      1. Check rotation from the AFD.
      2. After checking AFD rotation if a bypass is used, check rotation from the bypass.
5. Operation of the Drive and Motor
   a. It is preferred for testing from this point on be done with the motor coupled to the normal operating load.
   b. Testing of an unloaded application or just a motor is valid but should be noted in the commissioning documentation.
   c. Perform operational checks in accordance with manufacturer’s model-specific instructions

6. Typical operational checks include
    1. Record motor line voltage and compare to AFD display
    2. Record motor line current and compare to AFD display
7. Download the drive service file.

3.07 ANALOG METER

A. MECHANICAL AND VISUAL INSPECTION

1. Examine meter and accessories for:
    a. Shipped loose and shipped short components
    b. Shipping damage
    c. Loose or obviously damaged components
    d. Proper identification
    e. Physical damage from installation
    f. Alignment, dents, scratches, fit, and missing hardware
2. Inspect:
    a. All connections for tightness
    b. Current transformers for proper rating, polarity and wiring
3. Verify:

    a. Any incoming AC Power is turned off and locked out before performing any work on the meter

B. ELECTRICAL TESTS

1. Verify meter accuracy at cardinal points.
2. Perform and required calibration in accordance with the meter instruction book.

3.08 AUTOMATIC CIRCUIT RECLOSERS

A. MECHANICAL AND VISUAL INSPECTION

1. Verify proper nameplate identification and compliance to drawings.
2. Verify shipping brackets or fixtures have been removed (as applicable)
3. Verify anchorage and grounding in accordance with instruction book and application.
4. Inspect recloser after installation, and make note of any visual damage.
5. Verify there is no evidence of moisture
6. Loose or obviously damaged components
    a. Tank / Frame Damage / Lifting lugs
    b. Paint Condition
    c. Cables - verify all required cables are present and in good condition
    d. Amphenol Connectors (Damaged threads)
    e. Open/Close Indicator
    f. Bushings (cracked, chipped)
    g. Terminals (Bent conductor rods or damaged terminals)
    h. Fluid leaks (as applicable)

7. Visually inspect the operator mechanism:
   a. Check door gasket for effectiveness of seal.
   b. Visually inspect all components for worn or broken parts and corrosion.
   c. Check for broken or loose wiring terminals at the various components and terminal boards.
   d. Record counter reading in the record log.
8. Close and trip the recloser manually several times to check mechanical operation.
9. Check the contact erosion indicators of the vacuum interrupters.
10. Operate all other switches and handles
11. Obtain fluid sample and perform dielectric testing (if applicable)
12. Verify the electrical operation of the recloser:
13. Perform checkout procedures of recloser controls per applicable instruction book.

B. ELECTRICAL TESTS

1. Measure and record contact resistance of each pole.
2. Test insulation resistance phase to phase and phase to ground with recloser closed.
3. Perform a dielectric withstand test to check the insulation level of the recloser and the vacuum integrity of the interrupters.
4. [3]Perform a power-factor test on each bushing if equipped with capacitance tap.

3.09 AUTOMATIC POWER FACTOR CORRECTION UNIT – LOW VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the unit for:
   a. Shipped loose and shipped short components
   b. Shipping damage
   c. Loose or obviously damaged components
   d. Proper identification
   e. Physical damage from installation
   f. Doors, panels, and sections for alignment, dents, scratches, fit, and missing hardware
   g. Maintenance accessories for servicing and operating all devices
2. Inspect:
   a. Shipping splits to insure that all bus connections were properly connected and all control wiring splits have been properly terminated by contractor.
   b. Remove all temporary wiring for heaters if equipped
   c. Inspect grounding connections
   d. Insulators for evidence of physical damage or contaminated surfaces.
   e. Verify that capacitors are electrically connected in their specified configuration.

[3] Note to Spec. Writer – Optional

f. Inspect the discharge resistors fitted integral to the terminals. Check for secured and snug fit, discoloration, cracked or chapped modules.

g. If reactor is present inspect the reactor for any signs of discoloration and overheating.

h. Inspect and ensure the thermal switch wiring and the switches are securely in place into the hotspot region of the reactor winding.

i. Surge Arrester and/or Surge Suppression (as applicable)

j. Alignment and penetration of instrument transformer withdrawal disconnects, current carrying, and grounding components (as applicable)

k. Control power transformers (as applicable)

l. Wiring for damaged insulation, broken leads, proper crimping, and overall general condition

3. Verify structure, grounding, cables and bus assembly:

a. Anchorage (per local codes, wind and seismic considerations)

b. Required area clearances, correct alignment and cleanliness.

c. Make sure natural ventilation is not impeded

d. Verify the grounding electrode conductor is properly sized and terminated

e. The proper grounding of instruments, panels and connections.

f. That conductors are properly identified (as applicable)

g. Cable termination tightness

h. That all cables have been properly installed, routed and supported and are clear of energized parts

i. That conduits and conduit bushings are correctly installed

j. Unused openings have been properly closed and secured

k. Tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturers published data.

l. Correct barrier installation.

m. That filters are in place and/or vents are clear from obstructions

4. Verify control and instrumentation (as applicable):

a. All VT and CT ratios properly correspond to drawings and that polarity is correct

b. Shorting screws and bars are removed from CT’s and terminal blocks as required

c. Primary and secondary fuse ratings or circuit breakers match drawings

d. Meter scaling and type match drawings

B. ELECTRICAL TESTS

1. Perform a terminal to terminal continuity and resistance measurement using a multi-meter.

2. Perform insulation-resistance tests from terminal(s) to case for 30 sec on the capacitor cells. Ensure any 300V rated control components are isolated / disconnected from the test path.

3. Inspect all electrical connections for high resistance using a low-resistance ohmmeter.

4. Measure resistance of integral discharge resistors. The discharge resistors are three pronged internally delta connected just like the capacitors and have a printed value of the total resistance on them. The measured resistance between any two prongs should measure approximately two thirds of the printed value.

5. Measure the capacitance of all terminal combinations and verify it with the manufacturer's published table.

6. Perform a low voltage test to verify the proper operation of the bank,

a. Remove the three fuses on the primary side of the Control Power Transformer (CPT)

b. located on the control panel.

c. Tie / tape the door interlock limit switch shut to allow the control circuit interlock to be defeated temporarily.

d. Use an available 120V power source, suitably fused and connect the phase to the fuse and neutral to the grounded terminal.

e. While taking appropriate electrical precautions energize the 120V supply and turn the

f. ON/OFF switch on the front of the door to "ON" position.

g. The controller should power on and the ventilation fans should immediately power up.

h. Ensure the fans are rotating in the correct direction by feeling the draft of the air from the enclosure is in "exhaust" mode.

i. Engage the controller in the manual mode and step through the various stages, one step at a time, and hear for the contactor to pull in.

j. Once all contactors have been verified to energize, disconnect the 120V power supply, remove the defeat mechanism of the door interlock and replace the primary control fuses at the CPT.

C. Set control, metering, breaker trip units, and protective relay adjustments.

D. Insulation system:

1. Perform insulation-resistance tests on each bus section (if applicable), phase-to-phase, phase-to-ground, phase-to-neutral and neutral-to-ground

E. Control and Instrumentation (as applicable):

F. Perform the following tests on control power transformers

1. Perform insulation-resistance tests. Perform measurements from winding-to-winding and each winding-to-ground.

2. Perform a turns ratio test

G. Verify operation of heaters

H. Perform the following tests on potential transformers

1. Perform insulation-resistance tests.

2. Perform measurements from winding-to-winding and each winding-to-ground.

I. Perform the following tests on current transformers.

1. Ratio

2. Polarity

J. Test capacitors in accordance with Section 3.18

3.10 AUTOMATIC POWER FACTOR CORRECTION UNIT – MEDIUM VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the assembly line-up, including breakers, and accessories for:
   a. Shipped loose and shipped short components
   b. Shipping damage
   c. Loose or obviously damaged components
   d. Proper identification
   e. Physical damage from installation
   f. Doors, panels, and sections for alignment, dents, scratches, fit, and missing hardware
   g. Maintenance accessories for servicing and operating all devices
2. Inspect:
   a. Shipping Splits to insure that all bus connections were properly connected and all control wiring splits have been properly terminated by contractor.
   b. Remove all temporary wiring for heaters if equipped
   c. Inspect grounding connections
   d. Insulators for evidence of physical damage or contaminated surfaces.
   e. Verify that capacitors are electrically connected in their specified configuration.
   f. Inspect the discharge resistors fitted integral to the terminals. Check for secured and snug fit, discoloration, cracked or chapped modules.
   g. If reactor is present inspect the reactor for any signs of discoloration and overheating.
   h. Inspect and ensure the thermal switch wiring and the switches are securely in place into the hotspot region of the reactor winding.
   i. Surge Arrester and/or Surge Suppression (as applicable)
   j. Alignment and penetration of instrument transformer withdrawal disconnects, current carrying, and grounding components (as applicable)
   k. Control power transformers (as applicable)
   l. Wiring for damaged insulation, broken leads, proper crimping, and overall general condition
3. Verify structure, grounding, cables and bus assembly:
   a. Anchorage (per local codes, wind and seismic considerations)
   b. Required area clearances, correct alignment and cleanliness.
   c. Verify the grounding electrode conductor is properly sized and terminated
   d. The proper grounding of instruments, panels and connections.
   e. That conductors are properly identified (as applicable)
   f. Cable termination tightness
   g. That all cables have been properly installed, routed and supported

and are clear of energized parts

h. That conduits and conduit bushings are correctly installed

i. Unused openings have been properly closed and secured

j. Tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturers published data.

k. Correct barrier installation.

l. That filters are in place and/or vents are clear from obstructions

4. Verify control and instrumentation (as applicable):

a. All VT and CT ratios properly correspond to drawings and that polarity is correct

b. Shorting screws and bars are removed from CT's and terminal blocks as required

c. Primary and secondary fuse ratings or circuit breakers match drawings

d. Meter scaling and type match drawings

B. ELECTRICAL TESTS

1. Perform a terminal to terminal continuity and resistance measurement using the multi-meter.

2. Perform insulation-resistance tests from terminal(s) to case for 30 sec on the capacitor cells. Ensure any 300V rated control components are isolated / disconnected from the test path.

3. Inspect all electrical connections for high resistance using a low-resistance ohmmeter.

4. Measure resistance of integral discharge resistors. The discharge resistors are three pronged internally delta connected just like the capacitors and have a printed value of the total resistance on them. The measured resistance between any two prongs should measure approximately two thirds of the printed value.

5. Measure the capacitance of all terminal combinations and verify it with the manufacturer's published table.

6. Perform a low voltage test to verify the proper operation of the bank,

a. Remove the three fuses on the primary side of the Control Power Transformer (CPT) located on the control panel.

b. Tie / tape the door interlock limit switch shut to allow the control circuit interlock to be defeated temporarily.

c. Use an available 120V power source, suitably fused and connect the phase to the fuse and neutral to the grounded terminal.

d. While taking appropriate electrical precautions energize the 120V supply and turn the ON/OFF switch on the front of the door to "ON" position.

e. The controller should power on and the ventilation fans should immediately power up. Ensure the fans are rotating in the correct direction by feeling the draft of the air from the enclosure is in "exhaust" mode.

f. Engage the controller in the manual mode and step through the various stages, one step at a time, and hear for the contactor to pull in.

g. Once all contactors have been verified to energize, disconnect the 120V power supply, remove the defeat mechanism of the door interlock and replace the primary control fuses at the CPT.

7. Set control, metering, breaker trip units, and protective relay adjustments. The protective relay, metering, and control settings must be supplied prior to startup by the customers' engineer or from a Power System Study. If not supplied, device settings will be left on factory default.

8. Insulation system:

a. Perform insulation-resistance tests on each bus section, phase-to-phase, phase-to-ground, phase-to-neutral and neutral-to-ground

1. Values shall be in accordance with manufacturer's published data

b. Perform a high potential test for main bus assemblies

1. This field test should be made before the main cables are connected and should not exceed manufacturer's recommendations

2. Transformer primary fuses should be removed and surge protective devices such as capacitors and arresters disconnected during high potential tests

9. Control and Instrumentation (as applicable):

a. Perform the following tests on control power transformers

1. Perform insulation-resistance tests.

2. Perform measurements from winding-to-winding and each winding-to-ground.

3. Perform a turns ratio test

b. Verify operation of heaters.

c. Perform the following tests on potential transformers

1. Perform insulation-resistance tests.

2. Perform measurements from winding-to-winding and each winding-to-ground.

d. Perform the following tests on current transformers

1. Ratio

2. Polarity

10. Test capacitors in accordance with Section 3.19.

11. Verify operation of all protective devices in accordance with Section 3.54.

12. Test all circuit breakers in accordance with Section 3.70.

13. Test all load interrupter switches in accordance with Section 3.39.

3.11 AUTOMATIC TRANSFER CONTROLLER

A. MECHANICAL AND VISUAL INSPECTION

1. Examine relay and accessories for:

a. Shipped loose and shipped short components

b. Shipping damage

c. Loose or obviously damaged components
d. Proper identification
e. Physical damage from installation
f. Physical damage from installation
g. Alignment, dents, scratches, fit, and missing hardware

2. Inspect:
a. All connections for tightness
b. Potential transformers for proper rating, polarity and wiring for all power sources
c. For multi-tap potential transformers check that connections match applied system voltage

B. ELECTRICAL AND FUNCTION TESTS

1. Verifying equipment is ready for electrical testing:
a. Remove and account for all test equipment, jumper wires, and tools used during installation
b. Replace all barriers and covers

2. Simulate control power to the ATC

3. Program settings per manufacturer's instructions and setting provided by the owner to configure the ATC.

4. Apply simulated source voltages to the ATC

5. Insure that all operational LED indicators or HMI on the front of the display are as described in the IB for the system conditions.

6. Perform a functional test of the manual operation

7. Perform a functional test of the Engine start contact using the test button on the front of the controller

8. Perform a functional test of the automatic transfer system

9. [3]Electrical and Function Tests with Normal Power Sources connected
a. Develop a test plan that verifies that the ATC and automatic transfer system perform as designed
b. Before energizing:
1. Remove and account for all test equipment, jumper wires, and tools used during installation
2. Ensure all barriers and covers are in place
c. Measure the control power voltage from each source prior to applying control voltage to the ATC
d. Measure sources 1 and 2 voltages and phasing prior to applying source voltage to the ATC
e. Apply source voltages to the ATC
f. Ensure that all operational LED indicators on the front of the display are as described in the IB for the system conditions

[3] Note to Spec. Writer – Optional

g. Perform a functional test of the automatic transfer system
h. Perform a functional test of the manual operation
i. Perform a functional test of the Engine test using the test button on the front of the controller (if applicable)
j. Perform a utility outage test
k. Contact a customer representative to report results and follow-up actions
l. Document report with actions taken and findings

3.12 BOLTED PRESSURE SWITCH

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the switch and accessories for:
   a. Shipped loose and shipped short components
   b. Shipping damage
   c. Loose or obviously damaged components
   d. Proper identification
   e. Physical damage from installation
   f. If the unit was placed in temporary storage, verify and record that proper procedures were observed. Remove temporary heater wiring and shipping braces
   g. Doors, panels, and sections for alignment, dents, scratches, fit, and missing hardware
   h. Maintenance accessories for servicing and operating all devices
2. Inspect:
   a. Shipping splits to insure that all bus connections were properly connected and all control wiring splits have been properly terminated
      1. Remove all temporary wiring for heaters if equipped
   b. Grounding connections for cleanliness and alignment
   c. Insulators for evidence of physical damage or contaminated surfaces
   d. Surge Arrester and/or Surge Suppression size, type, installation and connection to determine if they are in accordance with the drawings (Refer to NEC Article 280)
   e. Main and arcing blade alignment, penetration, travel stops, and mechanical operation
   f. Verify that fuse sizes and types are in accordance with drawings and short-circuit and coordination study
   g. Verify that each fuse holder has adequate mechanical support
   h. Verify correct phase-barrier materials and installation
   i. Control power transformers
   j. Wiring for damaged insulation, broken leads, tightness of connections, proper crimping, and overall general condition
3. Verify structure, grounding, cables and switch assembly:

a. That conductors are properly identified
b. Cable termination tightness
c. That all cables have been properly installed, routed and supported
d. That conduits and conduit bushings are correctly installed
e. Unused openings have been properly closed and secured
f. Tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturers published data.

4. Verify Key Interlock System (as applicable):
a. Key number and exchange codes
b. Proper sequencing to comply with drawing notes
c. Attempt to close locked-open devices
d. Attempt to open locked-closed devices
e. Make key exchange with devices operated in off-normal positions
f. Disposition of duplicate keys per the owner’s safety policy

B. ELECTRICAL TESTS

1. Primary Circuit Resistance:
a. Measure contact resistance
b. Measure resistance of power fuses

2. Mechanism:
a. Perform five manual close and open operations
b. Inspect for proper lubrication

3. Insulation system:
a. Perform insulation-resistance tests, phase-to-phase and phase-to-ground

4. Verify operation of Ground Protection (as applicable)
a. Use a current source to verify the operation of the ground protection relay or use the test push button to verify the trip of the switch

3.13 BUSHINGS

A. MECHANICAL AND VISUAL INSPECTION

1. Examine bushing for:
a. Shipping damage
b. Physical damage from installation
c. Loose or obviously damaged components
d. Proper identification
e. Damage, defects, and contamination
f. Compliance to the drawings
g. If the unit was placed in temporary storage, verify and record that proper procedures were observed. Remove shipping braces

2. Verify:

a. Tightness of accessible bolted electrical connections with a calibrated torque-wrench
b. That shipping brackets or fixtures have been removed during installation
c. That the bushing has no cracks
d. Bushing is free of dirt or other contaminants
e. That there is no loss of oil or compound

B. ELECTRICAL TESTS

1. Always measure the condition of the Tap-To-Ground insulation when performing power factor tests on bushings equipped with test taps and potential taps
   a. In bushings the tap-to-ground insulation (or, tap insulation) is designated at C_2, whereas the main insulation between the center conductor and tap is referred to as C_1
2. Test the C_1 insulation of the bushing
   a. Remove the capacitance (or PF tap) tap cover from the bushing under test and make connections
   b. Put the Low Voltage switch of PF test in the UST mode
   c. The test voltage should NOT exceed the bushing rating
   d. Measure charging current and watt loss
   e. Calculate PF and capacitance; correct to 20 C
   f. Compare results to manufacturer’s PF and capacitance on nameplate
3. Test the C_2 insulation of the bushing
   a. Remove the capacitance (or PF tap) tap cover from the bushing under test and make connections
   b. Put the Low Voltage switch of PF test in Guard mode
   c. Guard C_1 insulation
   d. Measure charging current and watt loss
   e. Calculate PF and capacitance; correct to 20 C
   f. Compare results to manufacturer’s PF and capacitance on nameplate
   g. Limit test voltages to 500 V for bushings less than 69 kV unless the manufacturer specifies a lower rating for the tap
   h. Limit test voltages to 2,000 V for bushings greater than 72.5 kV
4. Test the insulation of the bushing without capacitance or PF taps, bushing not installed in equipment-i.e., spares
   a. Put Low Voltage switch of PF test in GST mode and make connections
   b. Measure I_T and watts loss; Calculate PF and correct for temperature

3.14 BUSWAY – LOW VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the busway and accessories for:
   a. Shipped loose and shipped short components
   b. Shipping damage
   c. Loose or obviously damaged components
   d. Proper identification
   e. Physical damage from installation
   f. If the unit was placed in temporary storage, verify and record that proper procedures were observed. Remove temporary heater wiring and shipping braces
   g. Sections for alignment, dents, scratches, fit, and missing hardware
2. Inspect:
   a. Joints to insure that all bus connections were properly tightened
   b. Enclosure to insure the filters and drain plugs are properly located
   c. Inspect all ground connections for tightness
      1. A ground strap is provided at each enclosure joint
   d. Main bonding jumper for proper size and termination.
   e. Insulators for evidence of physical damage or contaminated surfaces
3. Verify: (Enclosure, hangers, sealing ring, and bus assembly)
   a. Correct alignment
   b. That busway has been properly installed, routed and supported
   c. Verify the grounding electrode conductor is properly sized and terminated
   d. Tightness of bolted electrical connections by calibrated torque-wrench method in accordance with manufacturers published data
   e. Proper installation of gaskets, felt strips, and sealing rings at enclosure connections
   f. Bus phasing and continuity
   g. Heater circuit wiring and overload protection

B. ELECTRICAL TESTS

1. Perform insulation-resistance tests on each bus section, phase-to-phase and phase-to-ground
   a. Values shall be in accordance with manufacturer's published data
2. Perform an AC high potential test for Medium Voltage main bus assemblies. This field test should be made before the busway is connected and test values should not exceed:
   a. 2.2 kV, 60 HZ, 1 Minute, for 0.635 kV Bus Bust

3. Test continuity and record resistance value of heater circuit

3.15 BUSWAY – MEDIUM VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the Busway and accessories for:
   a. Shipped loose and shipped short components
   b. Shipping damage
   c. Loose or obviously damaged components
   d. Proper identification
   e. Physical damage from installation
   f. If the unit was placed in temporary storage, verify and record that proper procedures were observed. Remove temporary heater wiring and shipping braces
   g. Sections for alignment, dents, scratches, fit, and missing hardware
2. Inspect:
   a. Joints to insure that all bus connections were properly tightened
   b. Enclosure to insure the filters and drain plugs are properly located
   c. Inspect all ground connections for tightness
      1. A ground strap is provided at each enclosure joint
   d. Main bonding jumper for proper size and termination.
   e. Insulators for evidence of physical damage or contaminated surfaces
3. Verify: (Enclosure, hangers, sealing ring, and bus assembly)
   a. Correct alignment
   b. That busway has been properly installed, routed and supported
   c. Verify the grounding electrode conductor is properly sized and terminated
   d. Tightness of bolted electrical connections by calibrated torque-wrench method in accordance with manufacturers published data
   e. Proper installation of gaskets, felt strips, and sealing rings at enclosure connections
   f. Bus phasing and continuity
   g. Heater circuit wiring and overload protection

B. ELECTRICAL TESTS

1. Perform insulation-resistance tests on each bus section, phase-to-phase and phase-to-ground
   a. Values shall be in accordance with manufacturer's published data
2. Perform an AC high potential test for Medium Voltage main bus

assemblies. This field test should be made before the busway is connected and test values should not exceed:

a. 19.0 kV, 60 HZ, 1 Minute, for 4.76 kV Busway
b. 36.0 kV, 60 HZ, 1 Minute, for 15.0 kV Busway

3. Test continuity and record resistance value of heater circuit

3.16 CABLES – LOW VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the cables for:
   a. Physical damage or deformities to exposed portions of cable
   b. That compression-applied connectors are correct for cable and are compressed correctly
   c. Jacket and insulation condition
   d. Correct identification and arrangements
2. Inspect:
   a. Cable termination or load break elbows
   b. For proper shield grounding, cable support, and termination
3. Verify:
   a. That visible cable bends meet or exceed manufacturer's minimum allowable bending radius.
   b. Adequate fireproofing in common cable areas, if specified
   c. Cables terminated through window-type current transformers
      1. Inspect to verify the neutral and ground conductors are correctly placed and that shields are correctly terminated for operation of protective devices
   d. That conduits and conduit bushings are correctly installed
   e. Unused openings have been properly closed and secured
   f. Tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturers published data.
   g. Cables are properly routed through current transformers and shields are properly terminated.
   h. Both ends of cables are properly barricaded off for personnel protection
   i. Cable ends are properly isolated from environmental conditions that would affect test results

B. ELECTRICAL TESTS

1. Perform a shield-continuity test on each power cable with an ohmmeter
2. Record wet and dry-bulb temperatures or relative humidity and temperature
3. Perform an insulation-resistance test using a megohmmeter with a voltage output of 500Vdc for 300V rated cable and 1000Vdc for 600V rated cable.
   a. Individually test each conductor with all other conductors and

shields grounded

b. Test duration shall be one minute

c. Remove test lead with high voltage gloves

d. Apply grounds for a time period adequate to drain all insulation stored charge using high voltage gloves

3.17 CABLES – MEDIUM AND HIGH VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the cables for:
   a. Physical damage or deformities to exposed portions of cable
   b. That compression-applied connectors are correct for cable and are compressed correctly
   c. Jacket and insulation condition
   d. Correct identification and arrangements
2. Inspect:
   a. Cable termination or load break elbows
   b. For proper shield grounding, cable support, and termination
3. Verify:
   a. That visible cable bends meet or exceed manufacturer’s minimum allowable bending radius.
   b. Adequate fireproofing in common cable areas, if specified
   c. Cables terminated through window-type current transformers
      1. Inspect to verify the neutral and ground conductors are correctly placed and that shields are correctly terminated for operation of protective devices
   d. That conduits and conduit bushings are correctly installed
   e. Unused openings have been properly closed and secured
   f. Tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturers published data.
   g. Cables are properly routed through current transformers and shields are properly terminated.
   h. Both ends of cables are properly barricaded off for personnel protection
   i. Cable ends are properly isolated from environmental conditions that would affect test results

B. ELECTRICAL TESTS

1. Perform a shield-continuity test on each power cable with an ohmmeter
2. Record wet- and dry-bulb temperatures or relative humidity and temperature
3. Perform an insulation-resistance test using a megohmmeter with a voltage output of at least 2500 volts
   a. Individually test each conductor with all other conductors and

shields grounded

b. Test duration shall be one minute

c. Remove test lead with high voltage gloves

d. Apply grounds for a time period adequate to drain all insulation stored charge using high voltage gloves

4. Perform a dc high-potential test on all cables. Adhere to all precautions and limits as specified in the applicable NEMA/ICEA Standard for the specific cable. Perform tests in accordance with ANSI/IEEE Standard 400.

a. Test procedure shall be as follows, and the results for each cable test shall be recorded as specified herein. Test voltages shall not exceed 80 percent of cable manufacturer's factory test value or the maximum test voltage in Table 1.

1. Insure that the input voltage to the test set is stable

2. Test each section of cable individually

3. Individually test each conductor with all other conductors grounded

4. Ground all shields

5. Insure that the maximum test voltage does not exceed the limits for terminators specified in IEEE Standard 48 or manufacturer's specifications

6. Apply a dc high-potential test in at least five equal increments until maximum test voltage is reached. No increment shall exceed the voltage rating of the cable

7. Record dc leakage current at each step after a constant stabilization

8. Raise the conductor to the specified maximum test voltage and hold for 15 minutes on shielded cable and five minutes on non-shielded cable

9. Record readings of leakage current at 30 seconds and one minute and at one minute intervals thereafter

10. Reduce the conductor test potential to zero and measure residual voltage at discrete intervals

11. Apply grounds for a time period adequate to drain all insulation stored charge

12. When new cables are spliced into existing cables, the dc high-potential test shall be performed on the new cable prior to splicing. After test results are approved for new cable and the splice is completed, a shield-continuity test and an insulation-resistance test shall be performed on the length of new and existing cable including the splice. After a satisfactory insulation-resistance test, a dc high-potential test shall be performed on the cable utilizing a test voltage acceptable to owner and not exceeding 60 percent of factory test value

5. Shielding must exhibit continuity

a. Investigate resistance values in excess of ten ohms per 1000 feet of cable

6. Graphic plots may be made of leakage current versus step voltage at each increment and leakage current versus time at final test voltages.

7. [3]Perform dielectric withstand test with a very low frequency (VLF) test set.

8. [3]Perform dielectric withstand test with a power frequency test set.

3.18 CAPACITORS – LOW VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine capacitor and accessories for:
   a. Shipped loose and shipped short components
   b. Shipping damage
   c. Loose or obviously damaged components, particularly insulators and bushings for cracks.
   d. Proper identification
   e. Physical damage from installation
   f. Alignment, dents, scratches, fit, and missing hardware
2. Inspect:
   a. Inspect physical and mechanical condition and alignment.
   b. Visually inspect welds for any obvious problems.
   c. Verify that capacitors are electrically connected in their specified configuration, if assembled at time of Site Acceptance Testing.
3. Verify:
   a. Verify that all shipping bracing has been removed.
   b. Any incoming AC Power is turned off and locked out before performing any work on the capacitor.

B. ELECTRICAL TESTS

1. Perform a sampling of inspections of bolted electrical connections for high resistance using a low-resistance ohmmeter.
2. Perform insulation-resistance test from the phase terminal to case.
3. Measure the capacitance of all terminal combinations.
4. Measure resistance of internal discharge resistors.
5. Verify settings of all protective relaying and ensure they are activated (if applicable).
6. Test operate all load-break, disconnect, and grounding switches and secondary accessory equipment (if applicable).
7. Verify all supplied interlocks or other safety devices operate properly.

3.19 CAPACITORS – MEDIUM VOLTAGE

[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional

A. MECHANICAL AND VISUAL INSPECTION

1. Examine meter and accessories for:
   a. Shipped loose and shipped short components
   b. Shipping damage
   c. Loose or obviously damaged components, particularly insulators and bushings for cracks.
   d. Proper identification
   e. Physical damage from installation
   f. Alignment, dents, scratches, fit, and missing hardware
2. Inspect:
   a. Inspect physical and mechanical condition and alignment.
   b. Visually inspect welds for any obvious problems.
   c. Verify that capacitors are electrically connected in their specified configuration, if assembled at time of Site Acceptance Testing.
3. Verify:
   a. Verify that all shipping bracing has been removed.
   b. Any incoming AC Power is turned off and locked out before performing any work on the capacitor.

B. ELECTRICAL TESTS

1. Perform a sampling of inspections of bolted electrical connections for high resistance using a low-resistance ohmmeter.
2. Perform insulation-resistance test from the phase terminal to case.
3. Measure the capacitance of all terminal combinations.
4. Measure resistance of internal discharge resistors.
5. Verify settings of all protective relaying and ensure they are activated (if applicable).
6. Test operate all load-break, disconnect, and grounding switches and secondary accessory equipment (if applicable).
7. Verify all supplied interlocks or other safety devices operate properly.

3.20 CIRCUIT SWITCHERS – HIGH VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine equipment:
   a. Shipping and physical damage
   b. Switch is installed properly i.e. anchored, blades aligned
   c. Dents, scratches, fit, and missing hardware
   d. Loose or obviously damaged components
   e. Proper identification
   f. Compliance to drawings and specifications
   g. Insulators for cracks, contaminated surfaces, mounted

properly, tightness of connections

2. Verify:
   a. Motor operator limit switches are working properly, as applicable adjust is necessary
   b. Mechanical interlocks are functioning as designed
   c. The mechanical operation of the switch i.e. correct blade alignment, blade penetration, pressure, travel stops, arc interrupter operation
   d. Interlocking system sequencing and operation
   e. Correct operation of indicating and control devices (if applicable)
   f. Moving and/or current carrying parts are lubricated per manufacturer recommendation
   g. Switch grounding
   h. Adequate clearances
   i. Bolted electrical connections are properly torqued
   j. Operating rods and interphase linkages are not bent and tightened securely
   k. Operate switch electrically and/or mechanically to ensure proper functioning of switch assembly.

B. ELECTRICAL TESTS

1. Measure contact resistance
   a. Across Switchblades
   b. Fuse holders, if applicable
   c. All bolted, current carrying connections
2. Perform an AC High Potential Test, phase to phase and phase to ground with switch closed, across open contacts
3. Measure resistance of the fuse, if applicable
4. Perform insulation resistance test on control wiring, if applicable

3.21 CUTOUT SWITCHES

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the cutout switch for:
   a. Shipping and physical damage
   b. Shipped loose or shipped short components.
   c. Loose or obviously damaged components
   d. Insulators for evidence of physical damage or contaminated surfaces
   e. Proper alignment, penetration, and mechanical operation
   f. Proper identification
   g. Compliance to the drawings
   h. Physical damage from installation.
2. Verify:

a. Shipping brackets or fixtures have been removed (as applicable)
b. Equipment grounding is correct
c. Main and arcing blade alignment, penetration, travel stops, and mechanical operation
d. Fuse sizes and types are in accordance with drawings and short-circuit and coordination studies
e. Fuse holders have adequate mechanical support.

B. ELECTRICAL TESTS

1. Prior to testing, disconnect any arrestors or other connections that will impact the test being performed.
2. Perform an AC high potential test one pole at a time with the other poles and structure grounded
3. Perform and record resistance measurements for:
a. Switch contact resistance (micro-ohms)
b. Fuse resistance (milliohms), if applicable
c. Fuse and holder resistance (milliohms), if applicable

3.22 DC GENERATORS

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the generator, generator breaker, and control unit for:
a. Shipped loose and shipped short components
b. Shipping damage
c. Loose or obviously damaged components
d. Proper identification
e. Physical damage from installation
f. Remove temporary heater wiring and shipping braces
g. Doors, panels, and sections for alignment, dents, scratches, fit, and missing hardware
h. Maintenance accessories for servicing and operating all devices
2. Inspect:
a. All grounding connections
b. Brushes, air baffles, filter media and cooling fans (if applicable)
c. Commutator
d. Tachometer
e. Insulators for evidence of physical damage or contaminated surfaces
f. Surge Arrestor and/or Surge Suppression size, type, installation and connection to determine if they are in accordance with the drawings
g. Wiring for damaged insulation, broken leads, tightness

of connections, proper crimping, and overall general condition

3. Verify generator enclosure, cables and bus assembly for:
   a. Anchorage (per local codes, wind and seismic considerations)
   b. Required area clearances, correct alignment and cleanliness.
   c. That the grounding electrode conductor is properly sized and connected
   d. That conductors are properly identified
   e. Cable and control wire termination tightness
   f. That all cables have been properly installed, routed and supported
   g. That conduits and conduit bushings are correctly installed
   h. Unused openings have been properly closed and secured
   i. Tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturers published data
   j. That blocks or other temporary holding means used for shipment have been removed from all component devices in the enclosure interior
4. Verify relative polarity of shunt and series field windings and leads are properly marked.

B. ELECTRICAL TESTS

1. Perform an insulation resistance test per ANSI/IEEE Standard 43
   a. Calculate polarization index for machines larger than 200hp.
   b. Calculate dielectric absorption ratio for machines 200hp and less.
2. Perform ac or dc high-potential test per NEMA MG 1, Section 3.1, or IEEE 95, respectively, on the field windings, armature, interpoles and compensating windings (if applicable), and commutator.
3. Measure the resistance of the armature commutator bar-to-bar.
4. [3]Measure armature running and field current or voltage.
5. [3]Perform vibration tests
6. [3]Perform surge impulse comparison test on field and armature winding.
7. [3]Perform voltage drop of field poles.

[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional

3.23 DC MOTOR

A. MECHANICAL AND VISUAL INSPECTION

1. Examine motor for:
   a. Shipped loose and shipped short components
   b. Shipping damage
   c. Loose or obviously damaged
      1. Frame
      2. Termination box
      3. Shaft
      4. Tachometer
      5. Brake
      6. Zero speed switch
      7. Mounting feet or flange
   d. Proper motor lubrication
   e. Coupling alignment and lubrication
   f. Proper identification
   g. Compliance to drawings
   h. Customer field connections and signals
   i. Remove temporary heater wiring and shipping braces
2. Inspect:
   a. All grounding connections
   b. Insulators for evidence of physical damage or contaminated surfaces
   c. Surge Arrestor and/or Surge Suppression size, type, installation and connection to determine if they are in accordance with the drawings.
   d. Wiring for damaged insulation, broken leads, tightness of connections, proper crimping, and overall general condition
3. Verify structure, grounding, cables and bus assembly for:
   a. Anchorage (per local codes, wind and seismic considerations)
   b. Required area clearances, correct alignment and cleanliness.
   c. That the grounding electrode conductor is properly sized.
   d. That conductors are properly identified
   e. Cable and control wire termination tightness
   f. That all cables have been properly installed, routed and supported
   g. That conduits and conduit bushings are correctly installed
   h. Unused openings have been properly closed and secured
   i. Tightness of accessible bolted electrical connections by

calibrated torque-wrench method in accordance with manufacturers published data

j. That blocks or other temporary holding means used for shipment have been removed from the motor

k. That filters are in place and/or vents are clear from obstructions

B. ELECTRICAL TESTS

1. Perform an insulation resistance test per ANSI/IEEE Standard 43

a. Calculate polarization index for machines larger than 200hp.

b. Calculate dielectric absorption ratio for machines 200hp and less.

2. Perform ac or dc high-potential test per NEMA MG 1, Section 3.1, or IEEE 95, respectively, on the field windings, armature, interpoles and compensating windings (if applicable), and commutator.

3. Measure the resistance of the armature commutator bar-to-bar.

4. [3]Measure armature running and field current or voltage.

5. [3]Perform vibration tests

6. [3]Perform surge impulse comparison test on field and armature winding.

7. [3]Perform voltage drop of field poles.

3.24 DISTRIBUTION DRY-TYPE TRANSFORMERS (75KVA AND ABOVE)

A. MECHANICAL AND VISUAL INSPECTION

1. Examine transformer for:

a. Shipping damage

b. Physical damage from installation

c. Doors, panels, and sections for alignment, dents, scratches, fit, and missing hardware

d. Loose or obviously damaged components

e. Proper identification

f. Damage, defects, and contamination to the core and coil assemble

g. Compliance to the drawings

2. Verify:

a. Tightness of accessible bolted electrical connections with a calibrated torque-wrench (if specified)

[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional

b. Shipping brackets or fixtures have been removed (as applicable)
c. Resilient mounts are free per manufacturer's instructions
d. Winding core, frame, and enclosure grounds are correct
e. Cooling fan blades turn freely (as applicable)
f. Thermocouple or RTD wires are secured and clear of line conductors (as applicable)

B. ELECTRICAL TESTS

1. Perform Insulation Resistance Tests (as applicable). Do not test insulation resistance of transformers with DC voltage above 1000v without obtaining manufacturer's approval
   a. High to Low and Ground
   b. Low to High and Ground
2. Verify that core is solidly grounded
   a. If core is insulated and a removable core ground strap is available, perform core insulation-resistance test at 500 volts dc
3. Perform a turns-ratio test on all tap connections; retest on tap as left and record
4. Verify that winding polarities are in accordance with nameplate
5. Using temporary control power, verify that cooling fans operate correctly
6. Verify/set temperature relay setting.
7. [3]Perform a winding resistance test
8. [3]Calculate the Polarization Index

3.25 DRY-TYPE SUBSTATION TRANSFORMERS

A. MECHANICAL AND VISUAL INSPECTION

1. Examine transformer for:
   a. Shipping damage
   b. Physical damage from installation
   c. Doors, panels, and sections for alignment, dents, scratches, fit, and missing hardware
   d. Loose or obviously damaged components
   e. Proper identification
   f. Damage, defects, and contamination to the core and coil assemble
   g. Compliance to the drawings

[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional

2. Verify:
   a. Tightness of accessible bolted electrical connections with a calibrated torque-wrench (if specified)
   b. Shipping brackets or fixtures have been removed (as applicable)
   c. Resilient mounts are free per manufacturer's instructions
   d. Winding core, frame, and enclosure grounds are correct
   e. Cooling fan blades turn freely (as applicable)
   f. Thermocouple or RTD wires are secured and clear of line conductors (as applicable)

B. ELECTRICAL TESTS

1. Perform Insulation Resistance Tests (as applicable). Do not test insulation resistance of transformers with DC voltage above 1000v without obtaining manufacturer's approval
   a. High to Low and Ground
   b. Low to High and Ground
2. Verify that core is solidly grounded
   a. If core is insulated and a removable core ground strap is available, perform core insulation-resistance test at 500 volts dc
3. Perform a turns-ratio test on all tap connections; retest on tap as left and record
4. Verify that winding polarities are in accordance with nameplate
5. Using temporary control power, verify that cooling fans operate correctly
6. Verify/set temperature relay setting.
7. [3]Perform a winding resistance test
8. [3]Calculate the Polarization Index
9. [3]Perform a Power Factor or Dissipation Factor Test

3.26 ELECTRIC VEHICLE SUPPLY EQUIPMENT

A. MECHANICAL AND VISUAL INSPECTION

1. Inspect enclosure for structural integrity.
2. Inspect for loose, broken or missing hardware or components.
3. Inspect the electrical connections and perform a pull test on all customer and factory connections by giving a firm tug on all the connections.

[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional

4. Check tightness of bolted connections.
5. Inspect control wiring connections for tightness.
6. Inspect power cable for tightness (if accessible), insulation fraying and clearances.
7. Review EVSE connection for proper installation.
   a. Incoming power and communication wiring are each in their own conduit.
   b. All wiring has been accomplished to manufacturer's specifications for the size of the EVSE .
   c. The EVSE is clean and free of installation debris, equipment, or tools.

B. INITIAL ENEGIZATION

1. Perform Pre-Power meter checks.
   a. Confirm all power sources are tagged and locked and are de-energized.
   b. Verify battery and capacitors are discharged.
   c. Perform insulation resistance testing on EVSE leads
   d. Perform static checks in accordance with manufacturer's model-specific instructions
2. Perform initial power on safety checks.
   a. Ensure all appropriate control / communication wiring has been reconnected.
   b. Conduct a walk around of the EVSE and its connected load.
   c. Remove tags and locks for the disconnect supplying power to the EVSE disconnect.
   d. When safe to do so, energize the disconnect that supplies power to the EVSE disconnect.
   e. Using the DMM measure the AC line voltage at the supply side of the EVSE disconnect
   f. Record phase to phase voltage and phase to ground voltage
   g. Phase to phase are balanced within < 2%
   h. Phase to ground are balanced within < 2%
   i. Measure and record bus voltage
   j. Verify fans are operating properly
   k. Note any abnormal sound from running fans and power units.
   l. Verify proper operation of EMERGERNCY STOP button.
3. Setting the EVSE Parameters
   a. Program EVSE parameters as specified by the application and in accordance manufacturer's model-specific instructions

3.27 ELECTRONIC METERS

A. MECHANICAL AND VISUAL INSPECTION

1. Examine meter and accessories for:
   a. Shipped loose and shipped short components
   b. Shipping damage
   c. Loose or obviously damaged components
   d. Proper identification
   e. Physical damage from installation
   f. Alignment, dents, scratches, fit, and missing hardware
2. Inspect:
   a. All connections for tightness
   b. Current transformers for proper rating, polarity and wiring
3. Verify:
   a. Proper operation of indicators and displays
   b. Meter is correct for application
   c. Grounding

B. ELECTRICAL TESTS

1. Apply the appropriate AC control power to the meter.
2. Set the basic programming parameters for the system:
   a. Instrument transformer ratios
   b. System configuration
   c. Frequency
3. [3]Perform simulation tests to verify proper response of Voltage, Current, Frequency, Power Factor, kW, kVA, and kVAR functions.

3.28 GRID-TIED SOLAR INVERTER – UTILITY SCALE

A. REQUIRED DOCUMENTATION

1. Complete the Solar-Inverter Installation checklist prior to commissioning the inverter, including
   a. Medium Voltage Pad-Mounted Transformer site acceptance testing
   b. Inverter / Solar-System monitoring communications are operational
   c. SCADA Control is operational, as appropriate to commissioning the inverter
   d. Photovoltaic-modules, Transformer, and Inverter ready to be energized
   e. Utility power is available: supply and receive power to/from solar system.

[3] Note to Spec. Writer – Optional

B. ELECTRICAL TESTS

1. Insulation system:
   a. Perform insulation-resistance tests on each bus section, phase-to-phase, phase-to-ground, phase-to-neutral and neutral-to-ground
      1. Values shall be in accordance with manufacturer's published data
2. Control and Instrumentation (as applicable):
   a. Perform the following tests on control power transformers
      1. Perform insulation-resistance tests. Perform measurements from winding-to-winding and each winding-to-ground.
      2. unless otherwise specified by manufacturer
      3. Perform a turns ratio test
      4. Verify correct function of control transfer relays located in switchgear
      5. Verify operation of switchgear/switchboard heaters
   b. Perform the following tests on potential transformers
      1. Perform insulation-resistance tests. Perform measurements from winding-to-winding and each winding-to-ground.
      2. Perform the following tests on current transformers
         a. Ratio
         b. Polarity
3. Ground fault system (as applicable):
   a. Perform ground-fault test in accordance with manufacturer’s guidelines.
4. Verify operation of all protective devices.
5. Metering and power monitoring devices:
   a. Set up all meters or similar devices

3.29 GROUND FAULT PROTECTIONS SYSTEMS – LOW VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the Ground Fault System and accessories for:
   a. Shipped loose and shipped short components
   b. Physical damage from shipping or installation
   c. Loose components
   d. Proper identification
   e. Maintenance accessories for servicing and operating all devices, as required.
2. Inspect:
   a. Grounding electrode conductor to assure proper size and correct switchboard termination.
   b. Switchboard main bonding jumper for:
      1. Proper size

2. Termination on the source side of the neutral disconnect link
3. Termination on the source side of the zero sequence sensor or residual system neutral sensor

c. Switchboard neutral bus downstream of the neutral disconnect link to verify the absence of ground connections

d. Neutral scheme is correct to the provided prints, where applicable

3. Verify:

a. The ground sensor(s)are properly located around appropriate conductors

1. Zero sequence systems require that all phase conductors and the neutral pass through the sensor in the same direction
2. The grounding conductors do not pass through zero sequence sensors
3. Residual systems require that all phase and neutral conductors incorporate a sensor
4. That the neutral sensor is connected with the correct polarity on both the primary and secondary for residual systems and is the correct type / size.
5. Inspect wiring per manufacturer provided drawings for proper termination and that shipping split wiring (if applicable) has been connected.

B. ELECTRICAL TESTS

1. Settings:

a. Pickup and time-delay settings in accordance with the settings provided by the engineer of record. If no settings are present the breaker, or relay, will be left at minimum pickup values.

2. Verify Ground Fault System Performance for:

a. Correct response of the circuit-interrupting device by primary ground sensor current injection. Secondary injection can be performed if the device is capable of being tested by a secondary injection test set.

b. Measure and record ground fault relay pickup current and confirm timing to manufacturer’s curves at two separate points greater than 125%

3. Test reduced control voltage tripping operation at 57 percent of the rated voltage for zero sequence systems, where applicable.:

a. Verify correct Control Power Transformer secondary voltage by energizing primary winding at rated voltage with temporary test power.

1. Measure secondary voltage with the secondary wiring connected

b. Proper operation of ground fault indicator for correct indication of the ground fault trip

c. Proper sensor polarity of phase and neutral sensors for residual systems

1. Trip test

2. No trip test
3. Non-automatic operation

C. Neutral-To-Ground Insulation Resistance Measurement:

1. Remove the neutral disconnect link and measure the insulation resistance between the neutral to ground to verify the absence of grounds downstream of the neutral disconnect link. Test voltage shall be 1000V DC for one minute.

3.30 GROUND RESISTANCE

A. TESTING METHOD

1. Test ground resistance using one of the following two methods:
   a. Direct Method, or Two-Terminal Test
   b. Fall-of-Potential Method, or Three-Terminal Test

B. DIRECT METHOD LIMITATIONS

1. With this method, resistance of two electrodes is series is measured – the driven rod and the water system. But there are three important limitations:
   a. The water-pipe system must be extensive enough to have a negligible resistance
   b. The water-pipe system must be metallic throughout, without any insulating couplings or flanges
   c. The earth electrode under test must be far enough away from the water-pipe system to be outside is sphere of influence
2. In some locations, your earth electrode may be so close to the water-pipe system that you cannot separate the two by the required distance for measurement by the two-terminal method. Under these circumstances, if condition 1 and 2 above are met, you can connect to the water-pipe system and obtain a suitable earth electrode.

C. GROUND RESISTANCE VALUES

1. The NEC code states that the resistance to ground shall not exceed 25 ohm. This is the maximum value of ground resistance and in most applications a much lower ground resistance is required.
2. Accepted industry standards stipulate that transmission substations should be designed not to exceed one-ohm resistance. In distribution substations, the maximum recommended resistance is 5 ohm or even 1 ohm. In most cases, the buried grid system of any substation will provide the desired resistance.
3. In light industrial or in telecommunication central offices, 5 ohm is often the accepted value. For lightning protection, the arresters should be coupled with a maximum ground resistance of 1 ohm. Table 1 shows typical values of ground resistance for various types of installations.

3.31 GROUND RESISTOR

A. MECHANICAL AND VISUAL INSPECTION

1. Examine ground resistor and associated components for:

a. Shipping damage
b. Physical damage from installation
c. Loose or obviously damaged components
d. Proper identification
e. Damage, defects, and contamination to the resistor assemblies
f. Proper Installation
g. Compliance to the drawings
h. Remove shipping braces

2. Verify:
a. Resistor nameplate data is appropriate for application.
b. Tightness of accessible bolted electrical connections
c. Frame and enclosure grounds are correct
d. Current transformer is properly installed (as applicable)
e. Proper grounding

B. ELECTRICAL TESTS

1. Measure transformer ratio.
2. Perform primary and secondary insulation resistance tests.
3. Measure resistance value.
4. Test current transformer (as applicable)
5. Perform electrical circuit checks on entire secondary circuit.

3.32 INFRARED THERMOGRAPHY

A. VISUAL AND MECHANICAL INSPECTION

1. Remove all accessible and necessary covers prior to thermographic inspection. Use appropriate caution, safety devices, and personal protective equipment to provide a clear line of site to the equipment to be scanned.
2. In some cases, the infrared inspection may be conducted through permanently installed view ports or infrared transparent windows.
3. When significant, the environmental conditions surrounding the exception including the air temperature, wind speed and direction, and the sky conditions.
4. Scan all viewable bus, bus joints, feeder connections, and power stabs inside the enclosure to detect abnormal thermal conditions.
5. Scan viewable busway connections to switchgear.
6. Photograph thermal abnormalities to document for the customer report. Provide specific recommendations as to the severity of problems found, recommended correction times and corrective action required.
7. Particular attention should be given to perspective, focus, contrast, resolution, and lighting. Visible light images should align with the thermal image as closely as possible.
8. Place an infrared thermography sticker on the equipment scanned

identifying the date of service.

B. SERVICE REPORT

1. Provide a thermographic survey report that includes the following:.
   a. Designation / description of the equipment scanned.
   b. Discrepancies noted and locations.
   c. Temperature difference between the area of concern and the reference area.
   d. Probable cause of temperature difference.
   e. Areas inspected. Identify inaccessible and unobservable areas and equipment.
   f. Identify load conditions at time of inspection.
   g. Including color photographs and a specific recommendation for each abnormal hot-spot condition. One photograph will show the hot-spot area and temperature rise above ambient.
   h. Provide specific recommendations as to the severity of problems found, recommended correction times and corrective action required.

C. TEST PARAMETERS

1. Perform infrared thermography when at least 50% of the load is applied to the system and after 2 hours of operation.
2. Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1° C at 30° C.
3. Infrared Equipment shall detect emitted radiation and convert detected radiation to visual signal.

3.33 INSTRUMENT TRANSFORMERS

A. MECHANICAL AND VISUAL INSPECTION

1. Inspect enclosure for structural integrity (if applicable).
2. Verify proper door latching, interlocking and grounding operation for draw-out types.
3. Inspect for loose, broken or missing hardware or components.
4. Inspect the electrical connections and perform a pull test on all customer and factory connections by giving a firm tug on all the connections.
5. Check tightness of bolted connections.
6. Inspect cable for tightness (if accessible), insulation fraying and clearances.
7. Verify proper location and configuration of current transformers.
8. Confirm all voltage and current ratios properly correspond to drawings and that polarity is correct
9. Remove shorting screws and bars are from current transformers and terminal blocks as required
10. Verify primary and secondary fuse ratings or circuit breakers match drawings

11. Verify current transformer secondary circuits are grounded in accordance with ANSI/IEEE C57.13.3 and correspond to locations on engineer drawings.

B. ELECTRICAL TESTS

1. Perform the following tests on control power transformers
   a. Perform insulation-resistance tests. Perform measurements from winding-to-winding and each winding-to-ground.
   b. Perform the following tests on potential and voltage transformers
      1. Perform insulation-resistance tests. Perform measurements from winding-to-winding and each winding-to-ground.
      2. Polarity
2. Perform the following tests on current transformers in accordance with the testing methods in ANSI/IEEE C57.13.1
   a. Ratio
   b. Polarity

3.34 INSULATED CASE CIRCUIT BREAKERS

A. MECHANICAL AND VISUAL INSPECTION

1. Examine breaker for:
   a. Shipping damage and status of the tip over indicator
   b. Loose or obviously damaged components
   c. Application with the cell
   d. Compliance to drawings
2. Inspect
   a. Primary leads, insulators, current transformer mounting and terminations, and secondary disconnects
   b. Trip unit mounting and connectors
   c. Frame condition
   d. Mechanical and safety interlocks
   e. Ground contact
   f. Neutral current transformer polarity, connections and mounting (as applicable)
   g. Inspect arc chutes for cracks and defects. (if accessible)
   h. With the breaker open:
      1. Inspect the condition of the main and arcing contacts (if accessible).
      2. Inspect insulating links/push rods and interphase barriers for cracks and defects.
   i. With the breaker closed:
      1. Inspect main contact engagement (if accessible).
      2. Inspect arcing contact engagement (if accessible).
3. Verify the manual operation of the breaker:

a. Charge closing spring using manual charge handle
b. Close breaker manually
c. Trip breaker manually
d. Mechanical interlocks

4. Rack the breaker into the cell (“Test Position” as applicable) and check for binding or hesitation and the movement of the breaker position indicator.

5. Verify the proper operation of all breaker/cell accessories, auxiliary switches, cell MOC and TOC switches, and key interlocks (as applicable).

6. Verify the proper operation of all breaker /cell safety interlocks (if draw-out):
a. Closed breaker insertion/withdrawal interlock
b. Stored energy removal interlock
c. Breaker/cell rating code interlock

7. Verify proper operation of all status indicators (as applicable)

B. FUNCTIONAL TESTS WITH BREAKER IN CELL

1. Verify manual operation of breaker

2. Verify the electrical operation of each breaker (as applicable)

C. ELECTRICAL TESTS

1. Test the insulation resistance on each pole, phase-to-phase and phase-to-ground with the circuit breaker closed.

2. Test the insulation resistance across each pole, with the circuit breaker open.

3. Measure contact resistance using a digital low-resistance ohmmeter.

4. Test limiter resistance (as applicable)

5. Trip Unit Tests
a. Program trip unit settings per manufacturer’s instructions and in accordance with settings provided by the owner or approved coordination study device setting table otherwise test on default / minimum settings.
b. Check status of rating plug mounted battery (as applicable)
c. Verify all functions of the trip unit utilizing the manufacturer’s specified trip unit test device and record results.

6. Reset trip flags and restore all settings changed during testing

7. [3]Verify the proper operation of any automatic or remote control schemes, protective relays, and lock-out (86) devices which are integral to the breaker control circuit

8. [3]Verify all functions of the trip unit by means of primary current injection and record results.

9. [3]Perform an individual pole resistance test (millivolt drop)

[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional

3.35 LIQUID-TYPE SUBSTATION TRANSFORMERS

A. MECHANICAL AND VISUAL INSPECTION

1. Examine transformer for:
   a. Shipping and physical damage
   b. Impact recorder prior to unloading (as applicable)
   c. Tank, flanges and cooling fins for alignment, dents, scratches, fit, and missing hardware
   d. Loose or obviously damaged components
   e. Proper identification
   f. Compliance to the drawings
   g. Leaks
2. Verify:
   a. Shipping brackets or fixtures have been removed (as applicable)
   b. The correct liquid level in all tanks, bushings and cooling fins
   c. Proper pressure is maintained on nitrogen-blanketed transformers (as applicable)
   d. Equipment grounding is correct
   e. Cooling fan blades turn freely and appropriate safety guards are in place (as applicable)
   f. Alarm, control, and trip settings on temperature indicators (as applicable)

B. ELECTRICAL TESTS

1. Perform a turns-ratio test at all tap positions; retest on tap as left and record. Verify that winding polarities are in accordance with nameplate
2. Perform winding resistance tests on each winding separately.
3. Perform insulation resistance tests (as applicable).
   a. High to Ground
   b. Low to Ground
   c. High to Low
4. Using customer supplied temporary control power verify that control and alarm settings on temperature indicators are as specified
5. Test operation of all applicable alarm, control, and trip circuits from temperature and level indicators and fault pressure relay.
6. Test bushings and surge arrestors if present.
7. [3]Perform a power factor or dissipation factor test on all windings and bushings.
8. [3]Make C1 and C2 tests on bushings equipped with power factor or capacitance taps.

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[3] Note to Spec. Writer – Optional

[3] Note to Spec. Writer – Optional

9. [3]Perform individual exciting current tests on each phase.

10. [3]Perform a field oil dielectric breakdown test

11. [3]If core ground is accessible, measure core insulation resistance at 500 volts dc

12. [3]Polarization index test

13. [3]Sweep frequency response analysis

C. INSULATING LIQUID ANALYSIS

1. Collect an oil sample to be sent to a test lab for general fluid analysis including the following tests: Furanic Compound Analysis, Moisture Content, Color, Dielectric, Power Factor @ 25C, Interfacial Tension and Acid Number.

2. Collect an oil sample to be sent to a test lab for dissolved gas analysis (DGA)

3.36 LOW VOLTAGE POWER CIRCUIT BREAKERS

A. MECHANICAL AND VISUAL INSPECTION

1. Examine breaker for:
   a. Shipping damage and status of the tip over indicator
   b. Loose or obviously damaged components
2. Application with the cell
3. Compliance to drawings
4. Inspect
   a. Primary leads, insulators, current transformer mounting and terminations, and secondary disconnects
   b. Trip unit mounting and connectors
   c. Frame condition
   d. Mechanical and safety interlocks
   e. Ground contact
   f. Neutral current transformer polarity, connections and mounting (as applicable)
   g. Inspect arc chutes for cracks and defects.
   h. With the breaker open:
      1. Inspect the condition of the main and arcing contacts
      2. Inspect insulating links/push rods and interphase barriers for cracks and defects.
   i. With the breaker closed:
      1. Inspect main contact engagement
      2. Inspect arcing contact engagement

[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional

5. Verify the manual operation of the breaker:
   a. Charge closing spring using manual charge handle
   b. Close breaker manually
   c. Trip breaker manually
   d. Mechanical interlocks
6. Rack the breaker into the cell (“Test Position” as applicable) and check for binding or hesitation and the movement of the breaker position indicator (if applicable).
7. Verify the proper operation of all breaker/cell accessories, auxiliary switches, cell MOC and TOC switches, and key interlocks (as applicable).
8. Verify the proper operation of all breaker /cell safety interlocks (if applicable):
   a. Closed breaker insertion/withdrawal interlock
   b. Stored energy removal interlock
   c. Breaker/cell rating code interlock
9. Verify proper operation of all status indicators (as applicable)

B. FUNCTIONAL TESTS WITH BREAKER IN CELL

1. Verify manual operation of breaker
2. Verify the electrical operation of each breaker (as applicable)

C. ELECTRICAL TESTS

1. Test the insulation resistance on each pole, phase-to-phase and phase-to-ground with the circuit breaker closed.
2. Test the insulation resistance across each pole, with the circuit breaker open.
3. Measure contact resistance using a digital low-resistance ohmmeter.
4. Test limiter resistance (as applicable)
5. Trip Unit Tests
   a. Program trip unit settings per manufacturer’s instructions and in accordance with settings provided by the owner or approved coordination study device setting table otherwise test on default / minimum settings.
   b. Check status of rating plug mounted battery (as applicable)
   c. Verify all functions of the trip unit utilizing the manufacturer’s specified trip unit test device and record results.
   d. Reset trip flags and restore all settings changed during testing
6. [3]Verify the proper operation of any automatic or remote control schemes, protective relays, and lock-out (86) devices which are integral to the breaker control circuit
7. [3]Verify all functions of the trip unit by means of primary current injection and record results.

[3] Note to Spec. Writer – Optional

[3] Note to Spec. Writer – Optional

8. [3]Perform an individual pole resistance test (millivolt drop)

3.37 MEDIUM VOLTAGE SWITCH

A. MECHANICAL AND VISUAL INSPECTION

1. Inspect:
   a. Main and arcing blade alignment, penetration, travel stops, and mechanical operation in accordance with manufacturer's instruction book.
   b. Verify that fuse sizes and types are in accordance with drawings (as applicable)
   c. Verify that expulsion-limiting devices are in place and orientation is correct on all holders having expulsion-type elements (as applicable)
   d. Verify that each fuse holder has adequate mechanical support (as applicable)
   e. Verify correct phase-barrier materials and installation

B. ELECTRICAL TESTS

1. Insulation system:
   a. Perform an AC high potential test one pole at a time with the other poles and structure grounded.
   b. Perform and record resistance measurements for:
      1. Switch contact resistance
      2. Fuse resistance (as applicable)
      3. Fuse and holder resistance (as applicable)

3.38 METAL-CLAD VACUUM CIRCUIT BREAKER SWITCHGEAR

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the switchgear line-up, including breakers, and accessories for:
   a. Shipped loose and shipped short components
   b. Ensure factory supplied loose components are installed. Includes seam covers, boot joints, hardware, etc.
   c. Shipping damage
   d. Loose or obviously damaged components
   e. Proper identification
   f. Physical damage from installation
   g. Doors, panels, and sections for alignment, dents, scratches, fit, and missing hardware
      1. Note alignment of racking rails and mechanisms.
   h. Maintenance accessories for servicing and operating all devices
2. Inspect:
   a. Shipping splits to ensure that all bus connections were

[3] Note to Spec. Writer – Optional

properly connected and all control wiring splits have been properly terminated by contractor.

b. Remove all temporary wiring for heaters if equipped

c. Inspect grounding connections

d. Insulators for evidence of physical damage or contaminated surfaces

e. Surge Arrester and/or Surge Suppression (as applicable)

f. Breaker Cell(s), Primary and Secondary Disconnects for physical condition, cleanliness and lubrication (as applicable)

g. Alignment and penetration of instrument transformer withdrawal disconnects, current carrying, and grounding components (as applicable)

h. Control power transformers (as applicable)

i. Wiring for damaged insulation, broken leads, proper crimping, and overall general condition

3. Verify structure, grounding, cables and bus assembly:

a. Anchorage (per manufacturer's instructions)

b. Required area clearances, correct alignment and cleanliness.

c. Verify the grounding electrode conductor is properly sized and terminated

d. The proper grounding of instruments, panels and connections.

e. That conductors are properly identified (as applicable)

f. That all cables have been properly installed, routed and supported and are clear of energized parts

g. Verify factory connections by checking at least 10% of the total factory connections for tightness. If this spot check reveals loose connections, proceed to check all factory connections. These connections include bus hardware connections, circuit breaker and switch terminals, contactors, metering, and other connections, including the incoming terminals.

h. That conduits and conduit bushings are correctly installed

i. Unused openings have been properly closed and secured

j. Correct barrier and shutter installation and operation

k. That filters are in place and/or vents are clear from obstructions

l. A plenum and duct assembly is properly installed on top of the switchgear, when applicable.

m. Pressure relief devices are free to operate, when applicable.

4. Verify control and instrumentation (as applicable):

a. All VT and CT ratios properly correspond to drawings and that polarity is correct

b. Shorting screws and bars are removed from CT's and terminal blocks as required

c. Primary and secondary fuse ratings or circuit breakers match drawings

d. Meter scaling and type match drawings

5. Verify the proper operation of all circuit breaker cell and safety interlocks operation for fail-safe function.

6. Verify cell rejection plates are properly aligned and draw-out circuit breakers cannot be inserted into cells with the circuit breakers in the “closed” position.

7. Verify mechanical operation of MOC/TOC contact blocks Verify contact closure on at least 1 contact per switchgear cell.

8. Verify Key Interlock System (as applicable):

a. Key number and exchange codes

b. Proper sequencing to comply with drawing notes

c. Attempt to close locked-open devices

d. Attempt to open locked-closed devices

e. Make key exchange with devices operated in off-normal positions

f. Disposition of duplicate keys per the owner’s safety policy

B. ELECTRICAL TESTS

1. Insulation system:

a. Perform insulation-resistance tests on each bus section, phase-to-phase and phase-to-ground.

b. Perform a high potential test for main bus assemblies

a. This field test should be made before the main cables are connected and should not exceed manufacturer’s recommendations

b. Transformer primary fuses should be removed and surge protective devices such as capacitors and arresters disconnected during high potential tests

2. Control and Instrumentation (as applicable):

a. Perform the following tests on control power transformers:

1. Insulation-resistance measurements from winding-to-winding and each winding-to-ground.

2. Turns ratio test

b. Perform the following tests on voltage transformers:

1. Insulation-resistance measurements from winding-to-winding and each winding-to-ground.

2. Polarity

c. Verify correct function of control power transfer relays.

d. Verify operation of heaters.

e. Perform the following tests on current transformers in accordance with the testing methods in ANSI/IEEE C57.13.1

1. Ratio

2. Polarity

3. Verify operation of all vacuum circuit breakers per 3.68.

4. Verify operation of all protective relays per 3.52.

5. Test surge arresters in accordance with 3.61.

6. Test all medium voltage switches per 3.37.

7. Set up all metering and power monitoring devices in accordance with 3.27.

8. Test all integrated power distribution products in accordance with the applicable specification section.

9. [3]Perform a bus joint resistant test through all sections using a 100A low-resistance ohmmeter.

10. [3]Perform the excitation test on current transformers used in protective relay applications in accordance with the testing methods in ANSI/IEEE C57.13.1

11. [3]Measure current transformer burdens.

12. [3]Measure voltage transformer burdens.

3.39 METAL-ENCLOSED CONTROL – MEDIUM VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the Metal-Enclosed Control line-up for:
   a. Shipped loose and shipped short components
   b. Ensure factory supplied loose components are installed. Includes seam covers, boot joints, hardware, etc.
   c. Shipping damage
   d. Loose or obviously damaged components
   e. Proper identification, compare equipment nameplate data with drawings and specifications.
   f. Physical damage from installation
   g. Doors, panels, and sections for alignment, dents, scratches, fit, and missing hardware
   h. Maintenance accessories for servicing and operating all devices
2. Inspect:
   a. Shipping splits to ensure that all bus connections were properly connected and all control wiring splits have been properly terminated by contractor.
   b. Temporary wiring for heaters and remove if not already completed by installing contractor.
   c. Inspect grounding connections
   d. Insulators for evidence of physical damage or contaminated surfaces
   e. Surge Arrester and/or Surge Suppression (as applicable)
   f. Starter Cell(s), Isolation Disconnects for physical condition, cleanliness and lubrication (as applicable)
   g. Alignment and penetration of instrument transformer withdrawal disconnects, current carrying, and grounding components (as applicable)
   h. Control power transformers (as applicable)
   i. Wiring for damaged insulation, broken leads, proper crimping, and overall general condition
   j. Verify that fuse sizes and types comply with drawings and coordination study.

[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional

k. When applicable, verify arc-resistant plenum, duct, and flap assembly are installed and functioning correctly.

3. Verify structure, grounding, cables and bus assembly:

a. Anchorage (per local codes, wind and seismic considerations)

b. Required area clearances, correct alignment and cleanliness.

c. Verify the grounding electrode conductor is properly sized and terminated

d. The proper grounding of instruments, panels and connections.

e. That conductors are properly identified (as applicable)

f. Cable termination tightness

g. That all cables have been properly installed, routed and supported and are clear of energized parts

h. Verify factory connections by checking at least 10% of the total factory connections for tightness. If this spot check reveals loose connections, proceed to check all factory connections. These connections include bus hardware connections, circuit breaker and switch terminals, contactors, metering, and other connections, including the incoming terminals.

i. That conduits and conduit bushings are correctly installed

j. Unused openings have been properly closed and secured

k. Correct barrier and shutter installation and operation

l. That filters are in place and/or vents are clear from obstructions

m. That isolation switch is operating correctly

4. Verify control and instrumentation (as applicable):

a. All VT and CT ratios properly correspond to drawings and that polarity is correct

b. Shorting screws and bars are removed from CT’s and terminal blocks as required

c. Primary and secondary fuse ratings or circuit breakers match drawings

d. Meter scaling and type match drawings

5. Verify the proper operation of all starter cell and safety interlocks operation for fail-safe function.

a. Verify Key Interlock System (as applicable):

1. Key number and exchange codes
2. Proper sequencing to comply with drawing notes
3. Attempt to close locked-open devices
4. Attempt to open locked-closed devices
5. Make key exchange with devices operated in off-normal positions
6. Disposition of duplicate keys per the owner’s safety policy

B. ELECTRICAL TESTS

1. Insulation system:

a. Perform insulation-resistance tests on each bus section, phase-to-phase and phase-to-ground.

b. Perform a high potential test for main bus assemblies

1. This field test should be made before the main cables are connected and

should not exceed manufacturer's recommendations

2. Transformer primary fuses should be removed and surge protective devices such as capacitors and arresters disconnected during high potential tests

2. Control and Instrumentation (as applicable):

a. Perform the following tests on control power transformers:

1. Insulation-resistance measurements from winding-to-winding and each winding-to-ground.

2. Turns ratio test

b. Perform the following tests on voltage transformers:

1. Insulation-resistance measurements from winding-to-winding and each winding-to-ground.

2. Polarity

c. Verify correct function of control power transfer relays.

d. Verify operation of heaters.

e. Perform the following tests on current transformers in accordance with the testing methods in ANSI/IEEE C57.13.1

1. Ratio

2. Polarity

3. Verify operation of all protective devices per applicable specification section.

4. Verify operation of all protective relays per applicable specification section.

5. Test surge arresters in accordance with applicable specification section.

6. Test all medium voltage starters per the applicable specification section.

7. Test all medium voltage switches per applicable specification section.

8. Set up all metering and power monitoring devices in accordance with applicable specification section.

9. [3]Perform a bus joint resistant test through all sections using a 100A low-resistance ohmmeter.

10. [3]Perform the excitation test on current transformers used in protective relay applications in accordance with the testing methods in ANSI/IEEE C57.13.1

11. [3]Measure current transformer burdens.

12. [3]Measure voltage transformer burdens.

3.40 METAL-ENCLOSED SWITCHGEAR – MEDIUM VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the switchgear line-up, including breakers, and accessories for:

a. Shipped loose and shipped short components

b. Shipping damage

c. Loose or obviously damaged components

[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional

d. Proper identification

e. Physical damage from installation

f. Doors, panels, and sections for alignment, dents, scratches, fit, and missing hardware

1. Note alignment of racking rails and mechanisms.

g. Maintenance accessories for servicing and operating all devices

2. Inspect:

a. Shipping splits to ensure that all bus connections were properly connected and all control wiring splits have been properly terminated by contractor.

b. Temporary wiring for heaters and remove if not already completed by installing contractor.

c. Inspect grounding connections

d. Insulators for evidence of physical damage or contaminated surfaces

e. Surge Arrester and/or Surge Suppression (as applicable)

f. Breaker Cell(s), Primary and Secondary Disconnects for physical condition, cleanliness and lubrication (as applicable)

g. Racking mechanisms and lubricate if necessary.

h. Alignment and penetration of instrument transformer withdrawal disconnects, current carrying, and grounding components (as applicable)

i. Control power transformers (as applicable)

j. Wiring for damaged insulation, broken leads, proper crimping, and overall general condition

k. Verify that fuse sizes and types comply with drawings and coordination study.

l. When applicable, verify arc-resistant plenum, duct, and flap assembly are installed and functioning correctly

m. Verify CPT fuse block is oriented correctly

3. Verify structure, grounding, cables and bus assembly:

a. Anchorage (per manufacturer’s instructions)

b. Required area clearances, correct alignment and cleanliness.

c. Verify the grounding electrode conductor is properly sized and terminated.

d. The proper grounding of instruments, panels and connections .

e. That conductors are properly identified (as applicable)

f. Cable termination tightness

g. That all cables have been properly installed, routed and supported and are clear of energized parts.

h. Verify factory connections by checking at least 10% of the total factory connections for tightness. If this spot check reveals loose connections, proceed to check all factory connections. These connections include bus hardware connections, circuit breaker and switch terminals, contactors, metering, and other connections, including the incoming terminals.

i. That conduits and conduit bushings are correctly installed

j. Unused openings have been properly closed and secured

k. Correct barrier and shutter installation and operation

l. That filters are in place and/or vents are clear from obstructions

4. Verify control and instrumentation (as applicable):
   a. All VT and CT ratios properly correspond to drawings and that polarity is correct
   b. Shorting screws and bars are removed from CT's and terminal blocks as required
   c. Primary and secondary fuse ratings or circuit breakers match drawings
   d. Meter scaling and type match drawings

5. Verify the proper operation of all circuit breaker cell and safety interlocks operation for fail-safe function.
   a. Verify cell rejection plates are properly aligned and draw-out circuit breakers cannot be inserted into cells with the circuit breakers in the "closed" position.
   b. Verify mechanical operation of MOC/TOC contact blocks Verify contact closure on at least 1 contact per switchgear cell.
   c. Verify Key Interlock System (as applicable):
      1. Key number and exchange codes
      2. Proper sequencing to comply with drawing notes
      3. Attempt to close locked-open devices
      4. Attempt to open locked-closed devices
      5. Make key exchange with devices operated in off-normal positions
      6. Disposition of duplicate keys per the owner's safety policy

B. ELECTRICAL TESTS

1. Set control, circuit breaker trip units, and protective relay adjustments per applicable guideline. The protective relay and control settings must be supplied prior to testing by the customers' engineer or from a Power System Study. If not supplied, device settings will be left on factory default (minimum).

2. Insulation system:
   a. Perform insulation-resistance tests on each bus section, phase-to-phase, phase-to-ground, phase-to-neutral and neutral-to-ground
   b. Perform a high potential test for main bus assemblies
      1. This field test should be made before the main cables are connected and should not exceed manufacturer's recommendations.
      2. Transformer primary fuses should be removed and surge protective devices such as capacitors and arresters disconnected during high potential tests

3. Control and Instrumentation (as applicable):
   a. Perform the following tests on control power transformers
      1. Perform insulation-resistance tests. Perform measurements from winding-to-winding and each winding-to-ground.
      2. Perform a turns ratio test
   b. Verify correct function of control transfer relays located in Switchgear
   c. Verify operation of Switchgear heaters
   d. Perform the following tests on potential transformers:
      1. Perform insulation-resistance tests. Perform measurements from winding-to-winding and each winding-to-ground.

e. Perform the following tests on current transformers
1. Ratio
2. Polarity

4. Verify operation of all protective devices per the appropriate specification section.

5. Test all circuit breakers per the appropriate specification section.

6. Test all medium voltage switches per the appropriate specification section.

7. Metering and power monitoring devices:

a. Set up all PowerXpert, IQ meters or similar devices. Set points, alarms, and triggers to be provided by others. Unless otherwise specified, meters will be left at the default factory values.

8. Test all integrated power distribution products in accordance with the applicable specification section.

9. [3]Perform a bus joint resistant test through all sections using a 100A low-resistance ohmmeter.

10. [3]Perform the excitation test on current transformers used in protective relay applications in accordance with the testing methods in ANSI/IEEE C57.13.1

11. [3]Measure current transformer burdens.

12. [3]Measure voltage transformer burdens.

3.41 METAL-ENCLOSED DRAWOUT SWITCHGEAR – LOW VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the Switchgear line-up, including breakers, and accessories for:
a. Shipped loose and shipped short components
b. Shipping damage
c. Loose or obviously damaged components
d. Proper identification
e. Physical damage from installation
f. Doors, panels, and sections for alignment, dents, scratches, fit, and missing hardware
g. Maintenance accessories for servicing and operating all devices

2. Inspect:
a. Shipping Splits to insure that all bus connections were properly connected and all control wiring splits have been properly terminated by contractor.
b. Remove all temporary wiring for heaters if equipped
c. Inspect grounding connections
d. Insulators for evidence of physical damage or contaminated surfaces
e. Surge Arrester and/or Surge Suppression (as applicable)

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[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional

f. Breaker Cell(s), Primary and Secondary Disconnects for physical condition, cleanliness and lubrication (as applicable)

g. Alignment and penetration of instrument transformer withdrawal disconnects, current carrying, and grounding components (as applicable)

h. Control power transformers (as applicable)

i. Wiring for damaged insulation, broken leads, proper crimping, and overall general condition

j. Fuse clip contact pressure and contact means (as applicable)

3. Verify structure, grounding, cables and bus assembly:

a. Anchorage (per manufacturer's instructions)

b. Required area clearances, correct alignment and cleanliness.

c. Verify the grounding electrode conductor is properly sized.

d. The proper grounding of instruments, panels and connections.

e. That conductors are properly identified (as applicable)

f. Cable termination tightness

g. That all cables have been properly installed, routed and supported and are clear of energized parts

h. Verify factory connections by checking at least 10% of the total factory connections for tightness. If this spot check reveals loose connections, proceed to check all factory connections. These connections include bus hardware connections, circuit breaker and switch terminals, contactors, metering, and other connections, including the incoming terminals.

i. That conduits and conduit bushings are correctly installed

j. Unused openings have been properly closed and secured

k. Tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturers published data.

l. Correct barrier and shutter installation and operation

m. That filters are in place and/or vents are clear from obstructions

n. A plenum and duct assembly is properly installed on top of the switchgear, when applicable.

o. Pressure relief devices are free to operate, when applicable

4. Verify control and instrumentation (as applicable):

a. All VT and CT ratios properly correspond to drawings and that polarity is correct

b. Shorting screws and bars are removed from CT's and terminal blocks as required

c. Primary and secondary fuse ratings or circuit breakers match drawings

d. Meter scaling and type match drawings

5. Verify the proper operation of all circuit breaker cell and safety interlocks operation for fail-safe function.

6. Verify cell rejection plates are properly aligned and draw-out circuit breakers cannot be inserted into cells with the circuit breakers in the "closed" position.

7. Verify Key Interlock System (as applicable):

8. Key number and exchange codes

9. Proper sequencing to comply with drawing notes
10. Attempt to close locked-open devices
11. Attempt to open locked-closed devices
12. Make key exchange with devices operated in off-normal positions
13. Disposition of duplicate keys per the owner's safety policy

B. FUNCTIONAL TESTS WITH BREAKER IN CELL

1. Verify manual operation of breaker
2. Verify the electrical operation of each breaker (as applicable)

C. ELECTRICAL TESTS

1. Insulation system:
   a. Perform insulation-resistance tests on each bus section, phase-to-phase and phase-to-ground.
2. Control and Instrumentation (as applicable):
   a. Perform the following tests on control power transformers:
      1. Insulation-resistance measurements from winding-to-winding and each winding-to-ground.
      2. Turns ratio test
   b. Perform the following tests on voltage transformers:
      1. Insulation-resistance measurements from winding-to-winding and each winding-to-ground.
      2. Polarity
3. Verify correct function of control power transfer relays.
4. Verify operation of heaters.
5. Perform the following tests on current transformers in accordance with the testing methods in ANSI/IEEE C57.13.1
   a. Ratio
   b. Polarity
6. [3]Perform a bus joint resistant test through all sections using a 100A low-resistance ohmmeter.
7. [3]Perform the excitation test on current transformers used in protective relay applications in accordance with the testing methods in ANSI/IEEE C57.13.1
8. [3]Measure current transformer burdens.
9. [3]Measure voltage transformer burdens.
10. Test protective devices in accordance with applicable specification section
11. Test surge arresters in accordance with applicable specification section.
12. Ground fault system (as applicable):

[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional

a. Perform ground-fault test in accordance with Ground Fault or Circuit Breaker specification section.

13. Set up all metering and power monitoring devices in accordance with applicable specification section.

14. Test all integrated power distribution products in accordance with the applicable specification section.

3.42 MOLDED CASE CIRCUIT BREAKER

A. MECHANICAL AND VISUAL INSPECTION

1. Examine breaker for:
   a. Shipping damage
   b. Loose or obviously damaged components
   c. Primary lead connection tightness
   d. Limiter fuses rating (as applicable)
   e. Compliance to drawings
2. With breaker open, inspect:
   a. Primary leads
   b. Insulators
   c. Trip unit mounting and connectors
   d. Frame condition
   e. Mechanical and safety interlocks (as applicable)
3. Inspect circuit breaker mounting hardware and connections .
4. Inspect neutral CT polarity, connections, and mounting (as applicable).
5. Verify the proper operation of all breaker accessories, auxiliary switches, and key interlocks (as applicable).
6. Operate the circuit breaker ON and OFF (3) three times to verify the breaker mechanism operates smoothly without binding.

B. ELECTRICAL TESTS

1. Test the insulation resistance on each pole, phase-to-phase and phase-to-ground with the circuit breaker closed.
2. Test the insulation resistance across each pole, with the circuit breaker open.
3. Measure contact resistance using a digital low-resistance ohmmeter.
4. Test limiter resistance (as applicable).
5. Verify proper operation of all status indicators.
6. Trip Unit Tests
   a. Program trip unit settings per manufacturer’s instructions and in accordance with settings provided by the owner or approved coordination study device setting table otherwise test on default / minimum settings.
   b. Check status of rating plug mounted battery (as applicable).
   c. Verify all functions of the trip unit utilizing the manufacturer’s specified trip unit test device and record results.
   d. Reset trip flags and restore all settings changed during testing.

e. Note: Discrete test values may not be obtainable for all types of trip units. For these units, function testing is required only.

7. [3]Verify the proper operation of any automatic or remote control schemes, protective relays, and lock-out (86) devices which are integral to the breaker control circuit.

8. [3]Each phase of breaker shall be primary injected utilizing a low voltage, high current test source to determine if breaker trip characteristics are in compliance with the tests results as outlined in NEMA AB-4.

9. [3]Perform millivolt drop test on each pole of the circuit breaker in accordance with NEMA AB-4.

3.43 MOLDED CASE SWITCH

A. MECHANICAL AND VISUAL INSPECTION

1. Examine switch for:
   a. Shipping damage
   b. Loose or obviously damaged components
   c. Primary lead connection tightness
   d. Compliance to drawings
2. With switch open, inspect:
   a. Primary leads
   b. Insulators
   c. Frame condition
   d. Mechanical and safety interlocks (as applicable)
   e. Mounting
3. Verify the proper operation of all switch accessories, auxiliary switches, and key interlocks (as applicable).

B. ELECTRICAL TESTS

1. Test the insulation resistance on each pole, phase-to-phase and phase-to-ground with the switch closed.
2. Test the insulation resistance across each pole, with the switch open.
3. Measure contact resistance using a digital low-resistance ohmmeter.
4. [3]Perform millivolt drop test on each pole of the switch in accordance with NEMA AB-4.

3.44 MOTOR CIRCUIT PROTECTOR

A. MECHANICAL AND VISUAL INSPECTION

1. Examine motor circuit protector for:
   a. Shipping damage

[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional

b. Loose or obviously damaged components
c. Primary lead connection tightness
d. Compliance to drawings

2. With motor circuit protector open, inspect:
a. Primary leads
b. Insulators
c. Frame condition
d. Mechanical and safety interlocks (as applicable)
e. Mounting

3. Verify the proper operation of all motor circuit protector accessories, auxiliary motor switches, and key interlocks (as applicable).

B. ELECTRICAL TESTS

1. Test the insulation resistance on each pole, phase-to-phase and phase-to-ground with the motor circuit protector closed.

2. Test the insulation resistance across each pole, with the motor circuit protector open.

3. Measure contact resistance using a digital low-resistance ohmmeter.

4. [3]Perform millivolt drop test on each pole of the motor circuit protector in accordance with NEMA AB-4.

3.45 MOTOR CONTROL CENTERS – LOW VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the motor control center and accessories for:
a. Shipped loose and shipped short components
b. Shipping damage
c. Loose or obviously damaged components
d. Proper identification
e. Physical damage from installation
f. Doors, panels, and sections for alignment, dents, scratches, fit, and missing hardware
g. Maintenance accessories for servicing and operating all devices

2. Inspect:
a. Shipping Splits to insure that all bus connections were properly connected and torqued.
b. Verify all control wiring splits have been properly terminated by contractor.
c. Remove all temporary wiring for heaters if equipped
d. Remove all blocks or other temporary holding means used for shipment from all component devices in the MCC interior.
e. Grounding connections
f. Insulators for evidence of physical damage or contaminated surfaces
g. Surge Arrester and/or Surge Protective Devices (as applicable)

[3] Note to Spec. Writer – Optional

h. Circuit breaker and Secondary Disconnects for physical condition, cleanliness and lubrication (as applicable)

i. Alignment and penetration of instrument transformer withdrawal disconnects, current carrying, and grounding components (as applicable)

j. Control power transformers (as applicable)

k. Wiring for damaged insulation, broken leads, proper crimping, and overall general condition

l. Fuse clip contact pressure and contact means (as applicable)

m. Verify proper installation of isolation barriers and door latches for arc resistant models.

3. Verify structure, grounding, cables and bus assembly:
   a. Anchorage (per local codes, wind and seismic considerations)
   b. Required area clearances, correct alignment and cleanliness.
   c. Verify the grounding electrode conductor is properly sized and terminated.
   d. The proper grounding of instruments, panels and connections.
   e. That conductors are properly identified (as applicable).
   f. Cable termination tightness
   g. That all cables have been properly installed, routed and supported and are clear of energized parts
   h. That conduits and conduit bushings are correctly installed
   i. Unused openings have been properly closed and secured
   j. Verify factory connections by checking at least 10% of the total factory connections for tightness. If this spot check reveals loose connections, proceed to check all factory connections. These connections include bus hardware connections, circuit breaker and switch terminals, contactors, metering, and other connections, including the incoming terminals.
   k. That filters are in place and/or vents are clear from obstructions
4. Verify control and instrumentation (as applicable):
   a. All VT and CT ratios properly correspond to drawings and that polarity is correct
   b. Shorting screws and bars are removed from CT’s and terminal blocks as required
   c. Each current transformer is connected to a load, or a secondary shorting bar is installed.
   d. Primary and secondary fuse ratings or circuit breakers match drawings
   e. Meter scaling and type match drawings
5. Verify Key Interlock System (as applicable):
   a. Key number and exchange codes
   b. Proper sequencing to comply with drawing notes
   c. Attempt to close locked-open devices
   d. Attempt to open locked-closed devices
   e. Make key exchange with devices operated in off-normal positions
   f. Disposition of duplicate keys per the owner’s safety policy
6. Motor starter units:

a. Compare power and control circuits for agreement with the MCC wiring diagrams

b. Verify proper operating handle adjustment.

c. Verify tightness of power and control connections.

d. Inspect switches and indicating lights for proper operation.

e. Verify proper insertion alignment of starter buckets and operation of safety interlocks and position indicators (Flashgard).

f. Verify the operation of the automatic shutters (labyrinth vertical barrier system).

g. Manually exercise switches, circuit breakers, motor circuit protectors, and other operating mechanisms to verify they are properly aligned and operate freely

h. Set and adjust current and voltage trip mechanisms to the value specified by the owner. If no values are specified default settings will be applied.

i. Verify overload heater elements are installed and selected to the FLA shown on the nameplate of each motor.

B. ELECTRICAL TESTS

1. Insulation system:

a. Perform insulation-resistance tests on each bus section, phase-to-phase and phase-to-ground.

2. Control and Instrumentation (as applicable):

a. Perform the following tests on control power transformers:

1. Insulation-resistance measurements from winding-to-winding and each winding-to-ground.

2. Turns ratio test

b. Perform the following tests on voltage transformers:

1. Insulation-resistance measurements from winding-to-winding and each winding-to-ground.

2. Polarity

c. Verify correct function of control power transfer relays.

d. Verify operation of heaters.

e. Perform the following tests on current transformers in accordance with the testing methods in ANSI/IEEE C57.13.1:

1. Ratio

2. Polarity

3. Test protective devices in accordance with applicable specification section.

4. Test switches in accordance with applicable specification section.

5. Test surge arresters in accordance with applicable specification section e.

6. Ground fault system (as applicable):

a. Perform ground-fault test in accordance with Ground Fault or Circuit Breaker testing specification.

7. Set up all metering and power monitoring devices in accordance with applicable specification section.

8. Motor Control Buckets

a. Test motor starters, variable frequency drives and reduced voltage starters in accordance with applicable specification section.

9. Test all integrated power distribution products in accordance with the applicable specification section.

10. [3]Perform a bus joint resistant test through all sections using a 100A low-resistance ohmmeter.

11. [3]Perform the excitation test on current transformers used in protective relay applications in accordance with the testing methods in ANSI/IEEE C57.13.1

12. [3]Measure current transformer burdens.

13. [3]Measure voltage transformer burdens.

3.46 MOTOR STARTERS – LOW VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Motor starter units:

a. Compare power and control circuits for agreement with the MCC wiring diagrams

b. Verify proper operating handle adjustment.

c. Verify tightness of power and control connections.

d. Inspect switches and indicating lights for proper operation.

e. Verify proper insertion alignment of starter buckets and operation of safety interlocks and position indicators (Flashgard).

f. Verify the operation of the automatic shutters (labyrinth vertical barrier system).

g. Manually exercise switches, circuit breakers, motor circuit protectors, and other operating mechanisms to verify they are properly aligned and operate freely

h. Set and adjust current and voltage trip mechanisms to the value specified by the owner. If no values are specified default settings will be applied.

B. ELECTRICAL TESTS

1. Insulation system:

a. Perform insulation-resistance tests on each starter, phase-to-phase and phase-to-ground with the starter “closed” and across each pole with the starter “open”. Values shall be in accordance with manufacturer's published data.

2. Test motor protection devices in accordance with the manufacturer instruction book.

3. Measure and record the contact resistance of the disconnect for the motor starter.

4. [3]Test the overload protection device for proper time delay and tripping characteristics by current injection.

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[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional

3.47 NETWORK PROTECTOR

A. MECHANICAL AND VISUAL INSPECTION

1. Examine network protector for:
   a. Shipping damage and status of the tip over indicator
   b. Loose or obviously damaged components
   c. Application with the cell
   d. Compliance to drawings
2. Inspect
   a. Primary leads, insulators, current transformer mounting and terminations, and secondary disconnects.
   b. Control module mounting and connectors
   c. Frame condition
   d. Sight Glass and Door Gaskets
   e. Mechanical and safety interlocks
   f. Ground contact
   g. Inspect arc chutes for cracks and defects.
   h. With the network protector open:
      1. Inspect the condition of the main and arcing contacts
      2. Inspect insulating links/push rods and interphase barriers for cracks and defects.
   i. With the network protector closed:
      1. Inspect main contact engagement
      2. Inspect arcing contact engagement
3. Verify the manual operation of the network protector:
   a. Charge closing spring using manual charge handle
   b. Close network protector manually
   c. Trip network protector manually
   d. Mechanical interlocks
4. Rack the network protector into the enclosure (“Test Position” as applicable) and check for binding or hesitation and the movement of the network protector position indicator (if applicable).
5. Verify the proper operation of all network protector/cell accessories, auxiliary switches, cell MOC and TOC switches, and key interlocks (as applicable).
6. Verify the proper operation of all network protector /cell safety interlocks:
   a. Closed network protector insertion/withdrawal interlock
   b. Mechanical Anti-Close Interlock
   c. Anti-Close Feature
7. Inspect circuit network protector grounding connections.
8. Record contact position in de-energized state.
9. Verify proper operation of all status indicators (as applicable)

B. ELECTRICAL TESTS

1. Test the insulation resistance on each pole, phase-to-phase and phase-to-ground with the circuit network protector closed.

2. Test the insulation resistance across each pole, with the circuit network protector open.

3. Verify operation of anti-single phase device if mounted

4. Measure contact resistance using a digital low-resistance ohmmeter.

5. Verify the proper operation of all network protector accessories, auxiliary switches, and key interlocks (as applicable)

6. Verify proper operation of the Indicating Diagnostic Module per the instruction book.

7. Perform electrical device pickup and operation tests.

8. Measure contact pressure.

9. Test the MPC Relay Module using the manufacturer test set

3.48 OIL CIRCUIT BREAKER

A. MECHANICAL AND VISUAL INSPECTION

1. Examine breaker for:
   a. Shipping damage
   b. Loose or obviously damaged components
   c. Compliance to drawings
   d. Paint Condition

2. Examine primary bushings for chips or cracks.

3. Verify all AC and DC circuit wiring, as well as, fusing sizes are installed per wiring diagram.

4. Insure all devices in control compartment are properly labeled per specifications and/or manufacturers specifications. Insure all devices specified are supplied and properly mounted in control compartment. (Ammeters, monitors, etc.).

5. Thoroughly inspect circuit breaker operating mechanism for evidence of damage and/or manufacturing deficiencies.

6. Check primary lead connections and verify proper torque.

7. Check hydraulic fluid levels (if required) and fill as needed.

8. Ensure correct operation of all mechanical interlocks.

9. Inspect all pneumatic and hydraulic fittings and connections for leaks.

10. Inspect air compressor and hydraulic mechanism in accordance with manufacturer instruction manual.

11. Verify correct operation of operating mechanism in accordance with manufacturer instruction manual.

12. Verify circuit breaker ground connections are correctly installed.

13. Insure the circuit breaker has been installed plumb and level and has proper working clearances.

14. Verify foundation bolts are secure.

15. Verify proper operation of breather.

16. Inspect sample and check valve for proper operation.

17. Verify racking mechanism operation (if applicable).

18. Take an oil sample and send to lab for analysis.

19. Measure lift rod travel and verify it is in compliance with manufacturer specifications.

20. Measure stop clearance over travel and verify it is in compliance with manufacturer specifications.

21. Verify proper operation of heaters.

B. ELECTRICAL TESTS

1. With the breaker closed:
   a. Measure and record contact resistance
2. Perform insulation resistance tests
   a. Test insulation resistance phase to phase and phase to ground (circuit breaker closed)
   b. Test insulation resistance across each open pole
   c. Perform high potential test per manufacturer's instructions
3. Verify proper operation of auxiliary features.
4. [3]Determine minimum coil trip voltages
5. [3]Perform power factor or dissipation factor testing of bushings.
6. [3]Perform a breaker timing test
7. [3]Perform insulation resistance tests on control wiring.
8. [3]Trip circuit breaker by operating protective device.

3.49 PAD-MOUNTED SWITCHGEAR

A. MECHANICAL AND VISUAL INSPECTION

1. Examine Switchgear:
   a. Verify the nameplate information is compatible with the drawings
   b. Visually inspect all bushings to ensure there are no cracks, chips, or damage.
   c. Check 10% of the mechanical connections for tightness. If the check reveals loose connections, proceed to check all connections.
   d. Visually inspect welds for any obvious problems.
   e. Verify shipping brackets or fixtures have been removed (as applicable)
   f. Verify the correct liquid level in all tanks. (as applicable)
   g. Verify SF6 is at the proper pressure by checking the pressure gauge(s). (as applicable).

[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional

h. Proper pressure is maintained on nitrogen-blanketed (as applicable)
i. Equipment grounding is correct
j. Alarm, control, and trip settings indicate no obvious issues (as applicable)
k. There is no evidence of moisture
l. The enclosure holds positive/negative pressure. (fluid insulated only)
m. The manhole covers are tightly bolted. (fluid insulated only)
n. All protective covers are closed and bolted tight. (fluid insulated only)
o. Obtain and review Protective Relay Functions and Setting (as applicable):

B. ELECTRICAL TESTS

1. Test for VFI mechanical latching for all three phases
2. Perform (3) slow-close operations
3. Perform continuity checks as outlined in instruction book.
4. Perform Resistance testing with a low-resistance ohmmeter.
5. High Potential Testing
   a. Three (3) tests to Ground for the entire device. All devices closed, two phases grounded, one phase energized, repeat for each phase: A, B and C.
   b. Two (2) tests per way (or set of vacuum bottles, VFI or RVAC) with a DC High-Pot, or one (1) test per way with an AC High-Pot.
6. Perform visual tank leak inspection
7. Perform VFI electronic control functional trip testing
8. Operate all switches and handles
9. Collect a sample to be sent to a test lab for analysis (fluid filled)
10. Complete, record and provide a benchmark Dissolved Gas Analysis (DGA) for future maintenance records. (fluid filled)

3.50 PAD-MOUNTED TRANSFORMER

A. MECHANICAL AND VISUAL INSPECTION

1. Examine transformer for:
   a. Shipping and physical damage
   b. Impact recorder prior to unloading (as applicable)
   c. Tank, flanges and cooling fins for alignment, dents, scratches, fit, and missing hardware
   d. Loose or obviously damaged components
   e. Proper identification
   f. Compliance to the drawings
   g. Leaks
2. Verify:
   a. Shipping brackets or fixtures have been removed (as applicable)
   b. The correct liquid level in all tanks, bushings and cooling fins
   c. Proper pressure is maintained on nitrogen-blanketed transformers (as applicable)
   d. Equipment grounding is correct

e. Cooling fan blades turn freely and appropriate safety guards are in place (as applicable)

f. Alarm, control, and trip settings on temperature indicators (as applicable)

B. ELECTRICAL TESTS

1. Perform Insulation Resistance Tests (as applicable). Do not test insulation resistance of transformers with DC voltage above 1000v.

a. High to Ground

b. Low to Ground

c. High to Low

2. If core ground is accessible, measure core insulation resistance at 500 volts dc

3. Perform a turns-ratio test at all tap positions; retest on tap as left and record

4. Verify that winding polarities are in accordance with nameplate

5. Using customer supplied temporary control power verify that control and alarm settings on temperature indicators are as specified

6. Test operation of all applicable alarm, control, and trip circuits from temperature and level indicators and fault pressure relay

7. Collect an oil sample to be sent to a test lab for general fluid analysis

8. Collect an oil sample to be sent to a test lab for dissolved gas analysis (DGA) including the following tests: Furanic Compound Analysis, Moisture Content, Color, Dielectric, Power Factor @ 25C, Interfacial Tension and Acid Number.

9. Verify fan operation and temperature relay (as applicable)

10. [3]Perform a power factor or dissipation factor test on all windings.

11. [3]Perform a field oil Dielectric Breakdown test

12. [3]Calculate polarization index of insulation.

13. [3]Perform a sweep frequency response analysis

14. [3]Test winding resistance

3.51 PANELBOARDS

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the panelboard, including breakers, and accessories for:

a. Shipped loose and shipped short components

b. Shipping damage

c. Loose or obviously damaged components

d. Proper identification

e. Physical damage from installation

f. Doors, panels, and sections for alignment, dents, scratches, fit, and missing

[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional

hardware

g. Maintenance accessories for servicing and operating all devices

h. Ensue any packing material used for shipment have been removed

2. Inspect:

a. Insulators for evidence of physical damage or contaminated surfaces

b. Surge Arrester and/or Surge Suppression (as applicable)

c. Alignment and penetration of instrument transformer withdrawal disconnects, current carrying, and grounding components (as applicable)

d. Control power transformers (as applicable)

e. Wiring for damaged insulation, broken leads, proper crimping, and overall general condition

f. Fuse clip contact pressure and contact means (as applicable)

3. Verify structure, grounding, cables and bus assembly:

a. Cable termination tightness

b. That all cables have been properly installed, routed and supported and are clear of energized parts

c. That conduits and conduit bushings are correctly installed

d. Unused openings have been properly closed and secured

e. Verify factory connections by checking at least 10% of the total factory connections for tightness. If this spot check reveals loose connections, proceed to check all factory connections. These connections include bus hardware connections, circuit breaker and switch terminals, contactors, metering, and other connections, including the incoming terminals.

f. That filters are in place and/or vents are clear from obstructions

g. Verify all ground connections have been made properly

4. Verify control and instrumentation (as applicable):

a. All VT and CT ratios properly correspond to drawings and that polarity is correct

b. Shorting screws and bars are removed from CT’s and terminal blocks as required

c. Primary and secondary fuse ratings or circuit breakers match drawings

d. Meter scaling and type match drawings

e. Verify Key Interlock System (as applicable):

f. Key number and exchange codes

g. Proper sequencing to comply with drawing notes

h. Attempt to close locked-open devices

i. Attempt to open locked-closed devices

j. Make key exchange with devices operated in off-normal positions

k. Disposition of duplicate keys per the owner’s safety policy

B. ELECTRICAL TESTS

1. Insulation system:

a. Perform insulation-resistance tests on each bus section, phase-to-phase and phase-to-ground.

2. Control and Instrumentation (as applicable):

a. Perform the following tests on control power transformers:

1. Insulation-resistance measurements from winding-to-winding and each winding-to-ground.
2. Turns ratio test

b. Perform the following tests on voltage transformers:

1. Insulation-resistance measurements from winding-to-winding and each winding-to-ground.
2. Polarity

3. Verify correct function of control power transfer relays.

4. Verify operation of heaters.

5. Perform the following tests on current transformers in accordance with the testing methods in ANSI/IEEE C57.13.1

a. Ratio
b. Polarity

6. Verify operation of all overcurrent protective devices equal to and greater than 200A per the appropriate specification section.

7. Test switches in accordance with applicable specification section.

8. Test surge arresters in accordance with applicable specification section.

9. Ground fault system (as applicable):

a. Perform ground-fault test in accordance with Ground Fault or Circuit Breaker testing specification (as applicable).

10. Set up all metering and power monitoring devices in accordance with applicable specification section.

11. [3]Perform a bus joint resistant test through all sections using a 100A low-resistance ohmmeter.

12. [3]Test protective devices below 200A.

13. [3]Perform the excitation test on current transformers used in protective relay applications in accordance with the testing methods in ANSI/IEEE C57.13.1

14. [3]Measure current transformer burdens.

15. [3]Measure voltage transformer burdens.

3.52 PROTECTIVE RELAY

A. MECHANICAL AND VISUAL INSPECTION

1. Examine relay and accessories for:
   a. Shipped loose and shipped short components
   b. Shipping damage
   c. Loose or obviously damaged components
   d. Proper identification

[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional

e. Physical damage from installation
f. Condition of wiring on panels and switchboards
g. Clips of fuse holder for tightness and alignment (as applicable)
h. Relay for alignment, dents, scratches, fit, and missing hardware

2. Inspection and Settings:
a. Relay connections for tightness
b. Associated current transformers for proper rating, polarity and wiring
c. Shorting screws and bars are removed from CT's and terminal blocks as required
d. Verify logic files and tripping equations / mapping have been provided to Eaton prior to commencement of work.
e. Review the provided settings and logic to ensure correctness of instrument transformer ratios and that the settings and logic make sense. Report discrepancies.
f. Program the relay per the settings specified in the coordination study.
g. Download settings from relay and verify with the settings specified in coordination/protection settings study.

B. ELECTRICAL TESTS

1. Perform the following tests on the nominal settings specified
a. Verify the operation of basic metering (volts, amps, watts, vars, frequency, PF) as applicable to the specific relay being tested.
b. Minimum pickup parameters on each operating element
1. A pickup test is conducted to determine the minimum or maximum electrical quantity (current, voltage, power, frequency, etc.) that causes the element pickup status to become active (logical true)
c. Timing tests should be performed at two or more points on the time curve to verify the timing characteristics of the relay
d. Pickup and trip target indicator units operate with the intended elements
e. Output relays function with the intended protective elements
f. Verify open and closed contact resistance of each output relay
g. Special tests as required to check operation of restraint, directional, and other elements per manufacturer's instruction manual

2. Record all as left relay settings on test form

3. [3]Configure trip logic equations, event logs and communication features (if applicable).

C. RELAY ELEMENT TEST POINTS AND TEST CIRCUITS

1. Time Overcurrent Element
a. Check for minimum pickup and timing as per manufacturer's specifications. Pickup is defined as the value of current that will cause the element pickup bit to show active (logical true). Timing tests are compared to the time-current curve or equation. The testing of overcurrent relays is done one phase at a time; including neutral (if applicable).
b. Check the instantaneous unit pickup, and timing for fixed delay (if applicable).

[3] Note to Spec. Writer – Optional

c. Test the ground fault protection similarly to phase overcurrent functions; testing should be performed on both measured and calculated ground elements as applicable to the relay installation.

d. Verify proper operation of the target indicator.

2. Differential Relay Element

a. Check minimum pickup values using operating and differential currents.

b. Check the slope (differential characteristic) and harmonic restraint.

c. Trip all circuit breakers from differential relays for circuit verification.

3. Directional Overcurrent Relay Element

a. Test the directional control element for overcurrent elements for minimum pickup, and maximum torque angle.

4. Distance Relay Element

a. Test the distance characteristics near the fault and load angles.

b. Test the distance element for minimum pickup, and maximum torque angle.

c. Verify proper target operation.

5. Current Balance Relay Element

a. Check pickup of each coil as explained under section on overcurrent relays.

b. Check for no-trip condition by applying equal amounts of current to opposing coils. Test

c. Verify proper target operation.

6. Overvoltage Relay Element

a. Check minimum pickup of overvoltage elements. Check timing by selecting three timing points on the specified time dial. Pickup and timing points should be found within manufacturer's tolerances.

b. Check the instantaneous pickup (if applicable).

c. Verify proper target operation.

7. Breaker Failure Relay Element

a. Test the tripping time of the Breaker Failure protection for both internally and externally triggered tripping (as applicable to the installation). The actual times measured shall comply with the set-point times.

b. Verify the operation of the BF output contact and target indication.

8. Forward / Reverse Power Protection Relay Element

a. Check that the measured total tripping delays or individual tripping delays, threshold values (over or under power as set on the specific elements used), and dropout ratios correspond with those values specified. Permissible deviations/tolerances shall be per manufacturer's specification.

b. Verify operation of the appropriate output contact and target indication as applicable.

9. Undervoltage Relay Element

a. Check dropout of relay and time relay trip when voltage is suddenly reduced from rated voltage to desired test voltage. Select three timing points on the specified time characteristic. Dropout and timing points should be found within manufacturer's tolerances.

b. Verify operation of the appropriate output contact and target indication as applicable.

10. Voltage Restrained or Voltage Controlled Overcurrent Relay Element

a. Check for minimum pickup and timing of protective relay elements as per manufacturer's specifications.

b. Voltage restrained relay element

1. Check the current pickup change with the voltage applied to the voltage sensing coil; at least two voltages levels should be tested to confirm corresponding changes occur in the current pickup values.

c. Voltage controlled relay element

1. Verify that the overcurrent element will not function unless the applied voltage element is below the voltage threshold setting.

11. Under-Over Frequency Relay Element

a. Test the following functions as applicable:

1. Voltage cutoff or drop out
2. Over or under frequency pickup points
3. Time delay before trip when frequency is stepped from nominal to desired test frequency. The delay times are not necessarily equal with at different test frequencies.

12. Synchronism Check Relay Element

a. Test and verify the following conditions must be met to assert an "in sync" condition between the 'bus' and 'line' voltages: voltage differential, angular differential, and frequency differential. Each of these conditions must be tested independently.

b. If applicable, test the delay time associated with providing an output contact closure after the sync element is satisfied.

c. Test each logical condition that would bypass the synch check element to cause the output contact to close when one or more of the voltages is not present (dead line or dead bus conditions) as defined in the element settings.

13. Motor Relays

a. Test all metering and applicable protective functions as described in the previous sections of this document.

b. Test applicable motor starting control and logic functions according to manufacturer's literature. These could include but are not limited to:

1. Transition Current /Time
2. Starting limits (starts per hour, time between starts, etc.)
3. Protective Blockings during start (Block Instantaneous, Block Jam, etc.)

14. Other Protective Elements

a. Test each applied protective element not listed above in a manner appropriate to its function to verify its operating threshold (pickup), timing, and other associated characteristics. Refer to manufacturer's literature for information relating to testing these elements.

3.53 SF6 CIRCUIT BREAKER

A. MECHANICAL AND VISUAL INSPECTION

1. The circuit breaker exterior and control cabinet shall be completely inspected for evidence of damage and/or manufacturing deficiencies.

2. Verify the breaker nameplate and nameplates for auxiliary devices are installed and legible.

3. Insure breaker and associated auxiliary equipment match specification (i.e. CT ratios, breaker ratings, control voltage, etc.).

4. Verify circuit breaker ground connections are correctly installed.

5. Insure the circuit breaker has been installed plumb and level.

6. Verify foundation bolts are secure.

7. Verify all AC and DC circuit wiring, as well as, fusing sizes are installed per wiring diagram.

8. Insure all devices in control compartment are properly labeled per specifications and/or manufacturers specifications. Insure all devices specified are supplied and properly mounted in control compartment. (Ammeters, monitors, etc.).

9. Verify circuit breaker wiring matches specifications.

10. Thoroughly inspect circuit breaker operating mechanism for evidence of damage and/or manufacturing deficiencies.

11. Verify all adjustments specified by manufacturer.

12. Check primary lead connections and verify proper torque.

13. Check hydraulic fluid levels (if required) and fill as needed.

14. Ensure correct operation of all mechanical interlocks.

15. Inspect all pneumatic and hydraulic fittings and connections for leaks.

16. Perform leak detection on all fittings and portions of the circuit breaker containing. The leak detection method shall be approved by owner prior to performance.

17. Verify correct operation of operating mechanism.

18. Verify correct operation of moving parts.

B. ELECTRICAL TESTS

1. Verify operation of charging/pump motor. Record motor running amps. Record compressor run time from 0 PSIG to full pressure.

2. Verify operation of hydraulic/pneumatic pressure switches.

3. Record close/open values.

4. Record actual operating current from trip and close coils. Record voltage and amperage at minimum values.

5. Test number of operations to alarm and mechanical lockout. Start with breaker at full operating pressure and charging motor off. Record pressures and number of operations.

6. Verify operation of heaters (control cabinet and tank) and thermostats. Record heater amperage. Verify operation of all electrical auxiliary devices (cabinet lights, monitors, etc.) Install settings for breaker monitoring device.

7. Perform contact resistance measurement. Measurement made shall be at 100

amps DC.

8. Perform insulation resistance test at a minimum of 5 kV DC. Tests should be made phase to phase, phase to ground and across open contacts.

9. Perform power factor test of circuit breaker. Tests shall follow manufacturer guidelines or test procedures outlined by Doble Engineering for gas puffer circuit breakers. Power factor testing shall include hot collar tests of bushings.

10. Values of grading resistors shall be measured and recorded.

11. Perform travel and speed analysis using the methods described in the manufacturers literature. At a minimum, speed and travel shall be tested for a close, trip and close/trip (Trip-free Dwell) operation. Results of travel tests shall be submitted in tabular and graphical format.

12. [3]Calculate polarization index of insulation.

13. [3]Perform a sweep frequency response analysis

C. TESTING

1. Circuit breaker shall be filled with following manufacturer's instructions. shall not be added to the circuit breaker directly from a bottle unless specified by the manufacture and the gas bottle sample test (moisture and purity per manufacturer specifications) is satisfactory. If a gas cart is to be used, approval from the owner is required prior to commencing gas fill activities.

2. The moisture content and purity of each bottle of used to fill the breaker shall be tested prior to its use. Results from each bottle shall be recorded. Moisture levels shall be recorded in ppm.

3. The moisture content and purity of from each pole shall be taken and recorded after the unit is filled and compared to manufacture specifications.

4. The pressure after filling shall be recorded after the unit is filled and 72hrs later.

The pressure shall be recorded in PSIG and ambient temperature shall also be recorded in Fahrenheit.

5. Operation of alarm and cutout switches shall be verified during filling. Alarm and lockout pressures shall be recorded.

6. A second gas sample (moisture and purity) shall be taken and recorded 72 hours after initial fill process and compared to manufacturer specifications.

7. As left values of pressure and temperature results shall be recorded for each device containing .

3.54 SF6 LOAD BREAK SWITCH

A. MECHANICAL AND VISUAL INSPECTION

1. Examine Switch

a. The switch exterior and control cabinet shall be completely inspected for evidence of damage and/or manufacturing deficiencies.

b. Verify the switch nameplate and nameplates for auxiliary devices are installed and legible.

[3] Note to Spec. Writer – Optional

[3] Note to Spec. Writer – Optional

c. Insure switch and associated auxiliary equipment match specification (i.e. CT ratios, switch ratings, control voltage, etc.).

d. Distances of operating mechanism shall be in accordance with manufacturer's published data.

2. Disconnect Switch Installation

a. Verify switch ground connections and switch control are correctly installed. Measure and record resistance of ground connection; notify the Owner if ground connection resistance is more than 1 ohm.

b. Insure the switch has been installed plumb and level.

c. Verify foundation bolts are secure.

d. Installation shall follow all manufacturer's recommendations.

3. Switch Control Wiring

a. Verify all AC and DC circuit wiring, as well as, fusing sizes are installed per wiring diagram (see Wiring Verification).

b. Insure all devices in control compartment are properly labeled per specifications and/or manufacturers specifications. Insure all devices specified are supplied and properly mounted in control compartment. (Ammeters, monitors, etc.).

c. Verify switch wiring matches specifications.

4. Mechanical Inspection

a. Inspect each unit for loose hardware, damaged or contaminated porcelain, cracked cement, missing or incorrectly installed cotter pins, bent or misaligned pipes, etc.

b. Check tightness of all terminals, connections, and attachments and verify proper torque.

c. Verify all adjustments specified by manufacturer.

d. Operate switch manually to verify full and complete operation. Watch for binding or unusual stress while operating.

e. Check for proper alignment of whips, arcing horns, and associated equipment.

f. Check hydraulic fluid levels (if required) and fill as needed.

g. Ensure correct operation of all mechanical and electrical interlocks (KIRK keys).

h. Inspect all pneumatic and hydraulic fittings and connections for leaks.

i. Perform leak detection on all fittings and portions of the switch containing. The leak detection method shall be approved by owner prior to performance.

j. Verify correct operation of operating mechanism.

B. ELECTRICAL TESTS

1. Measure and record switch resistivity using a minimum of 100 ampere micro-ohmmeter (or low resistance ohm-meter). Measurements shall include the main contacts, hinge, and overall. Measurements over one (1) ohm are not acceptable.

2. 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.

3. Perform a dielectric withstand voltage test across each gas bottle with the switch in the open position. This needs to be completed in accordance with manufacturer's published data.

4. Perform a dielectric withstand voltage test. This needs to be completed in accordance with manufacturer's published data.

5. Verify open and close operation from all control devices (if applicable).

6. Electrical Tests (Motor Operated Disconnects)

a. Verify all AC and DC circuit wiring, as well as fusing sizing (see Wiring Verification)

b. Check all auxiliary contacts for correct alignment and operation

c. Verify motor stops and start contacts are adjusted for correct and full operation

d. Verify cabinet heaters are in working order

e. Measure and record ampere load of the motor while operating

f. Functionally operate by local and remote controls as designed

C. Testing

1.

1. Disconnect Switch shall be filled with following manufacturer's instructions. shall not be added to the switch directly from a bottle unless specified by the manufacture and the gas bottle sample test (moisture and purity per manufacturer specifications) is satisfactory. If a gas cart is to be used, approval from the owner is required prior to commencing gas fill activities.

2. The moisture content and purity of each bottle of used to fill the switch shall be tested prior to its use. Results from each bottle shall be recorded. Moisture levels shall be recorded in ppm.

3. The moisture content and purity of from each pole shall be taken and recorded after the unit is filled and compared to manufacture specifications.

4. The pressure after filling shall be recorded after the unit is filled and 72 hrs later. The pressure shall be recorded in PSIG and ambient temperature shall also be recorded in Fahrenheit.

5. Operation of alarm and cutout switches shall be verified during filling. Alarm and lockout pressures shall be recorded.

6. A second gas sample (moisture and purity) shall be taken and recorded 72 hours after initial fill process and compared to manufacturer specifications.

7. As left values of pressure and temperature results shall be recorded for each device containing .

3.55 SOLID-STATE REDUCED VOLTAGE STARTER - LOW VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the solid-state reduced voltage starter installation

a. Shipped loose and shipped short components

b. Shipping damage

c. Loose or obviously damaged components

d. Proper identification

e. Physical damage from installation

2. Inspect:

a. Inspect grounding connections

b. Insulators for evidence of physical damage or contaminated surfaces.

c. Wiring for damaged insulation, broken leads, proper crimping, and overall general condition

3. Review the solid-state reduced voltage starter sizing with the motor sizing and application requirements.

4. Review automation system to be used (as applicable) with solid-state reduced voltage starter

5. Perform safety inspection of the solid-state reduced voltage starter installation and its associated equipment.

a. Tag and lock out all power sources to the solid-state reduced voltage starter according to the end users and commissioners policies until the commissioner is prepared to energize the solid-state reduced voltage starter.

b. Perform a walk around of the application and equipment to determine level of preparedness for operation.

c. Survey the installation environment to ensure it is safe and is within Eaton Electrical solid-state reduced voltage starter ambient specifications for operation.

d. Establish whether solid-state reduced voltage starter testing will be performed with or without its load attached.

e. Have end user representative prepare equipment if necessary.

6. Review solid-state reduced voltage starter and its connected load for proper installation.

a. Incoming power, outgoing motor, and control wiring are each in their own conduit.

b. All wiring has been accomplished to manufacturer’s specifications for the size of the solid-state reduced voltage starter and its connected load.

c. The solid-state reduced voltage starter is clean and free of installation debris, equipment, or tools.

B. INITIAL ENEGIZATION

1. Perform Pre-Power meter checks.

a. Compare power and RVSS control circuits for agreement with the factory wiring diagrams

b. Verify that each motor is connected to the correct starter

c. Manually exercise switches, circuit breakers, and other operating mechanisms to verify they are properly aligned and operate freely

d. Set all parameter values and DIP Switches on IT

e. Record As-Found and As-Left settings

f. Verify that power circuit fuses in fusible switches are in accordance to NEC application requirements

2. Perform initial power on safety checks.

a. Confirm that all power is still tagged and locked out to the solid-state reduced voltage starter.

b. If disconnected, reconnect the line and/or motor leads.

c. Ensure all appropriate control wiring has been reconnected.

d. Conduct a walk around of the solid-state reduced voltage starter and its connected load.

e. Remove tags and locks for the disconnect supplying power to the solid-state reduced voltage starter disconnect.

f. When safe, energize the disconnect that supplies power to the solid-state reduced voltage starter disconnect.

3. Setting the solid-state reduced voltage starter parameters

a. Program solid-state reduced voltage starter parameters as specified by the customer and in accordance manufacturer's model-specific instructions

b. Typical parameters would include

1. Motor name plate information
2. solid-state reduced voltage starter controls
3. Motor protections

4. Check motor direction of rotation

a. Have customer representative confirm that the motor is ready to rotate.

b. Bump the motor to check it's direction of rotation in the following order:

1. Check rotation from the solid-state reduced voltage starter.
2. After checking solid-state reduced voltage starter rotation if a bypass is used, check rotation from the bypass.

5. Operation of the RVSS and Motor

a. It is preferred that the testing from this point on be done with the motor coupled to the normal operating load.

b. Testing of an unload application or just a motor is valid but should be noted in the commissioning documentation.

c. Perform operational checks in accordance with manufacturer's model-specific instructions

3.56 SOLID-STATE REDUCED VOLTAGE STARTER - MEDIUM VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the solid-state reduced voltage starter installation
   a. Shipped loose and shipped short components
   b. Shipping damage
   c. Loose or obviously damaged components
   d. Proper identification
   e. Physical damage from installation
2. Inspect:
   a. Mounting of the assembly
   b. Inspect grounding connections
   c. Insulators for evidence of physical damage or contaminated surfaces.
   d. Wiring for damaged insulation, broken leads, proper crimping, and overall general condition
3. Review the solid-state reduced voltage starter sizing with the motor sizing and application requirements.
4. Review automation system to be used (as applicable) with solid-state reduced voltage starter

5. Perform safety inspection of the solid-state reduced voltage starter installation and its associated equipment.

a. Tag and lock out all power sources to the solid-state reduced voltage starter according to the end users and commissioners policies until the commissioner is prepared to energize the solid-state reduced voltage starter.

b. Perform a walk around of the application and equipment to determine level of preparedness for operation.

c. Test all safety interlock operation

d. Survey the installation environment to ensure it is safe and is within Eaton solid-state reduced voltage starter ambient specifications (<40 Degrees C) for operation.

e. Establish whether solid-state reduced voltage starter testing will be performed with or without its load attached.

f. Have end user representative prepare equipment if necessary for integrated testing.

6. Review solid-state reduced voltage starter installation and its connected load for proper installation.

a. Record motor nameplate information.

b. Verify correct enclosure type for environment

c. Verify load cables are < 1000ft of total cable.

d. Note any load side capacitance that may adversely interact with soft-start including the motor terminal box.

e. Incoming power, outgoing motor, and control wiring are each in their own conduit.

f. All wiring has been accomplished to manufacturer's specifications for the size of the solid-state reduced voltage starter and its connected load.

g. The solid-state reduced voltage starter is clean and free of installation debris, equipment, or tools.

B. INITIAL ENEGIZATION

C. Perform Pre-Power checks.

1. Perform continuity tests on all power and control fuses.

2. Check connection of all fiber optic connections from the CPU board to the MV4S truck. Physically tug on all cables to make sure they are firmly seated.

3. Review cable and motor SAT test results.

D. Perform initial power on safety checks.

1. With the isolation switch in the off position plug an extension cord into the test plug in the low voltage control compartment.

2. Verify power-up of the control circuit, especially the motor protective relay (MPR) and MV4S control in the lower compartment. Verify green LEDs lit on all MV4S poles.

3. Verify programming of the MPR including programming notes on the schematic. Relay should NOT be set for reduced voltage operation.

4. Verify programming of the MV4S. Protection settings on the MV4S are backup for the MPR settings only and can be turned off or set to guard band positions. Guard band is defined as 10% wider than MPR settings.

5. If PT bus is used, read the voltage on all applicable starter metering and verify it reads correct with actual bus voltage.

6. Remove extension cord and replace test plug.

E. Powered Checklist

1. Close isolation switch and verify power-up of the control circuit.

2. Verify operation of the starter by performing a low output test.

3. Bump for rotation by placing the MV4S in jog mode and raising the jog voltage gradually.

a. Have customer representative confirm that the motor is ready to rotate.

b. Bump the motor to check it's direction of rotation in the following order:

1. Check rotation from the solid-state reduced voltage starter.

2. After checking solid-state reduced voltage starter rotation if a bypass is used, check rotation from the bypass.

4. Initiate a momentary start-stop sufficient to cause motor rotation and determine optimal starting voltage.

5. Place the MV4S in voltage ramp mode unless the current limit mode is specifically desired.

6. On set point page 2, enter the optimum starting voltage from the step above as initial voltage. Set ramp time to appropriate value.

7. On set point page 8, enter the expected acceleration time plus five seconds.

8. Obtain the maximum allowable start time from motor data sheet or motor manufacturer's representative.

9. Initiate a start. If problems are encountered consult the MV4S Troubleshooting Guide.

10. Program any additional solid-state reduced voltage starter parameters as specified by the customer and in accordance manufacturer's model-specific instructions

F. Operation of the RVSS and Motor

1. It is preferred that the testing from this point on be done with the motor coupled to the normal operating load.

2. Testing of an unload application or just a motor is valid but should be noted in the commissioning documentation.

3. Perform operational checks in accordance with manufacturer's model-specific instructions

3.57 STATION BATTERY SYSTEMS

A. MECHANICAL AND VISUAL INSPECTION

1. Inspect the structural integrity of the battery rack and/or cabinet

2. Verify that all applicable warning labels are visual and in readable condition

3. Inspect inter cell connections and main terminals for proper torque values

4. Inspect evidence of corrosion at terminations and on the mounting structure

5. Perform a detailed visual inspection of each cell
6. Inspect all cells for proper acid level

B. ELECTRICAL TESTS

1. Utilize IEEE Standard 450-1995 to perform the following tests:
   a. Measure input voltage to the battery charger prior to turning on the charger
   b. Measure input current of the battery charger
   c. Measure float voltage + to -
   d. Measure battery system voltage + to –
   e. Measure battery system voltage + to ground
   f. Measure battery system voltage – to ground
   g. Measure battery charger output volts
   h. Measure battery charger output amps
   i. Measure voltage of each cell
   j. Measure specific gravity of each cell
2. Refer to the OEM instruction books to determine if the battery system requires equalization.
3. Verify that the switchgear or substation battery bus has been tested and ready to be energized prior to putting the battery system into service

3.58 STATION CLASS CIRCUIT BREAKER

A. MECHANICAL AND VISUAL INSPECTION

1. Examine Enclosure
   a. The circuit breaker exterior and control cabinet shall be completely inspected for evidence of damage and/or manufacturing deficiencies.
   b. Verify the breaker nameplate and nameplates for auxiliary devices are installed and legible.
   c. Insure breaker and associated auxiliary equipment match specification (i.e. CT ratios, breaker ratings, control voltage, etc.).
   d. Verify circuit breaker ground connections are correctly installed. Measure and record resistance of ground connection; notify the Owner if ground connection resistance is more than 1 ohm.
   e. Insure the enclosure has been installed plumb and level.
   f. Verify foundation bolts are secure.
2. Circuit Breaker Control Wiring
   a. Verify all AC and DC circuit wiring, as well as, fusing sizes are installed per wiring diagram (see Wiring Verification).
   b. Insure all devices in control compartment are properly labeled per specifications and/or manufacturers specifications. Insure all devices specified are supplied and properly mounted in control compartment. (Ammeters, monitors, etc.).
   c. Verify circuit breaker wiring matches specifications.
3. Mechanical Inspection
   a. Thoroughly inspect circuit breaker operating mechanism for evidence of damage and/or manufacturing deficiencies.

b. Verify all adjustments specified by manufacturer.

c. Check primary lead connections and verify proper torque.

d. SF6 mechanisms

1. Check hydraulic fluid levels (if required) and fill as needed.
2. Ensure correct operation of all mechanical interlocks.
3. Inspect all pneumatic and hydraulic fittings and connections for leaks.
4. Perform leak detection on all fittings and portions of the circuit breaker containing . The leak detection method shall be approved by owner prior to performance.
5. Verify correct operation of operating mechanism.
6. Verify correct operation of moving parts.

e. Vacuum Mechanisms

1. Charge closing spring using maintenance tool (manual charge handle) then remove handle
2. Verify Charged/Discharged status indicators function properly
3. Close breaker manually and verify Closed and Discharged indicators
4. Charge breaker again, verify that the breaker remains closed
5. Trip breaker manually verify Open indicator
6. Repeat several times to confirm mechanism operates consistently and reliably
7. Charge closing spring and close manually

B. ELECTRICAL TESTS

1. SF6 Circuit Breaker Element

a. Verify operation of charging/pump motor. Record motor running amps. Record compressor run time from 0 PSIG to full pressure.

b. Verify operation of hydraulic/pneumatic pressure switches.

c. Record close/open values.

d. Record actual operating current from trip and close coils. Record voltage and amperage at minimum values.

e. Test number of operations to alarm and mechanical lockout. Start with breaker at full operating pressure and charging motor off. Record pressures and number of operations.

f. Verify operation of heaters (control cabinet and tank) and thermostats. Record heater amperage. Verify operation of all electrical auxiliary devices (cabinet lights, monitors, etc.) Install settings for breaker monitoring device.

g. Perform contact resistance measurement. Measurement made shall be at 100 amps DC.

h. Perform insulation resistance test at a minimum of 5 kVDC. Tests should be made phase to phase, phase to ground and across open contacts.

i. Perform power factor test of circuit breaker. Tests shall follow manufacturer guidelines or test procedures outlined by Doble Engineering for gas puffer circuit breakers. Power factor testing shall include hot collar tests of bushings.

j. Values of grading resistors shall be measured and recorded.

k. Perform travel and speed analysis using the methods described in the

manufacturers literature. At a minimum, speed and travel shall be tested for a close, trip and close/trip operation. Results of travel tests shall be submitted in tabular and graphical format.

2. Vacuum Circuit Breaker Element
   a. With the breaker closed:
      1. Inspect contact erosion indicator mark on vacuum interrupter moving stem
      2. Inspect contact wipe per manufacturer's instructions
      3. Measure and record contact resistance
   b. Perform insulation resistance tests
      1. Test insulation resistance phase to phase and phase to ground
      2. Perform high potential test per manufacturer's instructions
      3. Perform the vacuum integrity test per manufacturer's instructions and at the recommend value (reference the specific breaker I.B.) Do not exceed maximum voltage stipulated for this test.

C. TESTING

1. Circuit breaker shall be filled with following manufacturer's instructions. shall not be added to the circuit breaker directly from a bottle unless specified by the manufacture and the gas bottle sample test (moisture and purity per manufacturer specifications) is satisfactory. If a gas cart is to be used, approval from the owner is required prior to commencing gas fill activities.

2. The moisture content and purity of each bottle of used to fill the breaker shall be tested prior to its use. Results from each bottle shall be recorded. Moisture levels shall be recorded in ppm.

3. The moisture content and purity of from each pole shall be taken and recorded after the unit is filled and compared to manufacture specifications.

4. The pressure after filling shall be recorded after the unit is filled and 72hrs later.

The pressure shall be recorded in PSIG and ambient temperature shall also be recorded in Fahrenheit.

5. Operation of alarm and cutout switches shall be verified during filling. Alarm and lockout pressures shall be recorded.

6. A second gas sample (moisture and purity) shall be taken and recorded 72 hours after initial fill process and compared to manufacturer specifications.

7. As left values of pressure and temperature results shall be recorded for each device containing .

3.59 SURGE ARRESTERS – LOW VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine arrester for:
   a. Shipping damage
   b. Physical damage from installation
   c. Loose or obviously damaged components
   d. Proper identification
   e. Damage, defects, and contamination

f. Compliance to the drawings

2. Verify:
   a. Tightness of accessible bolted electrical connections
   b. Shipping brackets or fixtures have been removed during installation
   c. The arrester has no cracks
   d. Arrester is free of dirt or other contaminants
   e. Arrester properly installed and grounded

B. ELECTRICAL TESTS

1. Perform insulation resistance test
2. [3]Perform power factor test (as applicable)

3.60 SURGE ARRESTERS – MEDIUM VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine arrester for:
   a. Shipping damage
   b. Physical damage from installation
   c. Loose or obviously damaged components
   d. Proper identification
   e. Damage, defects, and contamination
   f. Compliance to the drawings
2. Verify:
   a. Tightness of accessible bolted electrical connections
   b. Shipping brackets or fixtures have been removed during installation
   c. The arrester has no cracks
   d. Arrester is free of dirt or other contaminants
   e. Arrester properly installed and grounded

B. ELECTRICAL TESTS

1. Perform insulation resistance test
2. [3]Perform power factor test (as applicable)

3.61 SWITCH – LOW VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine switch for:
   a. Shipping damage
   b. Loose or obviously damaged components
   c. Primary lead connection tightness
   d. Fuses rating and type (as applicable)
   e. Compliance to drawings
   f. Correct blade alignment and penetration

[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional

g. Proper installation of line and load conductors
h. Correct operation of indicating and control devices.
i. Proper lubrication on moving parts

2. With switch open, inspect:
a. Fuse clips
b. Insulators
c. Mechanical and safety interlocks (as applicable)
d. Mounting

B. ELECTRICAL TESTS

1. Measure contact resistance across each switchblade and fuse holder.

2. Perform insulation-resistance tests on each pole, phase-to-phase and phase-to-ground for one minute with switch closed, and across each open pole.

3. Test fuse resistance (if applicable)

4. Verify proper operation of all status indicators

5. Functional Tests only for switches with Motor Operator
a. Verify control power for close and trip functions
b. Verify the electrical operation of each electrically operated breaker
1. Perform trip and close tests
c. Verify operation of the switch from local switches or terminal blocks

3.62 SWITCHBOARDS – LOW VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the switchboard line-up, including breakers, and accessories for:
a. Shipped loose and shipped short components
b. Shipping damage
c. Loose or obviously damaged components
d. Proper identification
e. Physical damage from installation
f. Doors, panels, and sections for alignment, dents, scratches, fit, and missing hardware
g. Maintenance accessories for servicing and operating all devices
h. Ensure any packing material used for shipment have been removed

2. Inspect:
a. Shipping Splits to insure that all bus connections were properly connected and all control wiring splits have been properly terminated by contractor.
b. Remove all temporary wiring for heaters if equipped
c. Inspect grounding connections
d. Insulators for evidence of physical damage or contaminated surfaces
e. Surge Arrester and/or Surge Suppression (as applicable)
f. Breaker Cell(s), Primary and Secondary Disconnects for physical condition, cleanliness and lubrication (as applicable)

g. Alignment and penetration of instrument transformer withdrawal disconnects, current carrying, and grounding components (as applicable)

h. Control power transformers (as applicable)

i. Wiring for damaged insulation, broken leads, proper crimping, and overall general condition

j. Fuse clip contact pressure and contact means (as applicable)

3. Verify structure, grounding, cables and bus assembly:

a. Anchorage (per local codes, wind and seismic considerations)

b. Required area clearances, correct alignment and cleanliness.

c. Verify the grounding electrode conductor is properly sized.

d. The proper grounding of instruments, panels and connections.

e. That conductors are properly identified (as applicable)

f. Cable termination tightness

g. That all cables have been properly installed, routed and supported and are clear of energized parts

h. That conduits and conduit bushings are correctly installed

i. Unused openings have been properly closed and secured

j. Verify factory connections by checking at least 10% of the total factory connections for tightness. If this spot check reveals loose connections, proceed to check all factory connections. These connections include bus hardware connections, circuit breaker and switch terminals, contactors, metering, and other connections, including the incoming terminals.

k. Correct barrier and shutter installation and operation

l. That filters are in place and/or vents are clear from obstructions

4. Verify control and instrumentation (as applicable):

a. All VT and CT ratios properly correspond to drawings and that polarity is correct

b. Shorting screws and bars are removed from CT’s and terminal blocks as required

c. Primary and secondary fuse ratings or circuit breakers match drawings

d. Meter scaling and type match drawings

5. Verify the proper operation of all circuit breaker cell and safety interlocks operation for fail-safe function.

a. Verify cell rejection plates are properly aligned and draw-out circuit breakers cannot be inserted into cells with the circuit breakers in the “closed” position.

b. Verify Key Interlock System (as applicable):

c. Key number and exchange codes

d. Proper sequencing to comply with drawing notes

e. Attempt to close locked-open devices

f. Attempt to open locked-closed devices

g. Make key exchange with devices operated in off-normal positions

h. Disposition of duplicate keys per the owner’s safety policy

B. ELECTRICAL TESTS

1. Insulation system:

a. Perform insulation-resistance tests on each bus section, phase-to-phase and

phase-to-ground.

2. Control and Instrumentation (as applicable):
   a. Perform the following tests on control power transformers:
      1. Insulation-resistance measurements from winding-to-winding and each winding-to-ground.
      2. Turns ratio test
   b. Perform the following tests on voltage transformers:
      1. Insulation-resistance measurements from winding-to-winding and each winding-to-ground.
      2. Polarity
   c. Verify correct function of control power transfer relays.
   d. Verify operation of heaters.
   e. Perform the following tests on current transformers in accordance with the testing methods in ANSI/IEEE C57.13.1:
      1. Ratio
      2. Polarity
3. Ground fault system (as applicable):
   a. Perform ground-fault test in accordance with Ground Fault or applicable circuit breaker specification section.
4. Verify operation of all protective devices equal to and greater than 200A per the appropriate specification section.
5. Test switches in accordance with applicable specification section.
6. Test surge arresters in accordance with applicable specification section
7. Set up all metering and power monitoring devices in accordance with applicable specification section.
8. Test all integrated power distribution products in accordance with the applicable specification section.
9. [3]Perform a bus joint resistant test through all sections using a 100A low-resistance ohmmeter.
10. [3]Test protective devices below 200A.
11. [3]Perform the excitation test on current transformers used in protective relay applications in accordance with the testing methods in ANSI/IEEE C57.13.1
12. [3]Measure current transformer burdens.
13. [3]Measure voltage transformer burdens.

3.63 SYNCHRONOUS GENERATOR

A. MECHANICAL AND VISUAL INSPECTION

[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional

1. Examine generator for:
   a. Shipped loose and shipped short components
   b. Shipping damage
   c. Loose or obviously damaged
      1. Frame
      2. Termination box
      3. Shaft
      4. Tachometer
      5. Brake
      6. Zero speed switch
      7. Mounting feet or flange
   d. Proper generator lubrication
   e. Coupling alignment and lubrication
   f. Proper identification
   g. Compliance to drawings
   h. Customer field connections and signals
   i. Remove temporary heater wiring and shipping braces
2. Inspect:
   a. All grounding connections
   b. Insulators for evidence of physical damage or contaminated surfaces
   c. Surge Arrestor and/or Surge Suppression size, type, installation and connection to determine if they are in accordance with the drawings.
   d. Wiring for damaged insulation, broken leads, tightness of connections, proper crimping, and overall general condition
3. Verify structure, grounding, cables and bus assembly for:
   a. Anchorage (per local codes, wind and seismic considerations)
   b. Required area clearances, correct alignment and cleanliness.
   c. That the grounding electrode conductor is properly sized and connected.
   d. That conductors are properly identified.
   e. Cable and control wire termination tightness
   f. That all cables have been properly installed, routed and supported
   g. That conduits and conduit bushings are correctly installed
   h. Unused openings have been properly closed and secured
   i. Tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturers published data
   j. That blocks or other temporary holding means used for shipment have been removed from the generator
   k. That filters are in place and/or vents are clear from obstructions
4. Inspect and test the generator field and resistor circuit:
   a. Disconnect the generator field leads from terminals
   b. Generator collector rings must be clean and concentric
   c. Generator brushes must be new, seated, free in the brush holders with the proper spring tension, and all brush lead connections clean and tight

d. Generator field lead terminations must be clean and tight

B. ELECTRICAL TESTS

1. Perform an insulation resistance test in accordance with ANSI/IEEE Standard 43

2. Perform dielectric absorption tests on each phase separately for 10 minutes. Calculate polarization index.

3. Measure resistance of Wye connections.

4. [3]Perform power factor and watts loss tests on stator windings.

5. [3]Vibration tests

3.64 SYNCHRONOUS MOTOR

A. MECHANICAL AND VISUAL INSPECTION

1. Examine motor for:
   a. Shipped loose and shipped short components
   b. Shipping damage
   c. Loose or obviously damaged
      1. Frame
      2. Termination box
      3. Shaft
      4. Tachometer
      5. Brake
      6. Zero speed switch
      7. Mounting feet or flange
   d. Proper motor lubrication
   e. Coupling alignment and lubrication
   f. Proper identification
   g. Compliance to drawings
   h. Customer field connections and signals
   i. Remove temporary heater wiring and shipping braces

2. Inspect:
   a. All grounding connections
   b. Insulators for evidence of physical damage or contaminated surfaces
   c. Surge Arrestor and/or Surge Suppression size, type, installation and connection to determine if they are in accordance with the drawings.
   d. Wiring for damaged insulation, broken leads, tightness of connections, proper crimping, and overall general condition

3. Verify structure, grounding, cables and bus assembly for:
   a. Anchorage (per local codes, wind and seismic considerations)
   b. Required area clearances, correct alignment and cleanliness.
   c. That the grounding electrode conductor is properly sized and connected.

[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional

d. That conductors are properly identified.
e. Cable and control wire termination tightness
f. That all cables have been properly installed, routed and supported
g. That conduits and conduit bushings are correctly installed
h. Unused openings have been properly closed and secured
i. Tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturers published data
j. That blocks or other temporary holding means used for shipment have been removed from the motor
k. That filters are in place and/or vents are clear from obstructions

4. Inspect and test the motor field and resistor circuit:
a. Disconnect the motor field leads from terminals
b. Motor collector rings must be clean and concentric
c. Motor brushes must be new, seated, free in the brush holders with the proper spring tension, and all brush lead connections clean and tight
d. Motor field lead terminations must be clean and tight

B. ELECTRICAL TESTS

1. Perform an insulation resistance test on the motor field to ground at 500 VDC including the motor field leads
2. Measure and record the cold motor field resistance
3. [3]Perform a power factor or dissipation-factor test of motor insulation.
4. [3]Perform vibration tests

3.65 TRANSFER SWITCHES – LOW VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine controller and accessories for:
a. Shipped loose and shipped short components
b. Shipping damage
c. Loose or obviously damaged components
d. Proper identification
e. Physical damage from installation
f. Alignment, dents, scratches, fit, and missing hardware

2. Inspect:
a. All connections for tightness
b. Potential transformers for proper rating, polarity and wiring for all power sources
c. For multi-tap potential transformers check that connections match applied system voltage

3. Perform the mechanical and visual inspections in the appropriate Site Acceptance Testing & Start-up Guideline for circuit breaker and contactor components.

[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional

B. ELECTRICAL AND FUNCTION TESTS

1. Verifying equipment is ready for electrical testing:

a. Remove and account for all test equipment, jumper wires, and tools used during installation

b. Replace all barriers and covers

2. Simulate control power to the Automatic Transfer Controller (ATC)

3. Program settings per manufacturer's instructions and setting provided by the owner to configure the ATC (Note: Customer to provide settings prior to commencement of acceptance testing. Additional charges will apply to install settings after testing is complete.)

4. Apply simulated source voltages to the ATC

5. Insure that all operational LED indicators on the front of the display are as described in the IB for the system conditions

6. Perform a functional test of the manual operation

7. Perform a functional test of the Engine start contact using the test button on the front of the controller

8. Perform a functional test of the automatic transfer switch in accordance with the specific ATC instruction book.

3.66 TRANSFER SWITCHES – MEDIUM VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the switchgear line-up, including breakers, and accessories for:

a. Shipped loose and shipped short components

b. Shipping damage

c. Loose or obviously damaged components

d. Proper identification

e. Physical damage from installation

f. Doors, panels, and sections for alignment, dents, scratches, fit, and missing hardware

g. Maintenance accessories for servicing and operating all devices

2. Inspect:

a. Shipping Splits to insure that all bus connections were properly connected and all control wiring splits have been properly terminated by contractor.

b. Remove all temporary wiring for heaters if equipped

c. Inspect grounding connections

d. Insulators for evidence of physical damage or contaminated surfaces

e. Surge Arrester and/or Surge Suppression (as applicable)

f. Breaker Cell(s), Primary and Secondary Disconnects for physical condition, cleanliness and lubrication (as applicable)

g. Alignment and penetration of instrument transformer withdrawal disconnects, current carrying, and grounding components (as applicable)

h. Control power transformers (as applicable)

i. Wiring for damaged insulation, broken leads, proper crimping, and overall general condition

j. Fuse clip contact pressure and contact means (as applicable)

3. Verify structure, grounding, cables and bus assembly:

a. Anchorage (per manufacturer's instructions)

b. Required area clearances, correct alignment and cleanliness.

c. Verify the grounding electrode conductor is properly sized (if applicable) and terminated

d. The proper grounding of instruments, panels and connections.

e. That conductors are properly identified (as applicable)

f. That all cables have been properly installed, routed and supported and are clear of energized parts

g. Verify factory connections by checking at least 10% of the total factory connections for tightness. If this spot check reveals loose connections, proceed to check all factory connections. These connections include bus hardware connections, circuit breaker and switch terminals, contactors, metering, and other connections, including the incoming terminals.

h. That conduits and conduit bushings are correctly installed

i. Unused openings have been properly closed and secured

j. Correct barrier and shutter installation and operation

k. That filters are in place and/or vents are clear from obstructions

4. Verify control and instrumentation (as applicable):

a. All VT and CT ratios properly correspond to drawings and that polarity is correct

b. Shorting screws and bars are removed from CT's and terminal blocks as required

c. Primary and secondary fuse ratings or circuit breakers match drawings

d. Meter scaling and type match drawings

5. Verify the proper operation of all circuit breaker cell and safety interlocks operation for fail-safe function.

a. Verify cell rejection plates are properly aligned and draw-out circuit breakers cannot be inserted into cells with the circuit breakers in the "closed" position.

b. Verify Key Interlock System (as applicable):

1. Key number and exchange codes
2. Proper sequencing to comply with drawing notes
3. Attempt to close locked-open devices
4. Attempt to open locked-closed devices
5. Make key exchange with devices operated in off-normal positions
6. Disposition of duplicate keys per the owner's safety policy

6. Perform the mechanical and visual inspections in the appropriate specification section for circuit breaker and protective device components.

B. ELECTRICAL AND FUNCTION TESTS

1. Set control, metering, breaker trip units, and protective relay adjustments. The protective relay, metering, and control settings must be supplied prior to testing by the customers' engineer or from a Power System Study. If not supplied, device settings will

be left on factory default.

2. Insulation system:
   a. Perform insulation-resistance tests on each bus section, phase-to-phase, phase-to-ground, phase-to-neutral and neutral-to-ground
   b. Perform a high potential test for main bus assemblies
      1. This field test should be made before the main cables are connected and should not exceed manufacturer's recommendations
      2. Transformer primary fuses should be removed and surge protective devices such as capacitors and arresters disconnected during high potential tests
3. Control and Instrumentation (as applicable):
   a. Perform the following tests on control power transformers
      1. Perform insulation-resistance tests.
      2. Perform measurements from winding-to-winding and each winding-to-ground.
      3. Perform a turns ratio test
   b. Verify correct function of control transfer relays located in Switchgear
   c. Verify operation of Switchgear heaters
   d. Perform the following tests on potential transformers
      1. Perform insulation-resistance tests.
      2. Perform measurements from winding-to-winding and each winding-to-ground.
   e. Perform the following tests on current transformers
      1. Ratio
      2. Polarity
4. Verify operation of all protective devices per the appropriate specification section.
5. Test all circuit breakers per the appropriate specification section.
6. Test all surge protection per the appropriate specification section.
7. Test all integrated power distribution products in accordance with the applicable specification section.
8. Simulate control power to the Automatic Transfer Controller (ATC)
9. Program settings per manufacturer's instructions and setting provided by the owner to configure the ATC (Note: Customer to provide settings prior to commencement of acceptance testing. Additional charges will apply to install settings after testing is complete.)
10. Apply simulated source voltages to the ATC
11. Insure that all operational LED indicators on the front of the display are as described in the IB for the system conditions
12. Perform a functional test of the manual operation
13. Perform a functional test of the Engine start contact using the test button on the front of the controller
14. Perform a functional test of the automatic transfer switch in accordance with the specific ATC instruction book.

15. [3]Perform a bus joint resistant test through all sections using a 100A low-resistance ohmmeter.

16. [3]Measure voltage current burdens on voltage transformers.

17. [3]Perform the following tests on current transformers in accordance with the testing methods in ANSI/IEEE C57.13.1

a. Excitation (Relaying Applications)

b. Measure current burdens at transformer terminals

3.67 VACUUM CIRCUIT BREAKER – MEDIUM VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine breaker for:

a. Shipping damage and status of the tip over indicator

b. Loose or obviously damaged components

c. Application with the cell

d. Compliance to drawings

2. Verify the manual operation of the breaker:

a. Charge closing spring using maintenance tool (manual charge handle) then remove handle

b. Verify Charged/Discharged status indicators function properly

c. Close breaker manually and verify Closed and Discharged indicators

d. Charge breaker again, verify that the breaker remains closed

e. Trip breaker manually verify Open indicator

f. Repeat several times to confirm mechanism operates consistently and reliably

g. Charge closing spring and close manually

B. ELECTRICAL TESTS

1. With the breaker closed:

a. Inspect contact erosion indicator mark on vacuum interrupter moving stem

b. Inspect contact wipe per manufacturer's instructions

c. Measure and record contact resistance

2. Perform insulation resistance tests

a. Test insulation resistance phase to phase and phase to ground

b. Perform high potential test per manufacturer's instructions

c. Perform the vacuum integrity test per manufacturer's instructions and at the recommend value (reference the specific breaker I.B.) Do not exceed maximum voltage stipulated for this test.

C. Functional Tests with Breaker in Cell

1. Rack the breaker into the cell ("Test Position" if applicable) and check for binding or hesitation and the movement of the breaker position indicator

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[3] Note to Spec. Writer – Optional

[3] Note to Spec. Writer – Optional

[3] Note to Spec. Writer – Optional

2. Verify the proper operation of all breaker/cell accessories, shutters, auxiliary switches, cell MOC and TOC switches, and key interlocks (as applicable)

3. Verify the proper operation of all breaker /cell safety interlocks (as applicable):
   a. Levering interlock
   b. Passive interlock
   c. Active interlock
   d. Breaker/cell rating code interlock

4. Inspect circuit breaker grounding connections

5. Verify proper operation of all cell status indicators (as applicable)

6. Check for the correct value of control power for close and trip functions prior to racking breaker into cell

7. Verify the electrical operation of the breaker, including anti-pump and trip-free operation.

8. Verify operation of the breaker from all local switches or terminal blocks

9. Verify that each protective relay and lock-out (86) device trips the breaker as designed (as applicable)

10. [3]Measure minimum coil trip voltages

11. [3]Perform drop-out testing of under-voltage protective devices.

12. [3]Perform a power factor or dissipation factor test on circuit breaker bushings.

13. [3]Perform timing test of circuit breaker operating mechanism.

14. [3]Perform insulation resistance tests on control wiring.

3.68 VACUUM MOTOR STARTER – MEDIUM VOLTAGE

A. MECHANICAL AND VISUAL INSPECTION

1. Examine contactor for:
   a. Shipping damage and status of the tip over indicator
   b. Loose or obviously damaged components
   c. Application with the cell
   d. Compliance to drawings
   e. Customer field connections and signals.

2. With contactor out of the cell, inspect:
   a. Primary disconnects, insulators, and interphase barriers
   b. Primary and control fuse holders and connections
   c. Mechanical interlock linkages
   d. Contactor ground connection
   e. Control plug and wiring harness (as applicable)

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[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional
[3] Note to Spec. Writer – Optional

f. Verify coil voltage matches actual control voltage
1. For SL contactors check voltage setting on coil control board and dropout setting
g. Current transformer, polarity marks, mounting, and leads
h. Door fit and alignment

3. Insert the contactor into the cell (as applicable)
a. If necessary, lubricate contactor truck wheels
b. If necessary, lubricate main finger clusters for draw out contactors.

4. Verify the proper operation of all contactor /cell safety interlocks (as applicable):
a. Closed contactor insertion/withdrawal interlock
b. Isolation switch interlocks
c. Contactor/cell rating code interlock
d. Inspect contactor grounding connections
e. Where applicable, verify truck safety locking bolt is properly torqued.
f. Auxiliary switches (as applicable)

B. ELECTRICAL TESTS

1. Apply temporary control power to the contactor per the instruction book:
a. Close contactor
b. Inspect contact wear
c. Measure contact resistance
d. Measure power fuse resistance
e. Check continuity of all instrument and control fuses.
f. Perform “CLOSED” portions of the insulation resistance and high potential tests each phase to ground.
g. Open contactor

2. With the contactor open:
a. Perform the “OPEN” portion of the insulation resistance and high potential tests line to load to ground.
b. Perform the vacuum integrity test at the factory recommended voltage level. Do not exceed maximum voltage stipulated for this test.

C. [3]SYNCHRONOUS CONTROLS

1. Examine the Mark V field panel, discharge resistor, and step down transformer for:
a. Shipping damage
b. Loose or obviously damaged components
c. Proper identification
d. Voltage, current, control voltage, starting resistor value, motor stator data, and motor field data
e. Compliance to the drawings
f. Customer field connections and signals

2. Inspect and test the motor field and resistor circuit:

[3] Note to Spec. Writer – Optional

a. Disconnect the motor field leads from terminals F1 and F2

b. Motor collector rings must be clean and concentric

c. Motor brushes must be new, seated, free in the brush holders with the proper spring tension, and all brush lead connections clean and tight

d. Motor field lead terminations must be clean and tight

e. Perform an insulation resistance test on the motor field to ground at 500 VDC including the motor field leads

f. Measure and record the cold motor field resistance

1. The measured resistance reading should be between 70% and 80% of the motor name plate field voltage divided by the name plate field current

g. Measure the resistance at terminal F1 & F2 on the Mark V terminal strip

1. Value to be 250 ohms, plus/minus 15 ohms

h. Measure the resistance of the starting discharge resistor at terminals R1 & R3

1. The value should be as shown on the diagram accompanying the order

i. Measure the resistance between terminals VR and KA1 on the control board

1. The value should be 50 ohms plus the value measured between R1 & R3

j. Reconnect all leads removed during this check

3. Inspect and test the step down transformer:

a. Inspect transformer and fuse leads for tightness

b. Verify turns ratio and tap setting

c. Verify primary and secondary fuse ratings

4. Function Tests with Contactor in Cell with Primary Voltage

a. Disconnect motor leads from starter being sure to tape, label, and note the motor lead connections at T1, T2, & T3 leaving F1 and F2 connected. Isolate stator leads from ground, each other, and live parts

b. Close and latch all doors except those necessary to perform these tests

c. Notify personnel that the motor field is to be energized and rope off motor with warning tape

d. Close isolation switch

e. Motor field windings may be damaged if energized for more than two minutes with motor not rotating

f. Close the “M” contactor while monitoring voltage at F1 & F2 and field current at the panel meter

1. The voltage on F1 & F2 should be adjustable from 50% to 100%

2. Adjust field current for full load value

g. De-energize starter

h. Open isolation switch and remove contactor from cell

i. Reconnect motor to starter

j. Install contactor, fuses, and interphase barriers

k. Bump start the motor to verify motor rotation

l. Start motor and verify all customer field controls and signals

D. [3]REDUCED VOLTAGE AUTOTRANSFORMER

[3] Note to Spec. Writer – Optional

1. Examine the reduced voltage section contactors and transformer for:
   a. Shipping damage
   b. Loose or obviously damaged components
   c. Proper identification
   d. Rating (voltage, current, control voltage, current transformers, and interrupting rating)
   e. Compliance to the drawings
2. Inspect the reduced voltage section contactors:
   a. Primary leads, insulators, interphase barriers
   b. Mechanical interlock linkages
   c. Ground connections
   d. Control plug and wiring
   e. Auxiliary switches
   f. Door fit and alignment
3. Apply temporary control power to the main contactor per the instruction book:
   a. Close main contractor and allow transition to occur
   b. Verify the correct sequence of operation
4. Inspect reduced voltage contactors:
   a. Contact over-travel gap
   b. Measure contact resistance
   c. Perform “CLOSED” portions of the insulation resistance test and high potential test
   d. Open contactors
5. With the contactors open:
   a. Perform the “OPEN” portion of the insulation resistance test
   b. Perform the vacuum integrity test at the OEM recommended voltage level. Do not exceed maximum voltage stipulated for this test. Provide adequate barriers and protection against x-radiation during this test. Do not perform this test unless the contact displacement of each interrupter is within manufacturer's tolerance. (Be aware that some DC high-potential test sets are half-wave rectified and may produce peak voltages in excess of the breaker manufacturer's recommended maximum)
6. Perform control wiring insulation resistance at 500 volts DC. Do not perform this test on wiring connected to solid state components
7. Verify the proper operation of isolation switch/door key interlock system
8. Verify that all accessible moving components are adequately lubricated
9. Function Tests Reduced Voltage Starter with Primary Voltage
   a. Close isolation switch
   b. Verify control voltage level as a convenient point on the control panel
   c. Notify personnel that the motor field is to be energized and rope off motor with warning tape
   d. Verify that all reduced voltage setting have been made and fall within the recommend safe values

e. Be aware that there is a duty cycle rating on the transformer and the transformer will be damaged if more than three starts are attempted in less than one hour

f. Start the motor paying particular attention to:

1. Motor start transition current
2. Motor start transition time
3. Transition or trip on time-out
4. Incomplete sequence

g. The maximum permissible incomplete sequence time is 30 seconds. Manually stop motor in the event that the 30 seconds expires and the transition operation has not taken place. Investigate and correct cause before restarting the motor

3.69 VOLTAGE REGULATORS

A. MECHANICAL AND VISUAL INSPECTION

1. Examine the voltage regulator for:
   a. Proper identification
   b. Compliance to the drawings
   c. Leaks
2. Ensure regulator tanks, control enclosure and elevating structures are properly grounded
3. Inspect for damage in all areas of the regulator. Areas of concern are the position indicator, junction box, bushings, arrestor, radiators, and control cabinet.
4. Check fluid level in the oil sight gauge and look for signs of oil leakage

B. ELECTRICAL TESTS

1. Perform insulation resistance testing.
2. Determine low voltage ratio test at each step position.
3. Perform operational check with external voltage
4. Verify operation of heaters if present.
5. Test bushings and surge arrestors if present.

C. INSULATING LIQUID ANALYSIS

1. Perform a field oil dielectric breakdown test

3.70 EVALUATION OF TEST DATA

A. Test results should be evaluated in accordance with the manufacturer’s published data.

3.71 RESTORATION OF EQUIPMENT AND REPORTS

A. Before energizing:

1. Remove and account for all test equipment, jumper wires, and tools used during testing.
2. Remove and account for safety grounds and tools.
3. Replace all barriers and covers, close all doors, and secure all latches.
4. Remove safety locks and tags.

5. Insure all adjustable meters, relays and trip devices are properly set in accordance with the coordination study.

6. Apply testing label to equipment

B. Note corrective actions taken, deficiencies, recommendations and any general comments.

C. Finish recording data on test forms, completely filling in the blanks. Enter into electronic database as required in section 1.04.E

D. Turn in 3 copies of report to engineer for approval.

3.72 START-UP AND ENERGIZING SERVICES

A. Provide _ days for a manufacturer service representative to assist the contractor with startup and energization of all of the electrical apparatus.

Note to Spec. Writer:
Adjust the days for manufacturer service representative assistance based upon complexity and projected duration of the project.

3.73 [3]FOLLOW UP THERMAL SCAN

A. Included in above cost as part of original project.

B. One month prior to the expiration of the factory warranty schedule & perform a thermal scan of all breaker to cable, breaker, bus connections, cable to panel chassis. Scope is to include main transformer connections, main switchboard, all secondary switchboards, transformers, and panels. Tests are to be done with building normal loaded for 2 hours.

C. Thermal scans temperatures shall be evaluated as follows (based on comparable size or adjacent phases and loaded breakers, bus connections, and terminations)

1. 1-3 degrees C rise, Investigate as to the cause of temp rise.

2. 4 – 15 degree C rise, Repair as soon as possible.

3. 16 or higher degree C rise, Repair immediately.

D. Insure that all bus and breaker to cable connections are tight.

E. Note corrective actions taken, deficiencies, recommendations and any general comments.

F. Finish recording data on test forms, completely filling in the blanks.

G. Turn in 3 copies of report to engineer for approval.

[3] Note to Spec. Writer – Optional