

Extensive Substation Inspections and Tests (every 3 years) (based on ANSI/NETA MTS-2019)

Section	Description
7.1	Switchgear, Switchboard, and Panelboard Assemblies
A	Visual and Mechanical Inspection
1	Inspect physical, electrical, and mechanical condition.
2	Inspect anchorage, alignment, grounding, and required area clearances.
5	Verify that fuse and/or circuit breaker sizes and types correspond to drawings and coordination study as well as to the circuit breaker address for microprocessorcommunication packages.
6	Verify that current and voltage transformer ratios correspond to drawings.
7	Verify that wiring connections are tight and that wiring is secure to prevent damage during routine operation of moving parts.
9	<u>Confirm correct operation and sequencing of electrical and mechanical interlock systems.</u>
9.1	<ul style="list-style-type: none"> • Attempt closure on locked-open devices. Attempt to open locked-closed devices.
9.2	<ul style="list-style-type: none"> • Make key exchange with all devices included in the interlock scheme as applicable.
10	Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
11	Inspect insulators for evidence of physical damage or contaminated surfaces.
12	Verify correct barrier and shutter installation and operation.
13	Exercise all active components.
14	Inspect mechanical indicating devices for correct operation.
15	Verify that filters are in place and/or vents are clear.
16	Perform visual and mechanical inspection of instrument transformers in accordance with Section 7.10 .
17	Perform visual and mechanical inspection of surge arresters in accordance with Section 7.19 .
18	<u>Inspect control power transformers.</u>
18.1	<ul style="list-style-type: none"> • Inspect for physical damage, cracked insulation, broken leads, tightness of connections, defective wiring, and overall general condition.
18.2	<ul style="list-style-type: none"> • Verify that primary and secondary fuse ratings or circuit breakers match drawings.
18.3	<ul style="list-style-type: none"> • Verify correct functioning of drawout disconnecting and grounding contacts and interlocks.
B	Electrical Tests
2	Perform insulation-resistance tests for one minute on each bus section, phase-to-phase and phase-to-ground. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1 .
***3	Perform a dielectric withstand voltage test on each bus section, each phase-to-ground with phases not under test grounded, in accordance with manufacturer's published data. within the absence of manufacturer's published data, use Table 100.2 . The test voltage shall be applied for one minute. Refer to Section 7.1.3 before performing test.

***4	Perform insulation-resistance tests on control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components or control devices that cannot tolerate the applied voltage, follow manufacturer's recommendation.
5	Perform electrical tests on instrument transformers in accordance with Section 7.10 .
6	Perform ground-resistance tests in accordance with Section 7.13 .
7	Test metering devices in accordance with Section 7.11 .
8	<u>Control Power Transformers.</u>
8.1	<ul style="list-style-type: none"> Perform insulation-resistance tests. Perform measurements from winding-to-winding and each winding-to-ground. Test voltages shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1.
8.2	<ul style="list-style-type: none"> Verify correct function of control transfer relays located in switchgear with multiple power sources.
9	Verify operation of switchgear/switchboard heaters and their controller.
10	Perform electrical tests of surge arresters in accordance with Section 7.19 .
***11	Perform online partial-discharge survey in accordance with Section 11 .
12	Perform system function tests in accordance with Section 8 .
7.2.1.2 Transformers, Dry-Type, Air-Cooled, Large	
A	Visual and Mechanical Inspection
1	Inspect physical and mechanical condition.
2	Inspect anchorage, alignment, and grounding.
***5	Verify that control and alarm settings on temperature indicators are as specified.
6	Verify that cooling fans operate correctly.
11	Verify the presence of surge arresters.
B	Electrical Tests
1	Perform resistance measurements through bolted connections with a low-resistance ohmmeter in accordance with Section 7.2.1.2.A.7.1 .
2	Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5 . Calculate polarization index.
3	Perform insulation power-factor or dissipation-factor tests on all windings in accordance with the test equipment manufacturer's published data.
***4	Perform a power-factor or dissipation-factor tip-up test on windings rated greater than 2.5 kV.
5	Perform turns-ratio tests at the designated tap position.
6	Perform an excitation-current test on each phase.
***7	Measure the resistance of each winding at the designated tap position.
8	Measure core insulation resistance at 500 volts dc if the core is insulated and if the core ground strap is removable.
***9	Perform an applied voltage test on all high- and low-voltage windings-to-ground. See IEEE C57.12.91-2001, Sections 103.

10	Verify correct secondary voltage phase-to-phase and phase-to-neutral after energization and prior to loading.
11	Test surge arresters in accordance with Section 7.19 .
***12	Perform online partial-discharge survey on winding rated higher than 600 volts in accordance with Section 11 .
7.2.2 Transformers, Liquid-Filled	
A	Visual and Mechanical Inspection
1	Inspect physical and mechanical condition.
2	Inspect anchorage, alignment, and grounding.
3	Verify the presence of PCB labeling.
6	Verify operation of alarm, control, and trip circuits from temperature and level indicators, pressure-relief device, gas accumulator, and fault-pressure relay.
7	Verify that cooling fans and/or pumps operate correctly.
9	Verify correct liquid level in tanks and bushings.
10	Verify that positive pressure is maintained on gas-blanketed transformers.
11	Perform inspections and mechanical tests as recommended by the manufacturer.
12	Test load tap-changer in accordance with Section 7.12 .
13	Verify the presence of transformer surge arresters.
B	Electrical Tests
1	Perform resistance measurements through bolted connections with a low-resistance ohmmeter in accordance with Section 7.2.2.A.8.1 .
2	Perform insulation-resistance tests, winding-to-winding and each winding-to-ground. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5 . Calculate polarization index.
3	Perform turns-ratio tests at the designated tap position.
4	Perform insulation power-factor or dissipation-factor tests on all windings in accordance with test equipment manufacturer's published data.
5	Perform power-factor or dissipation-factor tests on each bushing equipped with a powerfactor/capacitance tap. In the absence of a power-factor/capacitance tap, perform hot-collar tests. These tests shall be in accordance with the test equipment manufacturer's published data.
6	Perform excitation-current tests in accordance with the test equipment manufacturer's published data.
***7	Perform sweep frequency response analysis tests.
8	Measure the resistance of each winding at the designated tap position.
***9	If core ground strap is accessible, remove & measure the core insulation resistance at 500 volts dc.
***10	Measure the percentage of oxygen in the gas blanket.
11	<u>Remove a sample of insulating liquid in accordance with ASTM D923. The sample shall be tested for the following.</u>
11.1	• Dielectric-breakdown voltage: ASTM D1816
11.2	• Acid neutralization number: ASTM D974
***11.3	• Specific gravity: ASTM D1298

11.4	• Interfacial tension: ASTM D971
11.5	• Color: ASTM D1500
11.6	• Visual condition: ASTM D1524
11.7	• Water in insulating liquids: ASTM D1533
**11.8	• Measure power factor or dissipation factor in accordance with ASTM D924
12	Remove a sample of insulating liquid in accordance with ASTM D3613 and perform dissolved-gas analysis (DGA) in accordance with IEEE C57.104 or ASTM D3612 .
13	Test the instrument transformers in accordance with Section 7.10 .
14	Test the surge arresters in accordance with Section 7.19 .
15	Test the transformer neutral grounding impedance devices.
7.3.3 Shielded Cables, Medium- and High-Voltage	
A Visual and Mechanical Inspection	
1	Inspect exposed sections of cables for physical damage and evidence of overheating and corona.
2	Inspect terminations and splices for physical damage, evidence of overheating, and corona.
5	Inspect shield grounding and cable support.
6	Verify that visible cable bends meet or exceed ICEA and/or manufacturer's minimum allowable bending radius.
***7	Inspect fireproofing in common cable areas.
8	If cables are terminated through window-type current transformers, inspect to verify that neutral and ground conductors are correctly placed and that shields are correctly terminated for operation of protective devices.
B Electrical Tests	
1	Perform resistance measurements through bolted connections with a low-resistance ohmmeter in accordance with Section 7.3.3.A.3.1 .
2	Perform an insulation-resistance test individually on each conductor with all other conductors and shields grounded. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1 .
3	Perform a shield-continuity test on each power cable by ohmmeter method.
4	<u>In accordance with ICEA, IEC, IEEE and other power cable consensus standards, testing can be performed by means of direct current, power frequency alternating current, very low frequency alternating current, or damped alternating current. These sources may be used to perform insulation withstand tests, and diagnostic tests such as partial discharge analysis, and power factor or dissipation factor. The selection can only be made after an evaluation of the available test methods, manufacturer's published data, and a review of the installed cable system.</u>
4.1	• Dielectric Withstand
4.1.1	▣ Direct current (DC) dielectric withstand voltage
4.1.2	▣ Very low frequency (VLF) dielectric withstand voltage
4.1.3	▣ Power frequency (50/60 Hz) dielectric withstand voltage
4.2	• Diagnostic Tests
4.2.1	▣ Power factor/dissipation factor (tan delta)
4.2.1.1	○ Power frequency (50/60 Hz)

4.2.1.2	○ Very low frequency (VLF)
4.2.1.3	○ Damped-alternating current (20 to 500 Hz)
4.2.2	▣ DC insulation resistance
4.2.3	▣ Partial discharge
4.2.3.1	○ Online (50/60 Hz)
4.2.3.2	○ Off line
4.3.2.1	○ Power frequency (50/60 Hz)
4.3.2.2	○ Very low frequency (VLF)
7.4	Metal-Enclosed Busways
A	Visual and Mechanical Inspection
1	Inspect physical and mechanical condition.
2	Inspect anchorage, alignment, and grounding.
4	Confirm physical orientation in accordance with manufacturer's labels to ensure adequate cooling.
5	Examine outdoor busway for removal of "weep-hole" plugs and for the correct installation of joint shield.
B	Electrical Tests
1	Perform resistance measurements through bolted connections and bus joints with a low-resistance ohmmeter in accordance with Section 7.4.A.3.1 .
2	Perform insulation resistance tests on each busway for one minute, phase-to-phase and phase-to-ground. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1 .
3	Perform a dielectric withstand voltage test on each busway, phase-to-ground with phases not under test grounded, in accordance with manufacturer's published data. If manufacturer has no recommendation for this test, it shall be in accordance with Table 100.17 . Where no dc test value is shown in Table 100.17 , ac value shall be used. The test voltage shall be applied for one minute.
***4	Perform a contact-resistance test on each connection point of uninsulated busway. On insulated busway, measure resistance of assembled busway sections and compare values with the adjacent phases.
5	Verify operation of busway space heaters.
***6	Perform online partial-discharge survey in accordance with Section 11 .
7.5.1.1	Switches, Air, Medium-Voltage, Metal-Enclosed
A	Visual and Mechanical Inspection
1	Inspect physical and mechanical condition.
2	Inspect anchorage, alignment, grounding, and required clearances.
5	Verify correct blade alignment, blade penetration, travel stops, arc interrupter operation, and mechanical operation.
6	Verify that fuse sizes and types are in accordance with drawings, short-circuit studies, and coordination study.
7	Verify that expulsion-limiting devices are in place on all fuses having expulsion-type elements.

8	Verify that each fuseholder has adequate mechanical support and contact integrity.
10	Verify operation and sequencing of interlocking systems.
11	Verify that phase-barrier mounting is intact.
12	Verify correct operation of all indicating and control devices.
13	Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
B	Electrical Tests
1	Perform resistance measurements through bolted connections with a low-resistance ohmmeter in accordance with Section 7.5.1.2.A.9.1 .
2	Measure contact resistance across each switchblade assembly and fuseholder.
3	Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with switch closed and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1 .
4	Perform a dielectric withstand voltage test on each pole with switch closed. Test each pole-to-ground with all other poles grounded. Test voltage shall be in accordance with manufacturer's published data or Table 100.2 .
5	Measure fuse resistance.
6	Verify cubicle space heater operation.
***7	Perform online partial-discharge survey in accordance with Section 11 .
7.5.1.3: Switches, Air, Medium- and High-Voltage, Open	
A	Visual and Mechanical Inspection
1	Inspect physical and mechanical condition.
2	Inspect anchorage, alignment, grounding, and required clearances.
5	Verify correct blade alignment, blade penetration, travel stops, arc interrupter operation, and mechanical operation.
6	Verify that fuse sizes and types are in accordance with drawings, short-circuit studies, and coordination study.
7	Verify that each fuseholder has adequate mechanical support and contact integrity.
9	Verify operation and sequencing of interlocking systems.
10	Perform mechanical operator tests in accordance with manufacturer's published data.
11	Verify correct operation and adjustment of motor operator limit switches and mechanical interlocks.
12	Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
B	Electrical Tests
1	Perform resistance measurements through bolted connections with a low-resistance ohmmeter in accordance with Section 7.5.1.3.A.8.1 .
2	Perform a contact-resistance test across each switchblade and fuseholder.

3	Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with switch closed and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1 .
***4	Perform insulation-resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components or control devices that cannot tolerate the applied voltage, follow manufacturer's recommendation.
5	Perform a dielectric withstand voltage test on each pole with switch closed. Test each pole-to-ground with all other poles grounded. Test voltage shall be in accordance with manufacturer's published data or Table 100.19 .
6	Measure fuse resistance.
7.5.4 Switches, SF₆, Medium-Voltage	
A Visual and Mechanical Inspection	
1	Inspect physical and mechanical condition.
2	Inspect anchorage, alignment, grounding, and required clearances.
5	Inspect and service mechanical operator and SF ₆ gas insulated system in accordance with the manufacturer's published data.
6	Verify correct operation of SF ₆ gas pressure alarms and limit switches as recommended by the manufacturer.
7	Measure critical distances as recommended by the manufacturer.
9	Verify that fuse sizes and types are in accordance with drawings, short-circuit studies, and coordination study.
10	Verify that each fuseholder has adequate mechanical support and contact integrity.
11	Verify operation and sequencing of interlocking systems.
12	Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
13	Test for SF ₆ gas leaks in accordance with manufacturer's published data.
B Electrical Tests	
1	Perform resistance measurements through accessible bolted electrical connections with a low-resistance ohmmeter. See Section 7.5.4.A.8.1 .
2	Perform a contact-resistance test.
3	Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with switch closed, and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1 .
***4	Remove a sample of SF ₆ gas and test in accordance with Table 100.13 .
5	Perform a dielectric withstand voltage test across each gas bottle with the switch in the open position in accordance with manufacturer's published data.
***6	Perform insulation-resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.

***7	Perform a dielectric withstand voltage test in accordance with manufacturer's published data.
8	Verify open and close operation from control devices.
9	Measure fuse resistance.
7.5.5 Switches, Cutouts	
A	Visual and Mechanical Inspection
1	Inspect physical and mechanical condition.
2	Inspect anchorage, alignment, and grounding.
6	Verify correct blade alignment, blade penetration, travel stops, latching mechanism, and mechanical operation.
7	Verify that fuse size and types are in accordance with drawings, short-circuit study, and coordination study.
8	Verify that each fuseholder has adequate mechanical support and contact integrity.
B	Electrical Tests
1	Perform resistance measurements through bolted connections with a low-resistance ohmmeter in accordance with Section 7.5.5.A.5.1 .
2	Measure contact resistance across each cutout.
3	Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with switch closed and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1 .
4	Perform a dielectric withstand voltage test on each pole, phase to ground with cutout closed. Ground adjacent cutouts. Test voltage shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1 .
5	Measure fuse resistance.
7.6.1.3 Circuit Breakers, Air, Medium-Voltage	
A	Visual and Mechanical Inspection
1	Inspect physical and mechanical condition.
2	Inspect anchorage, alignment, and grounding.
3	Verify that all maintenance devices are available for servicing and operating the breaker.
***4	Perform operator analysis (first-trip) test.
7	Inspect arc chutes.
8	Inspect moving and stationary contacts for condition, wear, and alignment.
9	If recommended by manufacturer, slow close/open breaker and check for binding, friction, contact alignment, contact sequence, and penetration. Verify that contact sequence is in accordance with manufacturer's published data. In the absence of manufacturer's published data, refer to IEEE C37.04 .
10	Perform all mechanical operation tests on the operating mechanism in accordance with manufacturer's published data.
12	Verify cell fit and element alignment.
13	Verify racking mechanism operation.
14	Inspect puffer operation.

15	Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
16	Perform contact timing test.
***17	Perform mechanism-motion analysis.
***18	Perform trip/close coil current signature analysis.
B	Electrical Tests
1	Perform resistance measurements through bolted connections with a low-resistance ohmmeter. See Section 7.6.1.3.A.11.1 .
2	Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with the circuit breaker closed, and across each open pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1 .
***3	Perform insulation-resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components or control devices that cannot tolerate the applied voltage, follow manufacturer's recommendation.
4	Perform a static contact/pole-resistance test.
5	<u>With the breaker in a test position, perform the following tests:</u>
5.1	• Trip and close breaker with the control switch.
5.2	• Trip breaker by operating each of its protective relays.
5.3	• Verify mechanism charge, trip-free, and antipump functions.
***6	Perform minimum pickup voltage tests on trip and close coils in accordance with manufacturer's published data. In the absence of manufacturer's published data refer to Table 100.20 .
***7	Perform power-factor or dissipation-factor tests with breaker in both the open and closed positions.
***8	Perform power-factor or dissipation-factor tests on each bushing equipped with a powerfactor/capacitance tap. In the absence of a power-factor/ capacitance tap, perform hot-collar tests. These tests shall be in accordance with the test equipment manufacturer's published data.
***9	Perform a dielectric withstand voltage test on each phase with the circuit breaker closed and the poles not under test grounded. Test voltage should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.19 .
10	Verify blowout coil circuit continuity.
11	Verify operation of heaters.
***12	Test instrument transformers in accordance with Section 7.10 .
7.6.3 Circuit Breakers, Vacuum, Medium-Voltage	
A	Visual and Mechanical Inspection
1	Inspect physical and mechanical condition.
2	Inspect anchorage, alignment, and grounding.

3	Verify that all maintenance devices are available for servicing and operating the breaker.
***4	Perform operator analysis (first-trip) test.
7	Inspect vacuum bottle assemblies.
8	Measure critical distances such as contact gap as recommended by the manufacturer.
9	If recommended by the manufacturer, slow close/open the breaker and check for binding, friction, contact alignment, contact sequence, and penetration.
10	Perform all mechanical operation tests on the operating mechanism in accordance with manufacturer's published data.
12	Verify cell fit and element alignment.
13	Verify racking mechanism operation.
14	Inspect vacuum bellows operation.
15	Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
16	Perform contact timing test.
***17	Perform mechanism-motion analysis.
***18	Perform trip/close coil current signature analysis.
B	Electrical Tests
1	Perform resistance measurements through bolted connections with a low-resistance ohmmeter in accordance with Section 7.6.3.A.11.1 .
2	Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phaseto-ground with circuit breaker closed and across each pole with the breaker open. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1 .
***3	Perform insulation-resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components or control devices that cannot tolerate the applied voltage, follow manufacturer's recommendation.
4	Perform a static contact/pole-resistance test.
5	<u>With breaker in a test position, perform the following tests:</u>
5.1	• Trip and close breaker with the control switch.
5.2	• Trip breaker by operating each of its protective relays.
5.3	• Verify mechanism charge, trip-free, and antipump functions.
***6	Perform minimum pickup voltage tests on trip and close coils in accordance with manufacturer's published data. In the absence of manufacturer's published data refer to Table 100.20 .
7	Perform a vacuum bottle integrity (dielectric withstand voltage) test across each vacuum bottle with the breaker in the open position in strict accordance with manufacturer's published data.
***8	Perform magnetron atmospheric condition (MAC) test on each vacuum interrupter.

***9	Perform a dielectric withstand voltage test on each phase with the circuit breaker closed and the poles not under test grounded. Test voltage should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.19 .
10	Verify operation of heaters.
***11	Test instrument transformers in accordance with Section 7.10 .
7.6.4 Circuit Breakers, SF₆	
A	Visual and Mechanical Inspection
1	Inspect physical and mechanical condition.
2	Inspect anchorage, alignment, and grounding.
3	Verify that all maintenance devices are available for servicing and operating the breaker.
*4	Perform operator analysis (first-trip) test.
***7	When provisions are made for sampling, remove a sample of SF ₆ gas and test in accordance with Table 100.13 . Do not break seal or distort sealed-for-life interrupters.
8	Inspect and service operating mechanism and/or hydraulic or pneumatic system and SF ₆ gas-insulated system in accordance with manufacturer's published data.
9	Test for SF ₆ gas leaks in accordance with manufacturer's published data.
10	Test alarms, pressure switches, and limit switches for pneumatic and/or hydraulic operators and SF ₆ gas pressure in accordance with manufacturer's published data.
11	If recommended by manufacturer, slow close/open breaker and check for binding, friction, contact alignment, and penetration. Verify that contact sequence is in accordance with manufacturer's published data. In the absence of manufacturer's published data, refer to IEEE C37.04 .
12	Perform all mechanical operation tests on the operating mechanism in accordance with manufacturer's published data.
14	Verify cell fit and element alignment.
15	Verify racking mechanism operation.
16	Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
17	Perform contact timing test.
***18	Perform mechanism-motion analysis.
***19	Perform trip/close coil current signature analysis.
B	Electrical Tests
1	Perform resistance measurements through all bolted connections with a low-resistance ohmmeter in accordance with Section 7.6.4.A.13.1 .
2	Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with breaker closed, and across each open pole. For single-tank breakers, perform insulation resistance tests from pole-to-pole. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1 .
3	Perform a static contact/pole-resistance test.
***4	Perform a dynamic contact/pole resistance test.

***5	Perform insulation-resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components or for control devices that cannot tolerate the voltage, follow manufacturer's recommendation.
6	<u>With breaker in a test position, perform the following tests:</u>
6.1	• Trip and close breaker with the control switch.
6.2	• Trip breaker by operating each of its protective relays.
6.3	• Verify trip-free and antipump functions.
***6.4	• Perform minimum pickup voltage tests on trip and close coils in accordance with Table 100.20 .
7	Perform power-factor or dissipation-factor tests on each pole with the breaker open and on each phase with breaker closed.
8	Perform power-factor or dissipation-factor tests on each bushing equipped with a powerfactor/capacitance tap. In the absence of a power-factor/ capacitance tap, perform hot-collar tests. These tests shall be in accordance with the test equipment manufacturer's published data.
***9	Perform a dielectric withstand voltage test in accordance with manufacturer's published data.
10	Verify operation of heaters.
***11	Test instrument transformers in accordance with Section 7.10 .
7.7	Circuit Switchers
A	Visual and Mechanical Inspection
1	Inspect physical and mechanical condition.
2	Inspect anchorage, alignment, and grounding.
5	Perform all mechanical operational tests on both the circuit switcher and its operating mechanism.
7	Verify operation of SF ₆ interrupters is in accordance with manufacturer's published data.
8	Verify SF ₆ pressure is in accordance with manufacturer's published data.
9	Verify operation of isolating switch is in accordance with manufacturer's published data.
10	Test all interlocking systems for correct operation and sequencing.
11	Verify all indicating and control devices for correct separation.
12	Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
B	Electrical Tests
1	Perform resistance measurements through all connections with a low-resistance ohmmeter in accordance with Section 7.7.A.6.1 .
2	Perform contact-resistance tests of interrupters and isolating switches.
3	Perform insulation-resistance tests on each pole, phase-to-ground. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1 .

***4	Perform insulation-resistance tests on all control wiring with respect to ground. The applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer's recommendation.
***5	Perform minimum pickup voltage tests on trip and close coils in accordance with Table 100.20 .
6	Verify correct operation of auxiliary features such as electrical close and trip operation, tripfree, and antipump function. Reset all trip logs and indicators.
7	Trip circuit switcher by operation of each protective device.
8	Verify correct operation of electrical trip of interrupters.
9	Perform a dielectric withstand voltage test in accordance with manufacturer's published data.
10	Verify operation of heaters.
7.9.1	Protective Relays, Electromechanical and Solid-State
A	Visual and Mechanical Inspection
1	Inspect relays and cases for physical damage.
3.1	<u>Relay Case</u>
3.1.4	• Inspect shorting hardware, connection paddles, and/or knife switches.
3.1.5	• Remove any foreign material from the case.
3.1.6	• Verify target reset.
3.2	<u>Relay</u>
3.2.1	• Inspect relay for foreign material, particularly in disk slots of the damping and electromagnets.
3.2.2	• Verify disk clearance. Verify contact clearance and spring bias.
3.2.3	• Inspect spiral spring convolutions.
3.2.4	• Inspect disk and contacts for freedom of movement and correct travel.
3.2.5	• Verify tightness of mounting hardware and connections.
3.2.6	• Burnish contacts.
3.2.7	• Inspect bearings and pivots.
4	Verify that all settings are in accordance with coordination study or setting sheet supplied by owner.
B	Electrical Tests
1	Perform insulation-resistance test on each circuit-to-frame. Procedures for performing insulation-resistance tests on solid-state relays should be determined from the relay manufacturer's published data.
2	<u>Test targets and indicators:</u>
2.1	• Determine pickup and dropout of electromechanical targets.
2.2	• Verify operation of all light-emitting diode indicators.
2.3	• Set contrast for liquid-crystal display readouts.
3	<u>Protection Elements (by ANSI device number)</u>
3.1	• 2/62 Timing Relay
3.1.1	▪ Determine time delay.

3.1.2	▣ Verify operation of instantaneous contacts.
3.2	• 21 Distance Relay
3.2.1	▣ Determine maximum reach.
3.2.2	▣ Determine maximum torque angle and directional characteristic.
3.2.3	▣ Determine offset.
**3.2.4	▣ Plot impedance circle.
3.3	• 24 Volts/Hertz Relay
3.3.1	▣ Determine pickup frequency at rated voltage.
3.3.2	▣ Determine pickup frequency at a second voltage level.
3.3.3	▣ Determine time delay.
3.4	• 25 Sync Check Relay
3.4.1	▣ Determine closing zone at rated voltage.
3.4.2	▣ Determine maximum voltage differential that permits closing at zero degrees.
3.4.3	▣ Determine live line, live bus, dead line, and dead bus set points.
3.4.4	▣ Determine time delay.
**3.4.5	▣ Determine advanced closing angle.
3.4.6	▣ Verify dead bus/live line, dead line/live bus and dead bus/dead line control functions.
3.5	• 27 Undervoltage Relay
3.5.1	▣ Determine dropout voltage.
3.5.2	▣ Determine time delay.
3.5.3	▣ Determine the time delay at a second point on the timing curve for inverse time relays.
3.6	• 32 Directional Power Relay
3.6.1	▣ Determine minimum pickup at maximum torque angle.
3.6.2	▣ Determine contact closing zone.
3.6.3	▣ Determine maximum torque angle.
3.6.4	▣ Determine time delay.
3.6.5	▣ Verify the time delay at a second point on the timing curve for inverse time relays.
**3.6.6	▣ Plot the operating characteristic.
3.7	• 40 Loss of Field (Impedance) Relay
3.7.1	▣ Determine maximum reach.
3.7.2	▣ Determine maximum torque angle.
3.7.3	▣ Determine offset.
**3.7.4	▣ Plot impedance circle.
3.8	• 46 Current Balance Relay
3.8.1	▣ Determine pickup of each unit.
3.8.2	▣ Determine percent slope.
3.8.3	▣ Determine time delay.
3.9	• 46N Negative Sequence Current Relay
3.9.1	▣ Determine negative sequence alarm level.
3.9.2	▣ Determine negative sequence minimum trip level.
3.9.3	▣ Determine maximum time delay.

3.9.4	▣ Verify two points on the (I ₂) ^{2t} curve.
3.10	• 47 Phase Sequence or Phase Balance Voltage Relay
3.10.1	▣ Determine positive sequence voltage to close the normally open contact.
3.10.2	▣ Determine positive sequence voltage to open the normally closed contact (undervoltage trip).
3.10.3	▣ Verify negative sequence trip.
3.10.4	▣ Determine time delay to close the normally open contact with sudden application of 120 percent of pickup.
3.10.5	▣ Determine time delay to close the normally closed contact upon removal of voltage when previously set to rated system voltage.
3.11	• 49R Thermal Replica Relay
3.11.1	▣ Determine time delay at 300 percent of setting.
3.11.2	▣ Determine a second point on the operating curve.
*3.11.3	▣ Determine minimum pickup.
3.12	• 49T Temperature (RTD) Relay
3.12.1	▣ Determine trip resistance.
3.12.2	▣ Determine reset resistance.
3.13	• 50 Instantaneous Overcurrent Relay
3.13.1	▣ Determine pickup.
3.13.2	▣ Determine dropout.
*3.13.3	▣ Determine time delay.
3.14	• 50BF Breaker Failure
3.14.1	▣ Determine current supervision pickup.
3.14.2	▣ Determine time delays.
3.14.3	▣ Test all used initiate inputs and all used outputs.
3.15	• 51 Time Overcurrent
3.15.1	▣ Determine minimum pickup.
3.15.2	▣ Determine time delay at two points on the time current curve.
3.16	• 55 Power Factor Relay
3.16.1	▣ Determine tripping lead and lag angles.
3.16.2	▣ Determine enable time delay.
3.16.3	▣ Determine operate time delay.
3.17	• 59 Overvoltage Relay
3.17.1	▣ Determine overvoltage pickup.
3.17.2	▣ Determine time delay to close the contact with sudden application of 120 percent of pickup.
3.18	• 60 Voltage Balance Relay
3.18.1	▣ Determine voltage difference to close the contacts with one source at rated voltage.
*3.18.2	▣ Plot the operating curve for the relay.
3.19	• 63 Transformer Sudden Pressure Relay
3.19.1	▣ Determine rate-of-rise or the pickup level of suddenly applied pressure in accordance with manufacturer's published data.
3.19.2	▣ Verify operation of the 63 FPX seal-in circuit.

3.19.3	▣ Verify trip circuit to remote operating device.
3.20	• 64 Ground Detector Relay
3.20.1	▣ Determine maximum impedance to ground causing relay pickup.
3.21	• 67 Directional Overcurrent Relay
3.21.1	▣ Determine directional unit minimum pickup at maximum torque angle.
3.21.2	▣ Determine contact closing zone.
*3.21.3	▣ Determine maximum torque angle.
*3.21.4	▣ Plot operating characteristics.
3.21.5	▣ Determine overcurrent unit pickup.
3.21.6	▣ Determine overcurrent unit time delay at two points on the time current curve.
3.22	• 79 Reclosing Relay
3.22.1	▣ Determine time delay for each programmed reclosing interval.
3.22.2	▣ Verify lockout for unsuccessful reclosing.
3.22.3	▣ Determine reset time.
*3.22.4	▣ Determine close pulse duration.
3.22.5	▣ Verify instantaneous overcurrent lockout.
3.23	• 81 Frequency Relay
3.23.1	▣ Verify frequency set points.
3.23.2	▣ Determine time delays.
3.23.3	▣ Determine undervoltage cutoff.
3.24	• 85 Pilot Wire Monitor
3.24.1	▣ Determine overcurrent pickup.
3.24.2	▣ Determine undercurrent pickup.
3.24.3	▣ Determine pilot wire ground pickup level.
3.25	• 87 Differential
3.25.1	▣ Determine operating unit pickup.
3.25.2	▣ Determine the operation of each restraint unit.
3.25.3	▣ Determine slope.
3.25.4	▣ Determine harmonic restraint.
3.25.5	▣ Determine instantaneous pickup.
*3.25.6	▣ Plot operating characteristics for each restraint.
4	Control Verification: Verify that each of the relay contacts performs its intended function in the control scheme including breaker trip tests, close inhibit tests, 86 lockout tests, and alarm functions.
7.9.2	Protective Relays, Microprocessor-Based
A	Visual and Mechanical Inspection
1	Record model number, style number, serial number, firmware revision, software revision, and rated control voltage.
***2	Download all events from the event recorder in filtered and unfiltered mode before performing any tests on the relay.
3	Download the sequence of events, maintenance data, and statistical data prior to testing the relay.
4	Verify operation of light-emitting diodes, display, and targets.

***5	Record passwords for all access levels.
6	Clean the front panel and remove foreign material from the case.
7	Check tightness of connections.
8	Verify that the frame is grounded in accordance with manufacturer's instructions.
9	Download settings and logic from the relay. Print a copy of the settings for the report and compare the settings to those specified in the coordination study.
10	Verify relay displays the correct date and time. Compare relay time to actual time and record the differential.
11	Check with owner for applicable firmware updates and product recalls.
B	Electrical Tests
***1	Perform insulation-resistance tests from each circuit to the grounded frame in accordance with manufacturer's published data.
2	Apply voltage or current to all analog inputs and verify correct registration of the relay meter functions.
***3	Verify SCADA metering values at remote terminals.
***4	Protection Elements: Check functional operation of each element used in the protection scheme as described for electromechanical and solid-state relays in Section 7.9.1.B.3 .
5	<u>Control Verification</u>
5.1	<ul style="list-style-type: none"> • Check operation of all active digital inputs.
5.2	<ul style="list-style-type: none"> • Check all output contacts or SCRs, preferably by operating the controlled device such as circuit breaker, auxiliary relay, or alarm.
***5.3	<ul style="list-style-type: none"> • Check all internal logic functions used in the protection scheme.
5.4	<ul style="list-style-type: none"> • For pilot schemes, perform protection system communication tests.
5.5	<ul style="list-style-type: none"> • Upon completion of testing, reset all min/max records and fault counters. Delete sequence-of-events records and all event records.
5.6	<ul style="list-style-type: none"> • Verify trip and close coil monitoring functions.
***5.7	<ul style="list-style-type: none"> • Verify setting change alarm to SCADA.
***5.8	<ul style="list-style-type: none"> • Verify relay SCADA communication and indications such as protection operate, protection fail, communication fail, fault recorder trigger.
***5.9	<ul style="list-style-type: none"> • Verify all communication links are operational.
7.10.1	Instrument Transformers, Current Transformers
A	Visual and Mechanical Inspection
1	Inspect physical and mechanical condition.
5	Verify that all required grounding and shorting connections provide contact.
6	Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
B	Electrical Tests
1	Perform resistance measurements through bolted connections with a low-resistance ohmmeter in accordance with Section 7.10.1.A.4.1 .
2	Perform insulation-resistance test of each current transformer and wiring-to-ground at 1000 volts dc for one minute. For units with solid-state components that cannot tolerate the applied voltage, follow manufacturer's recommendations.
***3	Perform a polarity test of each current transformer in accordance with IEEE C57.13.1 .

***4	Perform a ratio-verification test using the voltage or current method in accordance with IEEE C57.13.1 .
***5	Perform an excitation test on transformers used for relaying applications in accordance with IEEE C57.13.1 .
***6	Measure current circuit burdens at transformer terminals.
7	Perform insulation-resistance tests on the primary winding with the secondary grounded. Test voltages shall be in accordance with Table 100.5 .
8	Perform dielectric withstand voltage tests on the primary winding with the secondary grounded. Test voltages shall be in accordance with Table 100.9 .
***9	Perform power-factor or dissipation-factor tests in accordance with manufacturer's published data.
10	Verify that current circuits are grounded and have only one grounding point in accordance with IEEE C57.13.3 .
7.10.2	Instrument Transformers, Voltage Transformers
A	Visual and Mechanical Inspection
1	Inspect physical and mechanical condition.
5	Verify that all required grounding and connections provide contact.
6	Verify correct operation of transformer withdrawal mechanism and grounding operation.
7	Verify correct primary and secondary fuse sizes for voltage transformers.
8	Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
B	Electrical Tests
1	Perform resistance measurements through bolted connections with a low-resistance ohmmeter in accordance with Section 7.10.2.A.4.1
2	Perform insulation-resistance tests for one minute winding-to-winding and each winding-to-ground. Test voltages shall be applied in accordance with Table 100.5 . For units with solidstate components that cannot tolerate the applied voltage, follow manufacturer's recommendations.
***3	Perform a polarity test on each transformer, as applicable, to verify the polarity marks or H1-X1 relationship.
***4	Perform a turns-ratio test on as-found tap position.
***5	Measure voltage circuit burdens at transformer terminals.
***6	Perform a dielectric withstand voltage test on the primary windings with the secondary windings connected to ground. The dielectric voltage shall be in accordance with Table 100.9 . The test voltage shall be applied for one minute.
***7	Perform power-factor or dissipation-factor tests in accordance with manufacturer's published data.
8	Verify that potential circuits are grounded and have only one grounding point in accordance with IEEE C57.13.3 .
7.11.1	Metering Devices, Electromechanical and Solid-State
A	Visual and Mechanical Inspection
1	Inspect physical and mechanical condition.

3	Inspect cover gasket, cover glass, condition of spiral spring, disk clearance, contacts, and case-shorting contacts, as applicable.
6	Verify freedom of movement, end play, and alignment of rotating disk(s).
B	Electrical Tests
1	Perform resistance measurements through bolted connections with a low-resistance ohmmeter in accordance with Section 7.11.A.2.1 .
2	Verify accuracy of meters at all cardinal points.
3	Calibrate meters in accordance with manufacturer's published data.
***4	Verify all instrument multipliers.
7.11.2	Metering Devices, Microprocessor-Based
A	Visual and Mechanical Inspection
1	Inspect meters and cases for physical damage.
2	Clean front panel.
3	Verify tightness of electrical connections.
4	Record model number, serial number, firmware revision, software revision, and rated control voltage.
5	Verify operation of display and indicating devices.
6	Record passwords.
7	Verify unit is grounded in accordance with manufacturer's instructions.
8	Verify unit is connected in accordance with manufacturer's instructions and project drawings.
9	Download settings from the meter, print a copy of the settings for the report, and compare the settings to those specified.
B	Electrical Tests
1	Apply voltage or current as appropriate to each analog input and verify correct measurement and indication.
2	Confirm correct operation and setting of each auxiliary input/output feature in use, including mechanical relay, digital, and analog.
3	Confirm measurements and indications are consistent with loads present.
7.13	Grounding Systems
A	Visual and Mechanical Inspection
1	Verify ground system is in compliance with NFPA 70, National Electrical Code, Article 250 .
2	Inspect physical and mechanical condition.
4	Inspect anchorage.
B	Electrical Tests
1	Perform resistance measurements through bolted connections with a low-resistance ohmmeter in accordance with section 7.13.A.3.1 .
2	Perform fall-of-potential or alternative test in accordance with IEEE 81 on the main grounding electrode or system.
3	Perform point-to-point tests to determine the resistance between the main grounding system and all major electrical equipment frames, system neutral, and/or derived neutral points.

7.19.2	Surge Arresters, Medium- and High-Voltage Surge Protection Devices
A	Visual and Mechanical Inspection
1	Inspect physical and mechanical condition.
2	Inspect anchorage, alignment, and grounding.
5.1	• Use of a low-resistance ohmmeter in accordance with Section 7.19.2.B.1 .
5.2	• Verify tightness of accessible bolted electrical connections by calibrated torque wrench method in accordance with manufacturer's published data or Table 100.12 .
6	Verify that the ground lead on each device is individually attached to ground bus or ground electrode.
7	Verify that stroke counter, if present, is correctly mounted and electrically connected.
B	Electrical Tests
1	Perform resistance measurements through bolted connections with a low-resistance ohmmeter in accordance with Section 7.19.2.A.5.1 .
2	Perform insulation-resistance tests from phase terminal(s) to case for one minute. Test voltage and minimum resistance shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, refer to Table 100.1 .
3	Test the grounding connection in accordance with Section 7.13 .
***4	Perform a watts-loss test in accordance with test equipment manufacturer's published data.
7.20.1	Capacitors and Reactors, Capacitors
A	Visual and Mechanical Inspection
1	Inspect physical and mechanical condition.
2	Inspect anchorage, alignment, grounding, and required clearances.
5	Verify that capacitors are electrically connected in their specified configuration.
B	Electrical Tests
1	Perform resistance measurements through bolted connections with a low-resistance ohmmeter in accordance with Section 7.20.1.A.6.1 .
2	Perform insulation-resistance tests from phase terminal(s) to case for one minute. Test voltage and minimum resistance should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, refer to Table 100.1 .
3	Measure the capacitance of all terminal combinations.
4	Measure resistance of internal discharge resistors.
7.20.3	Capacitors and Reactors, Reactors (Shunt and Current-Limiting), Dry-Type
A	Visual and Mechanical Inspection
1	Inspect physical and mechanical condition.
2	Inspect anchorage, alignment, and grounding.
6	Verify that tap connections are as specified.
B	Electrical Tests
1	Perform resistance measurements through bolted connections with low-resistance ohmmeter in accordance with Section 7.20.3.1.A.5.1 .

2	Perform winding-to-ground insulation-resistance tests. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1 .
3	Measure winding resistance.
***4	Perform dielectric withstand voltage tests on each winding-to-ground.
***5	Perform online partial-discharge survey in accordance with Section 11 .
7.21	Outdoor Bus Structures
A	Visual and Mechanical Inspection
1	Inspect physical and mechanical condition.
2	Inspect anchorage, alignment, and grounding.
B	Electrical Tests
1	Perform resistance measurements through bolted connections with a low-resistance ohmmeter in accordance with Section 7.21.A.4.1 .
2	Measure insulation resistance of each bus, phase-to-ground with other phases grounded for equipment rated less than 46 kV. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1 .
***3	Perform dielectric withstand voltage test on each bus phase, phase-to-ground with other phases grounded in accordance with manufacturer's published data. In the absence of manufacturer's data use Table 100.19 . Test duration shall be for one minute.
***4	Perform insulation power-factor or dissipation-factor tests on each bus phase, phase-to-ground with other phases grounded.