

7. INSPECTION AND TEST PROCEDURES

7.12.1.1 Regulating Apparatus, Voltage, Step-Voltage Regulators

A. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Record position indicator as-found, maximum, and minimum values.
4. Prior to cleaning the unit, perform as-found tests, if required.
5. Clean the unit.
6. Verify auxiliary device operation.
7. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.12.1.1.B.1.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
8. Verify correct operation of motor and drive train and automatic motor cutoff at maximum lower and maximum raise positions.
9. Verify correct liquid level in all tanks and bushings.
10. Perform specific inspections and mechanical tests as recommended by the manufacturer.
- *11. Perform an internal inspection:
 1. Remove oil.
 2. Clean carbon residue and debris from compartment.
 3. Inspect contacts for wear and alignment.
 4. Inspect all electrical and mechanical connections for tightness using calibrated torque wrench method in accordance with manufacturer's published data or Table 100.12.
 5. Inspect tap-changer compartment terminal board, contact support boards, and insulating operating components for evidence of moisture, cracks, excessive wear, breakage, and/or signs of electrical tracking.

* Optional

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7.12.1.1 Regulating Apparatus, Voltage, Step-Voltage Regulators (*continued*)

6. Electrically operate tap-changer through full range of taps.
7. Replace gaskets and seal compartment.
8. Fill with filtered oil.
12. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
13. Perform as-left tests.
14. Record as-found and as-left operation counter readings.

B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter in accordance with Section 7.12.1.1.A.7.1.
2. Perform insulation-resistance tests on each winding-to-ground in any off-neutral position. 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 windings in accordance with test equipment manufacturer's published data.
4. Perform power-factor or dissipation-factor tests on each bushing equipped with a power-factor/ 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.
5. Measure winding resistance of source windings in the neutral position. Measure the resistance of all taps on load windings.
6. Perform special tests and adjustments as recommended by manufacturer.
- *7. If the regulator has a separate tap-changer compartment, measure the percentage of oxygen of the nitrogen gas blanket in the main tank.
8. Perform turns-ratio test on each voltage step position. Verify that the tap position indicator correctly identifies all tap positions.
9. Verify accurate operation of voltage range limiter.
10. Verify operation and accuracy of bandwidth, time delay, voltage, and line-drop compensation adjustments of tap-changer control device

* Optional

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- *11. If regulator has a separate tap-changer compartment, sample insulating liquid in the main tank in accordance with ASTM D3613 and perform dissolved-gas analysis in accordance with IEEE C57.104 or ASTM D3612.
- 12. Remove a sample of insulating liquid from the main tank or common tank in accordance with ASTM D923. Sample shall be tested in accordance with the referenced standard.
 - 1. Dielectric breakdown voltage: ASTM D877 and/or ASTM D1816
 - 2. Acid neutralization number: ASTM D974
 - 3. Specific gravity: ASTM D1298
 - 4. Interfacial tension: ASTM D971
 - 5. Color: ASTM D1500
 - 6. Visual condition: ASTM D1524
- *7. Power factor: ASTM D924
Required when the regulator voltage is 46 kV or higher.
- 8. Water in insulating liquids: ASTM D1533.
- 13. Remove a sample of insulating liquid from the tap-changer tank in accordance with ASTM D 923. Sample shall be tested in accordance with the referenced standard.
 - 1. Dielectric breakdown voltage: ASTM D877
 - 2. Color: ASTM D1500
 - 3. Visual condition: ASTM D1524
- *14. Remove a sample of insulating liquid from the tap-changer compartment or common tank in accordance with ASTM D 3613 and perform dissolved-gas analysis (DGA) in accordance with IEEE C57.104 or ASTM D3612.
- 15. Verify operation of heaters.

* Optional

7. INSPECTION AND TEST PROCEDURES

7.12.1.1 Regulating Apparatus, Voltage, Step-Voltage Regulators (*continued*)

C. Test Values – Visual and Mechanical

1. Auxiliary devices should operate in accordance with system design. (7.12.1.1.A.6)
2. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.12.1.1.A.7.1)
3. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.12.1.1.A.7.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.12.1.1.A.7.3)
5. Motor, drive train, and automatic cutoff should operate in accordance with manufacturer's design. (7.12.1.1.A.8)
6. Liquid level in tanks and bushings should be within indicated tolerances. (7.12.1.1.A.9)
7. On internal inspection, contact alignment and wear should be within manufacturer's recommendations for continued service. (7.12.1.1.A.11.3)
8. Bolt torque levels should be in accordance with Table 100.12 unless otherwise specified by the manufacturer. (7.12.1.1.A.11.4)
9. Terminal board, contact support boards, and insulating operating components should not show signs of moisture, cracking, excessive wear, breakage, or electrical cracking. (7.12.1.1.A.11.5)
10. The tap-changer should operate electrically through the full range of taps. (7.12.1.1.A.11.6)
11. The operation counter should move incrementally for each operation performed. (7.12.1.1.A.14)

D. Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. Resistance values shall be temperature corrected in accordance with Table 100.14. The polarization index shall be compared to previously obtained results.

* Optional

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7.12.1.1 Regulating Apparatus, Voltage, Step-Voltage Regulators (*continued*)

3. Maximum power-factor or dissipation-factor values of liquid-filled regulators should be in accordance with manufacturer's published data. In the absence of manufacturer's data, compare to test equipment manufacturer's published data. Representative values are indicated in Table 100.3.
4. Power-factor or dissipation-factor and capacitance values should be within ten percent of nameplate rating for bushings. Hot collar tests are evaluated on a milliamperere/milliwatt loss basis, and the results should be compared to values of similar bushings.
5. Consult manufacturer if winding-resistance values vary by more than two percent from test results of adjacent phases.
6. Special tests and adjustments should meet manufacturer's published requirements.
7. Investigate presence of oxygen in nitrogen gas blanket.
8. Turns-ratio test results should maintain a normal deviation between each voltage step and should not deviate more than one-half percent from the calculated voltage ratio.
9. Voltage range limiter should operate within manufacturer's recommendations.
10. Accuracy of bandwidth, time-delay, voltage, and live drop compensation adjustments should be as specified.
11. Results of dissolved-gas analysis of insulating liquid on the main tank of regulators having a separate tap-changer compartment shall be evaluated in accordance with IEEE C57.104 or ASTM D3612.
12. Results of insulating liquid tests on the main tank or common tank of single tank voltage regulators should be in accordance with Table 100.4.
13. Results of insulating liquid tests on the tap-changer tank of regulators having a separate tap-changer compartment should be in accordance with Table 100.4.
14. Compare results of dissolved gas analysis to previous test results.
15. Heaters should be operational.

* Optional

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7.12.1.2 Regulating Apparatus, Voltage, Induction Regulators

A. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Record position indicator as-found, maximum, and minimum values.
4. Prior to cleaning the unit, perform as-found tests, if required.
5. Clean the unit.
6. Verify correct auxiliary device operation.
7. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.12.1.2.B.1.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
8. Check motor and drive train for correct operation and automatic motor cutoff at maximum lower and maximum raise.
9. Verify appropriate liquid level in all tanks and bushings.
10. Perform specific inspections and mechanical tests as recommended by the manufacturer.
11. Use appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
12. Perform as-left tests.

B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter in accordance with Section 7.12.1.2.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.

* Optional

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7.12.1.2 Regulating Apparatus, Voltage, Induction Regulators (*continued*)

3. Perform power-factor or dissipation-factor tests on winding insulation in accordance with test equipment manufacturer's published data.
4. Perform power-factor or dissipation-factor tests on each bushing equipped with a power-factor/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.
5. Verify voltage regulation.
6. Verify that the indicator correctly identifies neutral position.
7. Perform winding resistance tests on each winding.
8. Sample insulating liquid in accordance with ASTM D923. Sample shall be tested in accordance with the referenced standard.
 1. Dielectric breakdown voltage: ASTM D877 and/or ASTM D1816
 2. Acid neutralization number: ASTM D974
 - *3. Specific gravity: ASTM D1298
 4. Interfacial tension: ASTM D971
 5. Color: ASTM D1500
 6. Visual condition: ASTM D1524
 - *7. Power factor: ASTM D924
Required when the regulator voltage is 46 kV or higher.
 - *8. Water content: ASTM D1533
Required when the regulator voltage is 25 kV or higher.
 - *9. Remove a sample of insulating liquid in accordance with ASTM D3613 and perform dissolved-gas analysis (DGA) in accordance with ASTM D3612 or IEEE C57.104.
 - *10. Test for the presence of oxygen in the gas blanket of liquid-filled regulators.
 11. Verify operation of control cabinet space heater.

* Optional

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7. INSPECTION AND TEST PROCEDURES

7.12.1.2 Regulating Apparatus, Voltage, Induction Regulators (*continued*)

C. Test Values – Visual and Mechanical

1. Auxiliary devices should operate in accordance with system design. (7.12.1.2.A.6)
2. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.12.1.2.A.7.1)
3. Bolt-torque levels should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.12.1.2.A.7.2)
4. Results of the thermographic survey shall be in accordance with Section 9. (7.12.1.2.A.7.3)
5. Motor, drive train, and automatic cutoff should operate in accordance with manufacturer's design intent and automatic motor cutoff should operate at maximum lower and maximum raise positions. (7.12.1.2.A.8)
6. Liquid level in tanks and bushings should be within indicated tolerances. (7.12.1.2.A.9)

D. Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Insulation-resistance values should be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. The polarization index shall be compared to previously obtained results.
3. Maximum power-factor or dissipation-factor values of liquid-filled regulators should be in accordance with manufacturer's published data. In the absence of manufacturer's data, compare to test equipment manufacturer's published data. Representative values are indicated in Table 100.3.
4. Power-factor or dissipation-factor and capacitance values should be within ten percent of nameplate rating for bushings. Hot collar tests are evaluated on a milliamperere/milliwatt loss basis, and the results should be compared to values of similar bushings.
5. The regulation should be a linear ratio throughout the range between the maximum raise and the maximum lower positions.
6. Indicator should indicate neutral position correctly.

* Optional

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7.12.1.2 Regulating Apparatus, Voltage, Induction Regulators (*continued*)

7. Consult the manufacturer if winding-resistance values vary by more than two percent from measurements of adjacent windings.
8. Results of insulating liquid tests should be in accordance with Table 100.4.
9. Evaluate results of dissolved-gas analysis in accordance with IEEE C57.104.
10. Investigate presence of oxygen in nitrogen gas blanket.
11. Heaters should be operational.

* Optional

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7.12.2 Regulating Apparatus, Current

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* Optional

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7. INSPECTION AND TEST PROCEDURES

7.12.3 Regulating Apparatus, Load Tap-Changers

A. Visual and Mechanical Inspection

1. Inspect physical and mechanical condition.
2. Inspect anchorage, alignment, and grounding.
3. Record position indicator as-found, maximum, and minimum values.
4. Prior to cleaning the unit, perform as-found tests.
5. Clean the unit.
6. Inspect bolted electrical connections for high resistance using one or more of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.12.3.B.1.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12.
 3. Perform a thermographic survey in accordance with Section 9.
7. Verify correct auxiliary device operation.
8. Verify motor and drive train for correct operation and automatic motor cutoff at maximum lower and maximum raise.
9. Verify correct liquid level in all tanks.
10. Perform specific inspections and mechanical tests as recommended by the manufacturer.
11. Visually inspect wear/erosion indicators on vacuum bottles.
- *12. Perform an internal inspection:
 1. Remove oil.
 2. Clean carbon residue and debris from compartment.
 3. Inspect contacts for wear and alignment.

* Optional