

## SECTION 34 21 80

### TRACTION POWER SYSTEM FIELD ACCEPTANCE TESTING

#### PART 1 - GENERAL

##### 1.01 SECTION INCLUDES

- A. General
- B. Installation verification tests
- C. AC switchgear tests
- D. AC Bus duct tests
- E. Rectifier Transformer tests
- F. Rectifier tests
- G. DC switchgear tests
- H. Substation functional tests
- I. Short circuit test
- J. Ground fault test
- K. Train start test

##### 1.02 MEASUREMENT AND PAYMENT

Not used

##### 1.03 REFERENCES

- A. American Society for Testing of Materials (ASTM):
  - 1. ASTM D877 Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes
  - 2. ASTM D923 Standard Practices for Sampling Electrical Insulating Liquids

3. ASTM D924 Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids
4. ASTM D1533 Standard Test Method for Water in Insulating Liquids by Coulometric Karl Fischer Titration
5. ASTM D3612 Standard Test Method for Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography

B. Institute of Electrical and Electronics Engineers (IEEE):

1. IEEE C37.20.1 Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear
2. IEEE C57.12.90 Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers, and Short Circuit Testing and Distribution and Power Transformers
3. IEEE Standard 4 Standard Techniques for High-voltage Testing

C. National Fire Protection Agency (NFPA):

1. NFPA 70E Standard for Electrical Safety in the Workplace

### 1.03 SUBMITTALS

- A. General: Refer to Section 01 33 00, Submittal Procedures, and Section 01 33 23, Shop Drawings, Product Data, and Samples for submittal requirements and procedures.
- B. Submit test program, test reports, list of test instruments, and certification of test instrument calibration in accordance with Section 01 45 24, Testing Program Requirements.

## PART 2 – PRODUCTS

Not Used

## PART 3 – EXECUTION

### 3.01 GENERAL

- A. Testing shall be in accordance with Section 01 45 24, Testing Program Requirements.
- B. This Section includes specifications for field-testing requirements of traction power facilities and associated items of equipment. Testing specified in this Section shall only be performed following completion of equipment installation.

- C. Additional tests involving operation of the traction power facilities with other BART operating systems including BARTNet, SCADA, telephone system, and other end-to-end tests covered under Systems Integration Testing is specified elsewhere.

### **3.02 INSTALLATION VERIFICATION TESTS**

- A. Equipment Assembly Inspection: Verify that the following:
  - 1. All equipment shipping bracing has been removed
  - 2. Enclosures and equipment are anchored correctly
  - 3. Assembled on-site equipment, including components and accessories, are correctly installed and labeled in accordance with approved shop drawings, and are in operable condition.
  - 4. Record all part numbers and serial numbers, and rectifier transformer nameplate data and main coil identification numbers.
- B. Verify presence of voltage shock hazard and arc-flash hazard warning safety labels are visibly installed on the front side, and at other access points, of the equipment enclosures per NFPA 70E.
- C. Grounding Connections Inspection: Verify that all enclosure, equipment, and relay grounding connections inside and outside of the ac and dc equipment houses, and rectifier transformer ground connections are in place, and properly made. Verify using approved drawings, which shall be marked as to completion.
- D. Verify all control power connections, including alarms, trips, lights, heaters, and control power. 34.5 kV incoming primary power connections and secondary bus connections are not made at this time. Verify using approved drawings, which shall be marked as to completion.
- E. Verify all doors for correct gaskets, closing and latching, and padlock provisions. Temporary locks shall be provided for securing the enclosures.
- F. Mechanical Integrity Tests
  - 1. Perform mechanical checks on the physical integrity of all equipment. These tests shall include, but shall not be limited to, verifying the correct alignment of the racking mechanism of all circuit breakers by withdrawing and inserting the breaker module, verifying interlocks, contact gap spacing, correct bus connection torquing and placing of torque marks, and checking up doors and access panels.
  - 2. Interchangeability of like-rated dc feeder breakers shall be confirmed. A dc feeder breaker shall not be interchangeable with a switchgear cubicle designed for a circuit breaker with a different rating. Dc feeder circuit breakers shall not be interchangeable with dc cathode circuit breakers.
  - 3. Verify correct mechanical and key interlocking. Transfer extra Kirk Keys to a secure location as directed by the District.

- G. Settings and Calibration: Verify the proper settings of all relays, and other protective and control systems and devices. Settings, including software parameters and configuration, shall be per approved coordination study . Confirm correct ratings of medium voltage fuses.
- H. Conform by bench testing or by injection of signals into installed equipment that all protective relays function in accordance with manufacturer's published data.
- I. Verify space heater operation.
- J. Weatherproofing tests: Following installation of each substation enclosure complete with throat connection assemblies enclosures shall be tested in accordance with ANSI C37.20.1.

### **3.03 AC SWITCHGEAR TESTS**

#### **A. General**

1. Tests shall be performed on all 34.5 kV ac circuit breakers and ac switchgear bus assemblies.
2. Tests shall be performed prior to connecting 34.5 kV cables and switchgear instrument transformers, and with AC bus duct disconnected from ac switchgear bus.
3. Tests shall be performed with potential transformer leads disconnected from the ac switchgear bus.

#### **B. Circuit Continuity Tests – Perform continuity checks to verify current transformer connections, shunt leads, and all medium voltage fuses.**

#### **C. Resistance Tests**

1. Using a low-resistance ohmmeter, check resistance of all bolted bus connections, including instrument transformer connections, and of closed circuit breaker contacts of each phase of each circuit breaker.
2. At each location tested, if the resistance of any phase differs by more than 50% from the lowest value among phases at that location, take measures to bring high value to within 50% of the lowest value, and retest.

#### **D. Insulation Resistance Tests**

1. Perform insulation resistance (meggar) tests at 5,000 volts for one minute at each circuit breaker pole, phase-to-phase and phase-to-ground with each circuit breaker closed, and across each open pole.
2. Perform insulation resistance tests at 5,000 volts for one minute at each current transformer connection, coil-to-ground.
3. Perform insulation resistance tests at 5,000 volts for one minute at each potential transformer pole, primary-to-ground with secondary winding grounded.

5. Measured insulation resistance shall be 25,000 M $\Omega$ , minimum.
6. For each test, record date, time, temperature, humidity, voltage levels, leakage current, and meg-ohms values.
7. Repeat insulation resistance tests following completion of dielectric withstand tests.

E. Dielectric Withstand Tests

1. Perform dielectric withstand (high potential) tests at 60 kV for one minute on each phase with the circuit breaker closed and the poles not under test grounded.
2. Measured current through circuit breaker vacuum bottles shall be less than 60  $\mu$ A or manufacturers recommended value, whichever is less.
3. For each test, record date, time, temperature, humidity, voltage levels, leakage current, and meg-ohms values.

**3.04 BUS DUCT TESTS**

A. General

1. Tests shall be performed on all 1,200V bus duct assemblies.
2. Tests shall be performed with bus duct sections connected, and bus duct disconnected from transformer, rectifier, and dc switchgear connections.

B. Resistance Tests

1. Using a low-resistance ohmmeter, check resistance of each bolted bus connection of each phase.
2. At each location tested, if the resistance of any phase differs by more than 50% from the lowest value among phases at that location, take measures to bring high value to within 50% of the lowest value, and retest.

C. Insulation Resistance Tests

1. Perform insulation resistance (meggar) tests at 2,500 volts for one minute for each phase, phase-to-phase and phase-to-ground.
2. Measured insulation resistance shall be 1,000 M $\Omega$ , minimum.
3. For each test, record date, time, temperature, humidity, voltage levels, leakage current, and meg-ohms values.

**3.05 RECTIFIER TRANSFORMER TESTS**

A. General

1. Tests shall be performed on all rectifier transformers, per IEEE C57.12.90.
2. Tests shall be performed prior to connecting line side 34.5 kV cables and load side 690V system cables.
3. Prior to energizing transformer, note oil pressure, temperature, and hot-spot indicator readings for comparison with readings following energization.

B. Turns Ratio Tests – Perform turns ratio tests at all tap positions, per IEEE C57.12.90.

C. Insulation Resistance Tests

1. Perform insulation resistance (meggar) tests at 5,000 volts for one minute from primary transformer windings to each group of secondary transformer windings. Conduct tests with secondary windings grounded.
2. Measured insulation resistance shall be 25,000 M $\Omega$ , minimum.
3. Perform insulation resistance (meggar) tests at 2,500 volts for one minute from each group of secondary transformer windings to primary side transformer windings. Conduct tests on each group of secondary windings with the other secondary winding group grounded and the primary windings grounded.
4. Measured insulation resistance shall be 2,500 M $\Omega$ , minimum.
5. For each test, record date, time, temperature, humidity, voltage levels, leakage current, and meg-ohms values.
6. Repeat insulation resistance tests following completion of dielectric testing.

D. Dielectric Withstand Tests

1. Perform dielectric withstand (high potential) tests at 50 kV for five minutes on each primary winding with the secondary windings grounded.
2. Perform dielectric withstand tests at 2.5 kV for five minutes on each secondary winding with the windings not under test grounded.
3. For each test, record date, time, temperature, humidity, voltage levels, leakage current, and meg-ohms values.

F. Insulating Oil Tests

1. Remove a sample of insulating liquid in accordance with ASTM D923, and test for the following:
  - a. Dielectric breakdown voltage: ASTM D877.
  - b. Dissolved-gas analysis: ASTM D3612.

2. If oil does not completely fill containment tank, inject inert gas as required by manufacturer's instructions.

### **3.06 RECTIFIER TESTS**

#### **A. General**

1. Tests shall be performed prior to connecting line side ac system cables and 1000V main dc switchgear bus.
2. Tests shall be performed with diode bridges shorted.

#### **B. Resistance Tests**

1. Using a low-resistance ohmmeter, check resistance of each bolted connection of each rectifier phase to main dc bus.
2. At each location tested, if the resistance of any phase differs by more than 50% from the lowest value among diode bridge connections, take measures to bring high value to within 50% of the lowest value, and retest.

#### **C. High Resistance Grounding Isolation Tests**

1. Perform isolation (meggar) test at 2,500 volts for one minute between rectifier frame and ground to verify isolation from ground.
2. Measured isolation resistance shall be 1,000 M $\Omega$ , minimum.
3. For each test, record date, time, temperature, humidity, voltage levels, leakage current, and meg-ohms values.
4. Repeat isolation tests following completion of dielectric testing.

#### **D. Dielectric Withstand Tests**

1. During dielectric withstand tests all diodes and diode stacks shall be jumpered together to maintain all diode stacks at the same potential.
2. Perform dielectric withstand tests at 2.5 kV dc for one minute on rectifier diode assembly, as one complete unit.
3. Perform dielectric withstand tests at 2.5 kV dc for one minute on interphase transformer.
4. For each test, record date, time, temperature, humidity, voltage levels, leakage current, and meg-ohms values.

**3.07 DC SWITCHGEAR TESTS**

**A. General**

1. Tests shall be performed on all 1000V dc circuit breakers and dc switchgear bus assemblies.
2. Tests shall be performed prior to connecting 1000V dc cables, and with rectifier bus disconnected from dc switchgear bus.

**B. Circuit Continuity Tests – Perform continuity checks to verify shunt leads, and all 1000V dc system fuses.**

**C. Resistance Tests**

1. Using a low-resistance ohmmeter, check resistance of all bolted bus connections and of closed circuit breaker contacts of each circuit breaker.
2. At each location tested, if the resistance of any connection differs by more than 50% from the lowest value among similar connections, take measures to bring high value to within 50% of the lowest value, and retest.

**D. Insulation Resistance Tests**

1. Perform insulation resistance (meggar) tests at 2.5 kV for one minute at each circuit breaker pole with circuit breaker closed, and across open pole.
2. Measured insulation resistance shall be 1,000 MΩ, minimum.
3. For each test, record date, time, temperature, humidity, voltage levels, leakage current, and meg-ohms values.
4. Repeat isolation tests following completion of dielectric testing.

**E. High Resistance Grounding Isolation Tests**

1. Isolation tests shall be conducted with all circuit breakers inserted in their switchgear cubicles.
2. Perform isolation (meggar) test at 2.5 kV for one minute between each switchgear cubicle frame and ground, and from each switchgear cubicle frame to the adjacent cubicle frames or from the rectifier frame, to verify isolation from ground.
3. Isolate one cubicle frame from the switchgear lineup and ground the cubicle frame. Perform isolation test at 2.5kV for one minute between switchgear lineup and ground. Repeat test for each cubicle frame.
4. Perform isolation test at 2.5 kV for one minute between dc switchgear negative bus and ground..
5. Measured isolation resistance for all tests shall be 1,000 MΩ, minimum.

6. For each test, record date, time, temperature, humidity, voltage levels, leakage current, and meg-ohms values.
7. Repeat isolation tests following completion of dielectric testing.

F. Dielectric Withstand Tests

1. Perform dielectric withstand (high potential) tests at 5.2 kV for one minute with the circuit breaker closed.
2. For each test, record date, time, temperature, humidity, voltage levels, leakage current, and meg-ohms values.

**3.08 SUBSTATION FUNCTIONAL TESTS**

A. General

1. All tested devices shall be clearly marked as to test date, test connections, and Tester ID.
2. Record all control, lighting, and HVAC circuit volts and amperes.
3. Prior to functional testing, the 34.5 kV and 1000V dc cables connecting substation equipment shall be tested per requirements of Section 34 22 23, Traction Power Cables.

B. When testing of discrete equipment and cables is complete, only power circuits and bus connections internal to the substation shall be connected. All bolted connections shall be torqued to manufacturer's recommended torque, and torque marks applied to all bolted connections.

C. Perform resistance tests at each bolted equipment interface point joining bus connections or cable terminations. At each location tested, if the resistance of any connection differs by more than 50% from the lowest value among similar connections, take measures to bring high value to within 50% of the lowest value, and retest.

D. The insulation resistance tests and dielectric withstand field tests previously done on discrete equipment shall be repeated following connection of bus work and power circuits.

E. Following successful of insulation resistance tests and dielectric withstand tests, all control power, control, indication, and alarm circuits shall be connected.

F. The substation 34.5 kV ac cables, but not the 1000V dc system cables, shall be connected. Ensure that cable shields are grounded, and that cable connections are taped per manufacturer's recommendations. Energize substation 34.5 kV circuits. Functional testing shall be performed to verify correct control and protection device settings and operation of all circuits per contract specifications, approved drawings, and approved coordination study, to include the following:

1. Closing and opening of each circuit breaker and checkups of the rectifier status and controls when energized.
2. Ac switchgear potential transformer output magnitude and polarity.
3. Rectifier-transformer unit phase sequence tests: Perform phase sequence tests, per IEEE C57.12.90. Record rectifier ac phase voltage magnitude and polarity, each phase, and rectifier dc voltage level and polarity, each diode leg.
4. Automatic reclosing circuits and equipment.
5. All local and remote control functions and indications.
6. Connection of all sensing and protective devices, including potential and current transformers, per approved coordination study.
7. Operation of all protective devices to prove correct control interfacing.
8. Verification of HVAC equipment and lights. Record all HVAC circuit volts and amperes.

### **3.09 SHORT CIRCUIT TEST**

- A. For the following system tests, the 1000V dc feeder cables and negative return system cables shall be connected at the test substation, and at adjacent substations as necessary.
- B. The short circuit test shall be performed on one traction power substation to be determined by the Engineer in coordination with the Contractor. All other traction power substations shall be de-energized during this test, except for scenarios that require an adjacent traction power substation to be energized as defined below.
- C. Contractor shall develop the test plan; select and install appropriate recording instrumentation with adequate resolution, sensitivity and recording speed to meet the following test objectives:
  1. Obtain data to calculate the specific inductance of the dc distribution system necessary to determine the rate-of-rise settings of the DC MPR.
  2. Verify the proper coordination and selectivity of the traction power substation protective relaying.
  3. Verify the fault clearing capability of the dc feeder breaker on the actual system.
  4. Check the proper operation of the transfer tripping, load measuring and auto-reclosing functions of the DC MPR in conjunction with the ETTS. Demonstrate that the dc feeder breakers will not re-close on a sustained fault, but will restore power to the contact rail system in case of a temporary fault. For these tests, the substations on both sides of the short circuit fault shall be energized.

5. Include all relevant MPR current and voltage trace records in test report for comparison with test equipment data.
- D. Contractor shall make a series of bolted short circuit faults between the contact rail and running rails by means of a short-circuiting switch or portable circuit breaker, at the following locations:
1. Just outside the substation near dc cable to contact rail connection.
  2. 1600 feet away from the substation
  3. 4000 feet away from the substation
  4. 7500-8000 feet away from the substation
- E. The following parameters shall be monitored and automatically recorded in graphics format in the substation:
1. DC bus voltage
  2. Voltage across the breaker contacts
  3. Traction power substation dc current
  4. Traction power substation primary ac voltage
  5. Traction power substation primary ac current
- F. The short circuit faults shall be cleared by the substation protective relays at their normal settings.
- G. Following each short circuit test, all equipment including train control related hardware subjected to the short circuit currents, shall be inspected for possible damage. After the completion of the short-circuit tests, the Contractor shall perform the necessary maintenance on the circuit breakers, such as cleaning the contacts and arc chutes, to restore the equipment to its original condition.

### **3.04 GROUND FAULT TEST**

- A. This test shall be performed to demonstrate the ability of the protective relay system to detect and isolate ground faults, as required. The test shall be performed with two adjacent traction power substations on either side of the simulated ground fault condition energized.
- B. Instrumentation and monitored parameters shall be as in the short circuit test, with the additional requirement of recording the positive and negative bus voltages to ground.
- C. The following ground faults shall be made:
  1. Positive bus to dc enclosure. This test may be done by connecting the load measuring resistor circuit to ground.

2. Negative bus to dc enclosure
3. Contact rail to ground fault in the vicinity of the monitored substation. Include all relevant MPR current and voltage trace records in test report for comparison with test equipment data.

### 3.05 TRAIN START TEST

- A. The train start test shall be monitored from one traction power substation to be determined by the Engineer. One or two traction power substations shall be energized for this test, depending on the objectives of the particular test setup.
- B. The testing shall be performed with one and two simultaneously accelerating trains, and shall include several locations for each scenario. The exact locations and number of train starts and length of train runs for this test series will be determined by the Engineer, in coordination with the Contractor.
- C. Contractor shall develop the test plan, and select and install appropriate recording instrumentation to meet the following test objectives:
  1. Obtain load current parameters necessary to determine (in conjunction with the short circuit test data) the rate-of-rise settings of the DC MPR. Confirm that such settings do not result in nuisance trips during train starts, but will trip the dc feeder breaker in the event of a remote short circuit fault.
  2. Verify the voltage regulation characteristic of the transformer/rectifier unit. In this test scenario the substation shall be operated with one transformer-rectifier unit loaded to at least 300 % of the nominal rating. At 300 percent load and 34.5 kV primary voltage, the rectifier output voltage shall be 880 volts with a tolerance of plus or minus 15 volts.
  3. Verify that noise levels outside the traction power substation meet the criteria requirements specified in Section 34 21 21, Transformer Rectifier Units. The ambient noise level shall be established with the meters in place and traction power substation de-energized. If ambient noise is too high during daytime, certain number of train starts may have to be performed at night, in order to measure more accurately the traction power substation-generated noise.
  4. Verify, through measurements, that the ripple on the dc voltage at different load levels is within the theoretical limits.
  5. Include all relevant MPR current and voltage trace records in test report for comparison with test equipment data.
- D. The following parameters shall be monitored and automatically recorded in the traction power substation during the test:
  1. DC bus voltage

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2. Traction power substation dc current
3. Feeder breaker dc current
4. Traction power substation ac voltage
5. Traction power substation ac power
6. Traction power substation ac power factor
7. Noise level inside the traction power substation
8. Noise level outside the traction power substation
9. Power factor on the 34.5 kV system

**END OF SECTION 34 21 80**