

# Participant Guide

**Course 201**  
**Inspection and Maintenance of**  
**Traction Power**  
**Distribution**  
**And**  
**Control Systems**

2021

## TRACTION POWER TRAINING CONSORTIUM

The national Traction Power Training Consortium (TPTC) is a group of public transportation agencies that are members of the American Public Transportation Association (APTA). Each participating agency assigns two subject matter experts to advise instruction designers and help shape the Consortium courses. As of January 2021, the following agencies have agreed to work with the Transportation Learning Center on the TPTC.

AGENCY	UNION	LOCATION
BART	SEIU 1021	Oakland, CA
CATS		Charlotte, NC
DART	ATU 1338	Dallas, TX
GCRTA	ATU 268	Cleveland, OH
Metro Transit	ATU 1005	Minneapolis, MN
NFTA	ATU 1342	Buffalo, NY
SacRT	IBEW 1245	Sacramento, CA
SEPTA	TWU 234	Philadelphia, PA
Tacoma Link Sound Transit		Tacoma, WA
VTA	ATU 2665	Santa Clara, CA

The Consortium identified fifteen courses that are distributed over three levels designed to upskill new and experienced traction power maintainers. Each agency assigns two subject matter experts (SMEs) who have been working with the Center's skilled instructional system designers (ISDs) to build courses on traction power maintenance. The sequence of Traction Power Consortium courses are shown in the following chart and this course is outlined in red.

TRACTION POWER COURSE SEQUENCE						
Topic Areas	Course No.	100 LEVEL Introduction and Overview	Course No.	200 LEVEL Inspection and Maintenance	Course No.	300 LEVEL Troubleshooting, Adjustment and Repair
Overview	100	Overview, General Safety, and Regulations of Traction Power Systems	200	Prep for Insp and Maint of Traction Power Systems	300	Principles of Troubleshooting Traction Power Systems
Power Distribution	101	Introduction to Traction Power Dist and Control Systems	201	Insp and Maint of Power Dist and Control Systems	202	Troub, Adjust & Repair of Power Dist and Control Systems
Substations	102	Introduction to Substations	202	Insp and Maint of Substations	302	Troub, Adjust & Repair of Substations
Overhead Systems	103	Introduction to Overhead Systems	203	Insp and Maint of Overhead Systems	303	Troub, Adjust & Repair of Overhead Systems
Third Rail	104	Introduction to Third Rail Systems	204	Insp and Maint of Third Rail Systems	304	Troub, Adjust & Repair of Third Rail Systems

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# MODULE 1

## Overview to Course

### Outline

- 1-1 Overview and scope of this course
- 1-2 Line diagrams of Traction Power Systems
- 1-3 Control Systems
- 1-4 Grounding and Bonding Theory
- 1-5 Summary

### Learning Outcomes

This module gives an overview of inspecting and maintaining power distribution and control systems in a traction power system. Following the completion of this module, the participant should be able to complete the objectives with an accuracy of 75% or greater:

- 201-1-1 Identify areas of traction power system for inspection and maintenance.
- 201-1-2 Examine and interpret line diagrams of traction power system.
- 201-1-3 Recognize monitoring and control systems in a traction power substation.
- 201-1-4 Examine theory of grounding and bonding.

### Key Terms

- Line diagrams
- SCADA
- Grounding
- Bonding
- Ground and Test Devices (G&T)

### Abbreviations

TPSS	Traction Power Substation
NEC	National Electrical Code (NFPA 70) published by the National Fire Protection Association (NFPA)
CIC	Communications Interface Cabinet
SCADA	Supervisory Control and Data Acquisition
G&T	Ground and Test Devices

## 1-5 SUMMARY

This module gave the participant an overview to this course which has four modules. In this module, the participant was introduced to SCADA control systems and the theory of grounding and bonding.

### Sources:

1. Holt, M. (2020). *Mike Holt's Illustrated Guide to Understanding NEW Requirements for Bonding and Grounding, based on the 2020 NEC*. Mike Holt Enterprise.
2. Forquer, Paul (2013). *The Tao of Traction Power Substations*. Paul Forquer, PE.
3. D. Paul, "DC traction power system grounding," Conference Record of the 2001 IEEE Industry Applications Conference. 36th IAS Annual Meeting (Cat. No.01CH37248), Chicago, IL, USA, 2001, pp. 2133-2139 vol.4, doi: 10.1109/IAS.2001.955922.
4. Electric Power eTool: Illustrated Glossary. OSHA, 2020.  
[https://www.osha.gov/SLTC/etools/electric\\_power/illustrated\\_glossary/index.html](https://www.osha.gov/SLTC/etools/electric_power/illustrated_glossary/index.html). Retrieved August 10, 2020.

# MODULE 2

## *Alternate Current Power Systems*

### Outline

- 2-1 Overview
- 2-2 AC Switchgear
- 2-3 AC Circuit Breakers
- 2-4 Control and Monitoring Equipment
- 2-5 Busbar
- 2-6 Summary

### Learning Outcomes

This module gives an overview of the principles of operation of power conversion and distribution for traction power use. Following the completion of this module, the participant should be able to complete the objectives with an accuracy of 75% or greater:

- 201-2-1 Explain and conduct maintenance on AC switchgear components.
- 201-2-2 Maintain disconnect switches (load and non-load).
- 201-2-3 Interpret SCADA codes specific to AC systems.
- 201-2-4 Inspect raceway/conduit including busbar and other conduit components.

### Key Terms

- Draw-out type circuit breaker
- Programmable Logic Controller (PLC)
- Insulation-resistance test
- Vacuum circuit breaker
- Metal-clad switchgear
- Remote terminal unit (RTU)
- Over-potential test

### Abbreviations

AC	Alternating Current
APTA	American Public Transportation Association
DC	Direct Current
IEEE	Institute of Electrical and Electronics Engineers
OEM	Original Equipment Manufacturer
SCADA	Supervisory Control and Data Acquisition
TPSS	Traction Power Substation

## APTA Standards for AC Switchgear

The American Public Transportation Association (APTA) has published recommended standards for the inspection and maintenance for AC switchgear. Your agency may be a member of APTA. The following is from APTA's inspection and maintenance working group and are recommendations periodic inspection and maintenance AC switchgear.

### Visual

1. Inspect physical and mechanical condition.
2. Verify appropriate anchorage and required area clearances.
3. Verify appropriate equipment grounding.
4. Verify correct blade alignment, blade penetration, travel stops and mechanical operation.
5. Verify that fuse sizes and types (if applicable) are in accordance with the drawings.
6. Verify that expulsion-limiting devices are in place on all holders having expulsion-type elements.
7. Verify that each fuse holder (if applicable) has adequate mechanical support.
8. Inspect bolted electrical connections using one of the following methods:
  - a. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with OEM published data.
  - b. Perform a thermographic survey of the equipment.
  - c. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with OEM published data.
  - d. Perform a thermographic survey of the equipment.

### Electrical Test

1. Perform **insulation-resistance tests** on each pole, phase-to-phase and phase-to-ground, with the switch closed and across each open pole for 1 min. Test voltage shall be in accordance with OEM published data.
2. Perform an **over-potential test** on each pole with the switch closed. Test each pole-to-ground with all other poles grounded. Test voltage shall be in accordance with OEM published data.
3. Perform resistance measurements through each bolted connection with a low-resistance ohmmeter.



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connection shows any sign of corrosion, then the connection shall be cleaned or replaced.

- b. Perform a thermographic survey of equipment.
8. Verify appropriate contact lubrication per OEM recommendations on:
  - a. moving current-carrying parts; and
  - b. moving and sliding surfaces.
9. Record as-found and as-left operation counter readings.

### Electrical tests

1. Perform a contact resistance test using a low-resistance ohmmeter capable of reading 2  $\mu\Omega$ . The maximum reading is to be established by the rail transit system.
2. Verify trip, close, trip-free and anti-pump operations.
3. Trip the circuit breaker by operation of each of the protective devices.
4. Perform resistance measurements on bolted connections with a low-resistance ohmmeter.
5. Perform insulation-resistance tests pole-to-pole, pole-to-ground and across open poles in accordance with the OEM manual.
6. Perform vacuum bottle integrity (over-potential) test across each vacuum bottle with the breaker in the open positions in strict accordance with OEM published data. 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 OEM tolerance.
7. Perform insulation-resistance test at 1000 VDC on all control wiring. For units with solid-state components, follow OEM recommendations.

### Operation checks

1. Check each circuit breaker for proper operation. Perform the following checks as a minimum:
  - a. Open and close the breaker via local control.
  - b. Open and close the breaker via remote control (SCADA if applicable).
  - c. Open and close the breaker while in the test position.
  - d. Verify mechanical trip features where applicable.
2. For each operation check, verify the following (when applicable):

# MODULE 3

## *Direct Current Power Systems*

### Outline

- 3-1 Overview
- 3-2 DC Switchgear Components
- 3-3 Grounding
- 3-4 Summary

### Learning Outcomes

This module gives an overview the distribution of power between the substation and rail vehicles. Following the completion of this module, the participant should be able to complete the objectives with an accuracy of 75% or greater:

- 201-3-1 Explain and maintain circuit breakers and protective devices.
- 201-3-2 Maintain DC switchgear
- 201-3-3 Maintain disconnect switches (load and non-load).
- 201-3-4 Inspect raceway/conduit. Include busbar and other conduit components.

### Key Terms

- Arc chute
- Breaker isolation mechanism
- Circuit breaker closing mechanism
- Circuit breaker contacts
- Control switches
- Control panel
- Current shunts
- DC Bus Bar System
- Lightning or Surge arresters
- Mechanism operated cell switches
- Primary disconnects
- Protective relays
- Transducers
- Truck operated cell switches

### Abbreviations

ANSI	American National Standards Institute
IEEE	Institute of Electrical and Electronics Engineers
NEC	National Electrical Code
SCADA	Supervisory Control and Data Acquisition.
TPSS	Traction Power Substation.

## 3-2 DC SWITCHGEAR ASSEMBLY

The DC switchgear assembly is typically enclosed in metal housing or “cubicles” and is usually self-supporting, and floor-mounted. The assembly may be made up of several individual metal-enclosed compartments that house the circuit breaker, bus system, cables and relays. They vary in layout by TPSS type, size, OEM, and transit agency need.



*Figure 3.2 DC Switchgear Cubicle –courtesy DART*

Under normal conditions switchgear equipment enables routine switching operations to occur. During maintenance switchgear equipment disconnects and isolates a piece of equipment so maintenance work can be performed.

Under abnormal conditions, switchgear equipment will automatically disconnect faulted equipment from the rest of the power system in order to minimize damage and maximize safety.

The switchgear operates by pulling apart contacts (electrical conductors). An arc forms between the contacts as they are pulled apart while power is flowing through the device. To interrupt current flow, the arc must be extinguished with insulating material (fluid or air). If there is a fault or short circuit in the system, the relay signals the circuit breaker to prevent or minimize damage to the switchgear equipment. Interruption of current flow happens with one of two methods: **high resistance**, and low resistance or current zero interruption method (applicable only for the AC circuit).

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Component	Function
<b>Mechanism operated cell switches</b>	Switches mounted in circuit breaker cells that change state as the circuit breaker is opened and closed
<b>Meters</b>	Devices for indicating the magnitude of electrical parameters such as voltage, current or kilowatts.
<b>Primary disconnects</b>	The primary disconnects feature two insulated shutters that are operated by the position of the DC circuit breaker in the cubicle. Upon withdrawal of the circuit breaker the shutters can be padlocked closed.
<b>Transducers</b>	Devices that are usually connected to a shunt or through fuses to the bus. Transducers provide isolation and have a low current output, usually 0-1 ma, which can be transmitted long distance or used by a SCADA System.
<b>Truck operated cell switches</b>	Switches mounted in circuit breaker cells that change state as the circuit breaker is moved from the disconnected position to the connected position.
Source: Forquer, Paul (2013). <i>The Tao of Traction Power Substations</i> . Paul Forquer, PE.	

PREVIEW

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deburring the contact surface. To avoid damage to the contact surface, consult the OEM-recommended procedure to determine the proper cleaning method.

- b. Wipe: Check contacts for proper wipe. Adhere to the OEM-recommended procedure for checking contact wipe. Make necessary adjustments according to the OEM-recommended practice.
  - c. Pressure: Check contacts for proper pressure. Adhere to the OEM-recommended procedure for checking contact pressure. Make necessary adjustments in accordance with the OEM-recommended practice.
12. Clean arc chutes by performing the following tasks as a minimum:
- a. Inspect for any breakage to the inside sheet, arc plates or arc runner.
  - b. Inspect the interrupting structure for the presence of foreign particles such as chips of insulation and metal.
  - c. Inspect the exterior of the arc chute for any damage or deformation to the outside sheets.
  - d. Remove any foreign bodies or objects.
  - e. Wipe the arc runner and arc horn with a dry cloth to remove dirt and dust accumulation.
  - f. Wipe all insulated parts with a cloth saturated with an oil-free solvent to remove any oil vapor film.
13. Check to ensure that each puffer provides a moderate amount of air at the contact when the breaker is opened. Use a suitable medium such as a piece of paper to detect air movement. If the puffers do not show signs of puffing action, then do not place the breaker in service.

### Electrical tests

1. Measure the contact resistance using a low-resistance ohmmeter capable of reading 2  $\mu\Omega$ . Maximum reading to be established by the rail transit system.
2. Perform a contact-resistance test.
3. Verify trip, close, trip-free and anti-pump operations.
4. Trip the circuit breaker by operation of each of the protective devices.
5. Perform resistance measurements on each bolted connection with a low-resistance ohmmeter.
6. Perform insulation-resistance tests pole-to-pole, pole-to-ground and across open poles in accordance with the OEM manual.
7. Perform an insulation-resistance test at 1000 VDC on all control wiring. For units with solid-state components, follow the OEM recommendations.

### 3-3 SUMMARY

This module presented the participant with the inspection and maintenance of equipment on the DC side of the traction power substation. After a description of the main functions of the DC equipment, this module listed standard inspection, testing, and maintenance steps of the DC switchgear assembly and grounding equipment.

#### Sources

1. Forquer, Paul (2013). *The Tao of Traction Power Substations*. Paul Forquer, PE.

Notes:

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