Participant Guide

Course 101

Introduction to Traction Power And Control Systems

September 2020

PREVIEW

TRACTION POWER TRAINING CONSORTIUM

REVISION INDEX

Additions, deletions, or revisions are listed in the table below.

Date	Module and Section	Description of Change	Revision Author
Sep 2020	All	Edits, new illustrations.	Subject matter experts from Consortium agencies.

PREVIEW

Disclaimer: This course is intended to educate employees of public transportation systems that have agreed to voluntarily participate in the Traction Power Training Consortium. It is intended only as informal guidance on the matters addressed, and should not be relied upon as the only method or manner for performing the tasks or work outlined in the materials. Anyone using this document or information provided in the associated training program should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of care in any given circumstances. These materials are based on compendiums of knowledge from transit employees, manufacturers and outside consultants, each of whom may approach a repair, update, or maintenance in their own unique way. Always follow the safety and maintenance procedures from your own agency, union, relevant OEM(s) and/or regulatory organizations. In addition, the course materials include examples from member agencies, nomenclature, procedures, and configurations which can vary from one transit location to another. The document that you are now referencing may have been modified by the Consortium member. For the original versions, please go to www.TransitTraining.net or contact the Transportation Learning Center.

The Traction Power Training Consortium, its participating agencies and labor unions, as well as the Transportation Learning Center, make no guaranty or warranty as to the accuracy or completeness of any information provided herein. The Traction Power Training Consortium, its participating agencies and labor unions, as well as the Transportation Learning Center, disclaim liability for any injury or other damages of any nature whatsoever, directly or indirectly, resulting from the use of or reliance on this document or the associated training program.

Note: All images contained within this document were contributed by Traction Power Training Consortium members unless otherwise noted.

TRACTION POWER TRAINING CONSORTIUM

The national Traction Power Training Consortium (TPTC) s 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 June 2020, the following agencies have agreed to work with the Transportation Learning Center on the TPTC.

AGENCY	UNION	LOCATION
BART	SEIU 1021	Oakland, CA
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

As of April 2020, the Consortium identified 16 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.

TRACTION POWER COURSE SEQUENCE

Course No.	100 LEVEL Introduction and Overview	Course No.	200 LEVEL Inspection and Maintenance	Course No.	300 LEVEL Troubleshooting, Adjustment and Repair
100	Overview, General Safety, and Regulations of Traction Power Systems	200	Preparation for Inspection & Maintenance	300	Principles of Troubleshooting
101	Power Distribution & Control Systems	201	Power Distribution & Control Systems	301	Power Distribution & Control Systems
102	Substations	202	Substations	302	Substations
103	Overhead Systems	203	Overhead Systems	303	Overhead Systems
104	Third Rail Systems	204	Third Rail Systems	304	Third Rail Systems

PREVIEW

PURPOSE OF THE COURSE

Course 101, *Introduction to Traction Power*, provides participants with an overview to the principles of traction power systems as they prepare to work on overhead and third rail traction power systems for a public transportation agency. This course is one in the series of Consortium courses on traction power.

HOW TO PREPARE FOR THIS COURSE

This course requires that participants understand the basic principles of electricity including knowledge of voltage, current, resistance, power, electric charge, and power efficiency. Participants should be familiar with resistors, capacitors, electrical units, and Ohm's law.

HOW TO USE THE PARTICIPANT GUIDE

Each course module begins with an outline, a learning outcome statement, a list of key terms, and a list of acronyms. The outline will discuss the main topics to be addressed in the module. The *Learning Outcome* lists the basic skills, knowledge, and abilities course participants should be able to demonstrate to show that they have learned the material presented in the module. A list of *key terms* identifies important terminology that will be introduced in this module. *Exercises* are built in throughout the course materials to assist the participants in learning and reviewing key information.

PREVIEW

Table of Contents

PREVIEW

Table of Figures

PREVIEW

MODULE 1

Overview to Traction Power

Outline

Learning Outcomes

This module gives an overview of the principles of operation in a traction power system as well as well as describes its major components. Following the completion of this module, the participant should be able to complete the objectives with an accuracy of 75% or greater:

101-1-1 Identify modes of rail electrification.

101-1-2 Describe functions of the electric traction system.

101-1-3 Describe the principles of direct current and alternating current.

101-1-4 Identify the main subsystems of an electric traction system.

Key Terms

- Alternating Current (AC)
- Direct Current (DC)
- Catenary
- Conductor Rail (Third Rail)
- Power Generation
- Power Distribution
- Power Transmission
- Substation
- Third Rail

Abbreviations

TPSS Traction Power Substation
TPE Traction Power Electrification

PREVIEW

1-1 OVERVIEW

Electrical energy makes its way through a path of complex steps before it can be used by the rail vehicle. This module introduces the traction power maintainer to these complex paths of electrical energy from its generation, through transmission, and then to distribution to the subsystem that provides the electrical energy to the rail vehicle.

This module outlines the path of electrical power from the source of generation to the rail vehicle in two sections:

1. Generated power distributed to the rail transit agency.

2. Power distribution through the transit agency's systems.

Along these two paths are complex systems in which electrical power is modified in various forms to meet the needs of the transit agency. Our focus in this course is on the distribution of electrical energy to the rail transit vehicle and the methods and equipment used to make various forms of electrical power available to transport passengers safely and efficiently.

1-2 ELECTRICAL POWER SUPPLY TO TRANSIT PROPERTY

Electrical energy makes its way to the transit property through a series of stages that can be divided into three distinct areas:

1. Generation. This is the area where electricity is produced by a power company. This power company can be a commercial or municipal public utility company.

2. Transmission. This is the process by which electricity is moved from where it is generated to centralized plants and substations.

3. Distribution. This is the area where electricity is delivered to individual sub-transmission customers including the transit property.

Figure 1.1 is a simple overview of the complex steps involved in the generation of electricity through transmission and then to distribution. Electricity is produced at lower voltages (10,000 to 25,000 volts) at generators from various fuel sources, such as nuclear, coal, oil, natural gas, hydro power, geothermal, photovoltaic, and others. Some generators are owned by the same electric utilities that serve the end-use customer; some are owned by independent power producers (IPPs); and others are owned by customers themselves—particularly large industrial customers and municipal-owned power companies.

PREVIEW

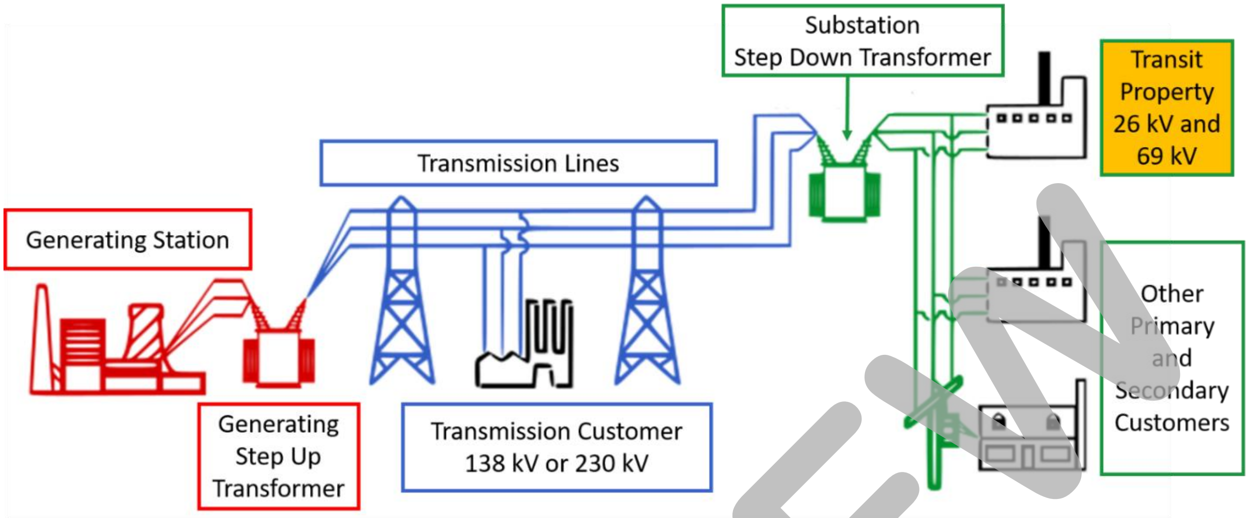

Figure 1.1 Power Generation, Transmission, and Distribution.

Electricity from generators is "stepped up" to higher voltages for transportation in bulk over transmission lines. Operating the transmission lines at high voltage (i.e., 230,000 to 765,000 volts) reduces the losses of electricity from conductor heating and allows power to be shipped economically over long distances. Transmission lines are interconnected at switching stations and **substations** to form a network of lines and stations called a power "grid." Electricity flows through the interconnected network of transmission lines from the generators to the loads much the same way that water flows through a network of canals following paths of least resistance. When the power arrives near a load center, it is "stepped down" to lower voltages for distribution to customers.

A **substation** is a facility that operates within a system of electrical power generation and distribution. Substations convert power from the utility or service company that provides it to be used by the rail vehicles or system that requires power. This process typically is done in three steps and may flow through several substations before arriving at the rail vehicle. Conversion of electric utility happens in a substation to useable forms and from high to low, low to high, AC to DC power, etc. accordingly.

PREVIEW

MODULE 2

Power Conversion

Outline

2-1 Overview
2-2 Incoming High Voltage AC Power
2-3 Step-down Power and Conversion
2-4 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:

101-2-1 Describe characteristics of incoming utility power.

101-2-2 Describe principles of conditioning energy for traction power.

Key Terms

- Three-phase power
- Conversion
- Frequency
- Ohm's Law
- Power Conversion
- Rectifier
- Sine wave
- Step-up
- Transformer
- Wavelength
- Voltage

Abbreviations

TPSS Traction Power Substation
AC Alternating Current
DC Direct Current

PREVIEW

2-1 OVERVIEW

In the previous module, we outlined the path of electrical supply from the source, such as the utility company, to the transit property. In this module, we will examine how that electrical supply is conditioned to meet the needs of transit rail vehicles. We will describe some basic electrical concepts as they relate to rail electrification systems.

The three main parameters of rail electrification systems are voltage, current (direct and alternating), and contact systems (overhead lines and third rail). The following table lists the definitions of some common terms that are used throughout this module and course.

Ampere (Amp)	The unit of measurement of electrical current produced in a circuit by 1 volt acting through a resistance of 1 Ohm.
Circuit	A conductor or a system of conductors through which electric current flows.
Conductor	Metal wires, cables, and bus-bar used for carrying electric current. conductors may be solid or stranded, that is, built up by an assembly of smaller solid conductors.
Current (I)	A flow of electrons in an electrical conductor. The strength or rate of movement of the electricity is measured in amperes.
Ground	This term in used in electrical engineering to mean the reference point in an electrical circuit from which voltages are measured, a common return path for electric current, or a direct physical connection to the earth.
Hertz (Hz)	Units of frequency (equal to 1 cycle per second).
Load	The amount of electric power delivered or required at any specific point(s) on the circuit.
Ohm (Ω)	The unit of measurement of resistance in an electric circuit, denoted by the omega symbol Ω.
Resistance (R)	Measured in ohms, resistance is the electrical “friction” that must be overcome through a device in order for current to flow when voltage is applied.
Volt (V)	The unit of measurement of voltage in an electric circuit.
Voltage (E)	The difference in electrical potential between any two conductors or between a **conductor** and **ground.** It is a measure of the electric energy per electron that electrons can acquire and/or give up as they move between the two conductors.
Watt (W)	The unit of real power in an electric circuit.

PREVIEW

Within the primary DC TPSS, two major changes have to be applied to the utility power:

1. High voltage needs to be stepped-down to lower voltage. This is the function of the substation's **transformer**.

2. AC voltage needs to be converted to DC voltage for traction. This is the function of the substation's **rectifier**.

Transformers and rectifiers are the core equipment in a traction power substation (TPSS). Often these core functions are combined into a single **Transformer Rectifier Unit** (TRU).

Figure 2.5 Transformer Rectifier Unit in TPSS –MCG Transformer Company Website

Transformer

A transformer is an electrical device that uses electromagnetism to change voltage from one level to another. It is also a device that isolates one voltage from another. The transformer passes an alternating (AC) signal from one electrical circuit to another or to multiple circuits.

In other electrical applications there are certain types of transformers are used to **step-up** or increase low AC voltages to high.

PREVIEW

MODULE 3

Wayside Power Distribution and Control

Outline

3-1 Overview

3-2 Essentials of the Wayside Electrical Circuit

3-3 Energy Regeneration

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:

101-3-1 Describe the principle of energy regeneration.

101-3-2 Describe wayside energy recovery systems.

101-3-3 List wayside components in an overhead contact system.

101-3-4 List wayside components of a third rail system.

101-3-5 Define and describe supervisory control and data acquisition system (SCADA)

Key Terms

- Energy Regeneration
- Bidirectional Converter
- Dynamic Braking
- Flywheel
- Energy storage systems
- Inverter
- Regenerative Braking
- Reversible substation
- Supercapacitors
- Wayside energy storage systems

Abbreviations

SCADA	Supervisory Control and Data Acquisition.
TPSS	Traction Power Substation.
ESS	Energy storage systems.
WESS	Wayside energy storage systems.
WERS	Wayside energy recovery systems.

PREVIEW

3-3 ENERGY REGENERATION

The DC rail traction system consumes substantial amounts of electrical energy. This energy can be recouped from rail vehicles during the process of **dynamic braking**. Dynamic braking occurs when the traction motors of the rail cars are used to slow the train. In essence, the traction motors act like electrical generators. The electrical power produced by dynamic braking is used in one of two ways:

1. **Regenerative Braking**: If the DC high voltage power source (third rail, catenary, or, in some cases, battery power) is receptive and can absorb the current, power is returned back to the source. Electrical energy can be reused to power the train or to send along the rail to help power an accelerating train nearby (Figure 3.5).

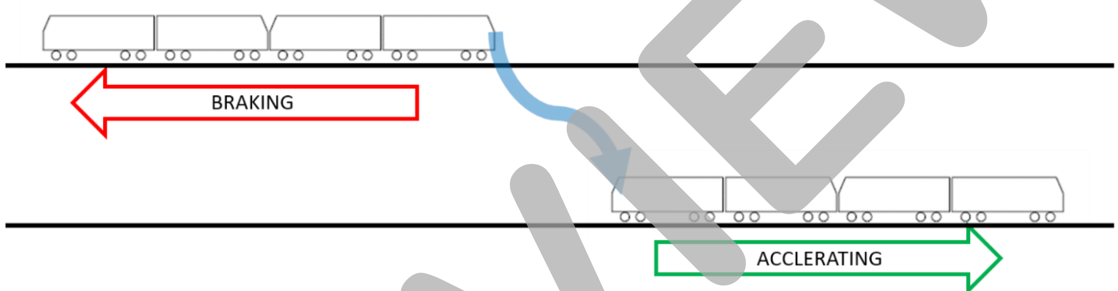

Figure 3.5 Regenerated DC energy from braking train is used by accelerating train within specific proximity.

2. **Rheostatic Braking**: If the DC high voltage power source is not receptive and cannot absorb the current, then power is redirected to the brake grid resistors (Figure 3.6).

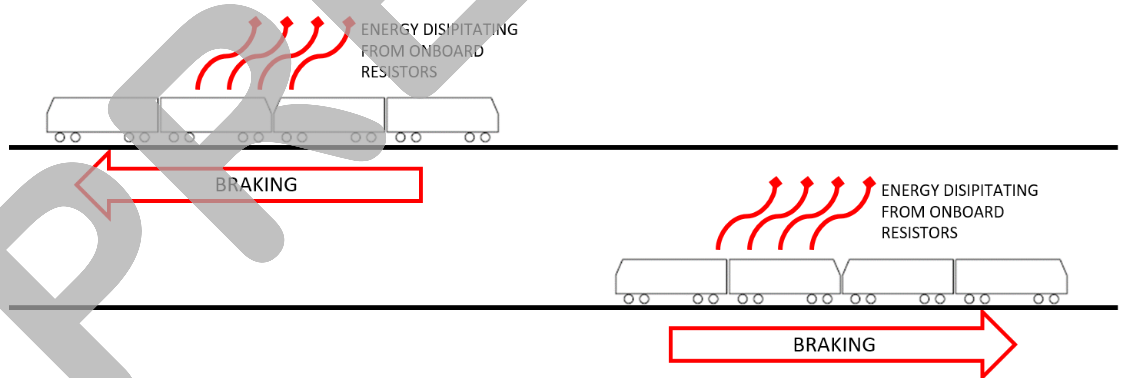

Figure 3.6 DC energy dissipating from resistors

PREVIEW

There are three main types of ESS:

1. **Flywheels** (FESS) are the simplest design of all three ESS. It is a mechanical storage device that stores electrical energy by converting it to kinetic energy. An FESS uses a rotor that rotates at high angular speed. The rotor is a hollow cylinder that has magnetic bearings to minimize the friction. The device is installed at a train station of the traction power substation.

2. **Supercapacitors** (SESS) are electrochemical storage devices where energy is stored in an electrostatic field by means of charge separation. Supercapacitors can deliver at least ten times higher power than most batteries of equivalent size.

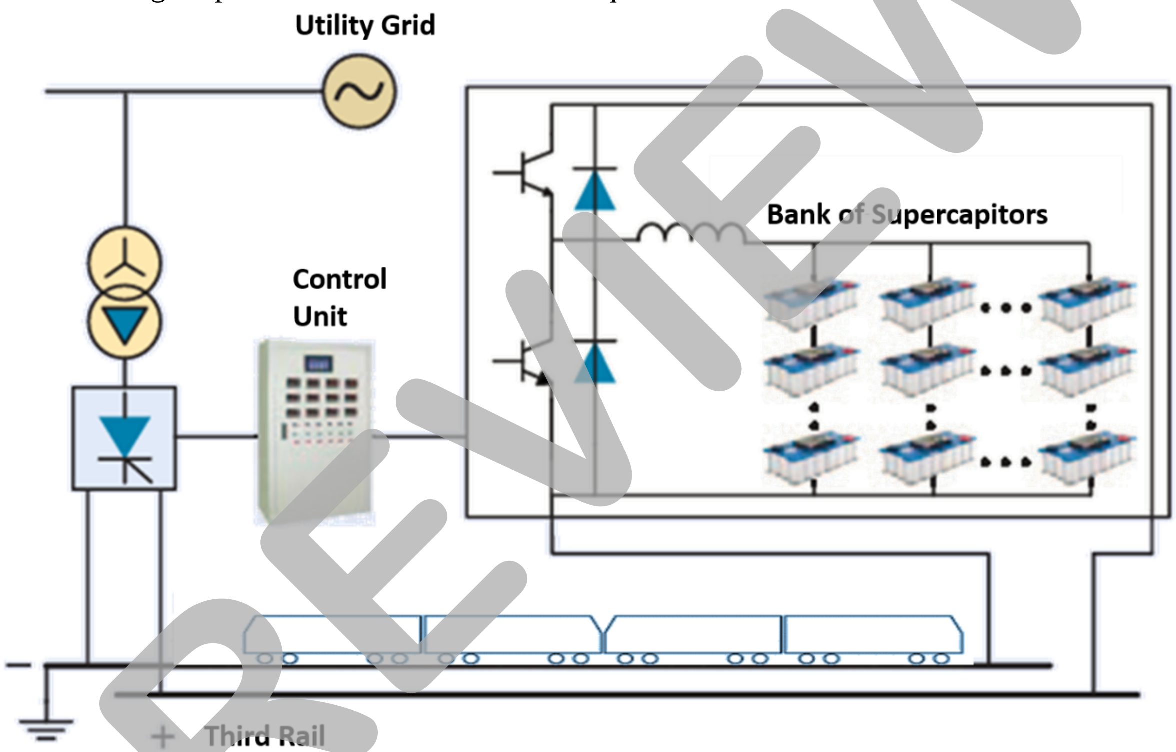

Figure 3.8 Wayside Energy Recovery System

3. **Batteries** (BESS) store energy through an electrochemical reaction. Batteries range in terms of size, chemistry and power ratings. In the Philadelphia region, SEPTA applied battery energy storage systems to several routes in a successful program that produced significant Figure 3.9 shows the cycle of regenerated energy rail vehicle and returned to the substation.

PREVIEW