Electric Power Technology Training Systems

8010

LabVolt Series

Datasheet

* The product images shown in this document are for illustration purposes; actual products may vary. Please refer to the Specifications section of each product/item for all details. Festo Didactic reserves the right to change product images and specifications at any time without notice.

Festo Didactic
en 120 V - 60 Hz
03/2025

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General Description

The production of energy using renewable natural resources such as wind, sunlight, rain, tides, geothermal heat, etc., has gained much importance in recent years as it is an effective means of reducing greenhouse gas (GHG) emissions. The need for innovative technologies to make the grid smarter has recently emerged as a major trend as the increase in electrical power demand observed worldwide makes it harder for the actual grid in many countries to keep up with demand. Furthermore, electric vehicles, from bicycles to cars, are developed and marketed with more and more success in many countries all over the world.

The Electric Power Technology Training Program was developed to answer the increasingly diversified needs for training in the wide field of electrical energy. It is a modular study program for technical institutes, colleges, and universities.

The program starts with a variety of courses providing in-depth coverage of basic topics related to the field of electrical energy such as ac and dc power circuits, power transformers, rotating machines, ac power transmission lines, industrial controls, and power electronics. These basic courses incorporate most of the subject matter covered in other well established training systems such as the Electromechanical Training System, Model 8006, Power Electronics Training System, Model 8032, Industrial Controls Training Systems, Series 8036, and Power Transmission Training System, Model 8055, as well as many new topics related to recent technologies.

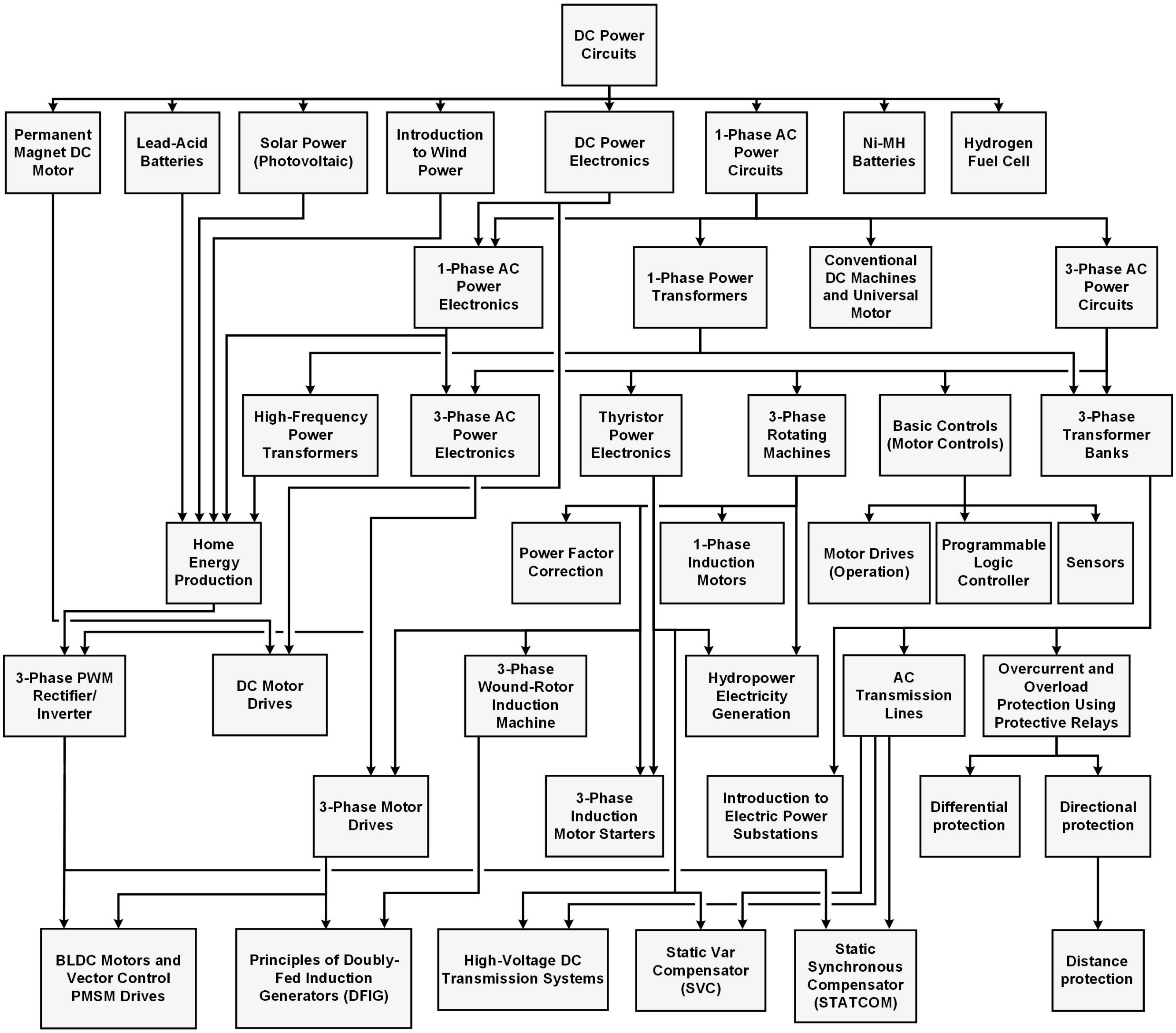
The program then builds on the knowledge gained by the student through these basic courses to provide training in more advanced subjects such as home energy production from renewable resources (wind and sunlight), large-scale electricity production from hydropower, large-scale electricity production from wind power (doubly-fed induction generator [DFIG], synchronous generator, and asynchronous generator technologies), smart-grid technologies (SVC, STATCOM, HVDC transmission, etc.), storage of electrical energy in batteries, and drive systems for small electric vehicles and cars.

The Electric Power Technology Training Systems, Series 8010, are based on the Electric Power Technology Training Program, each system providing a turn-key solution dealing with some aspects of the wide field of electrical energy. Each system is based on a proven modular design approach. Also, most systems use computer-based data acquisition and control to provide unrivaled training in electrical energy. For this purpose, the Four-Quadrant Dynamometer/Power Supply, Model 8960, and the Data Acquisition and Control Interface, Model 9063, were developed. These modules are powerful USB peripherals that greatly enhance the learning experience of students.

The Electric Power Technology Training Program being highly modular, both hardware and courseware wise, it allows courses to be selected (topic coverage) in order to build a training solution matching specific needs.

Electric Power Technology Training Program

The Electric Power Technology Training Program is a modular study program divided into courses, each course dealing with a specific aspect of the wide field of electrical energy. The program is shown below as a flow chart, each box in the flow chart representing a course. Each course in the program includes a full-color student manual providing all the theoretical matter required, guided lab-exercise procedures to be performed with the training equipment, and review questions that test the knowledge gained by the student. Whenever possible, each course is built to bring the student to actual applications as soon as possible. A full-color instructor guide providing all lab results and answers to questions is also included with each course. Refer to the Course Description section of this data sheet for additional information about each of the courses in the Electric Power Technology Training Program.


DC Power Circuits
Permanent Magnet DC Motor
Lead-Acid Batteries
Solar Power (Photovoltaic)
Introduction to Wind Power
DC Power Electronics
1-Phase AC Power Circuits
Ni-MH Batteries
Hydrogen Fuel Cell
1-Phase AC Power Electronics
1-Phase Power Transformers
Conventional DC Machines and Universal Motor
3-Phase AC Power Circuits
High-Frequency Power Transformers
3-Phase AC Power Electronics
Thyristor Power Electronics
3-Phase Rotating Machines
Basic Controls (Motor Controls)
3-Phase Transformer Banks
Home Energy Production
Power Factor Correction
1-Phase Induction Motors
Motor Drives (Operation)
Programmable Logic Controller
Sensors
3-Phase PWM Rectifier/ Inverter
DC Motor Drives
3-Phase Wound-Rotor Induction Machine
Hydropower Electricity Generation
AC Transmission Lines
Overcurrent and Overload Protection Using Protective Relays
3-Phase Motor Drives
3-Phase Induction Motor Starters
Introduction to Electric Power Substations
Differential protection
Directional protection
BLDC Motors and Vector Control PMSM Drives
Principles of Doubly-Fed Induction Generators (DFIG)
High-Voltage DC Transmission Systems
Static Var Compensator (SVC)
Static Synchronous Compensator (STATCOM)
Distance protection

Electric Power Technology Training Systems

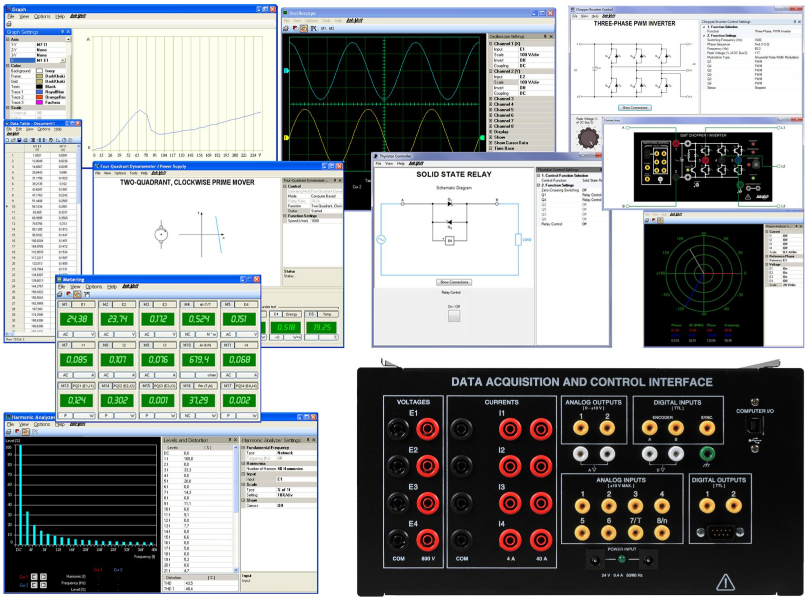
The following training systems based on the Electric Power Technology Training Program are available:

- DC and AC Power Circuits Training System, Model 8010-1
- Solar Power Training System, Model 8010-2
- Small-Scale Wind Power Electricity Generation Training System, Model 8010-3
- Lead-Acid Batteries Training System, Model 8010-4
- Basic Renewable Energy Training System, Model 8010-5
- DC Power Electronics Training System, Model 8010-6
- Home Energy Production Training System, Model 8010-7
- Hydrogen Fuel Cell Training System, Model 8010-8
- Electromechanical Training System, Model 8010-9 (this system closely matches the classic Electromechanical Training System, Model 8006)
- Power Electronics Training System, Model 8010-A (this system closely matches the classic Power Electronics Training System, Model 8032)
- AC Power Transmission Training System, Model 8010-B (this system closely matches the classic Electric Power Transmission Training System, Model 8055)
- Smart Grid Technologies Training System, Model 8010-C
- DFIG Principles Training System, Model 8010-D

Other training systems will be created as additional courses in the Electric Power Technology Training Program become available. Each training system is a turn-key solution that includes the equipment and courseware material required to perform a different combination of courses in the Electric Power Technology Training Program (see table on the next two pages) focusing on specific aspects related to the wide field of electrical energy. Each system uses the Four-Quadrant Dynamometer/Power Supply, Model 8960, and/or the Data Acquisition and Control Interface, Model 9063, two powerful USB peripherals that greatly enhance hands-on learning. Refer to the Lists of Equipment section of this data sheet for the list of equipment included in each training system.

Four-Quadrant Dynamometer / Power Supply LabVolt Series 8960-20
OPERATING MODE
DYNAMOMETER
POWER SUPPLY
MANUAL CONTROL
START/STOP
FUNCTION
COMMAND
Voltage
Current
Status
Power
STATUS
CONTROL
FUNCTION
N
POWER INPUT
I/O FOR ADVANCED FUNCTIONS
COMMAND INPUT
SHAFT ENCODER OUTPUTS
THERMISTOR INPUT
ANALOG OUTPUTS
RATING

The Four-Quadrant Dynamometer/Power Supply, Model 8960, is a highly versatile USB peripheral that is used for multiple functions (dc power source, single-phase ac power source, prime mover, brake, wind turbine emulator, etc.) in the lab exercises included with the various courses in the Electric Power Technology Training Program.


THREE-PHASE PWM INVERTER
TWO-QUADRANT, CLOCKWISE PRIME MOVER
SOLID STATE RELAY
DATA ACQUISITION AND CONTROL INTERFACE
VOLTAGES
CURRENTS
ANALOG OUTPUTS
DIGITAL INPUTS
COMPUTER I/O
ANALOG INPUTS
DIGITAL OUTPUTS
POWER INPUT

The Data Acquisition and Control Interface, Model 9063, is a highly versatile USB peripheral used for measuring, observing, analyzing, and controlling electrical parameters in electric power systems and power electronics circuits.

The following table indicates the combination of courses which can be performed with each Electric Power Technology Training System. Black dots in the table indicate the courses that can be performed with each training system. Red dots indicate popular complementary courses that can optionally be added to a training system.

If none of these Electric Power Technology Training Systems meets your specific training needs, please refer to the Custom Training Solutions section of this data sheet to learn how a training solution can be adapted to your needs.

Courseware		**Electric Power Technology Training System (Model 8010-X)**													
Title	**Part Number**	**-1**	**-2**	**-3**	**-4**	**-5**	**-6**	**-7**	**-8**	**-9**	**-A**	**-B**	**-C**	**-D**	**-E**
DC Power Circuits	86350	●	●	●	●	●	●	●		●		🔴			
Lead-Acid Batteries	86351			●	●	●		●							
Ni-MH Batteries	86354														
Solar Power	86352		●			●		●							
Introduction to Wind Power	86353			●		●			●						
Permanent Magnet DC Motor	86357									●					
Hydrogen Fuel Cell	86355								●						
DC Power Electronics	86356						●	●			●				
DC Motor Drives	88553										●				
Single-Phase AC Power Circuits	86358	●						●		●		🔴			
Single-Phase Power Transformers	86377							●		●		🔴			
Conventional DC Machines and Universal Motor	88943									🔴					
Single-Phase AC Power Electronics	86359							●			●				
High-Frequency Power Transformers	86378							●							
Home Energy Production	86361							●					●		
Three-Phase AC Power Circuits	86360									●		●			
Three-Phase Rotating Machines	86364									●		🔴			
Power Factor Correction	20116									●					
Single-Phase Induction Motors	88944									🔴					

Courseware		Electric Power Technology Training System (Model 8010-X)													
Title	Part Number	-1	-2	-3	-4	-5	-6	-7	-8	-9	-A	-B	-C	-D	-E
Three-Phase Wound-Rotor Induction Machine	86367													●	
Three-Phase Transformer Banks	86379									●		●			
AC Transmission Lines	20521											●			
Introduction to Electric Power Substations	20528														
Basic Controls	87774														
Motor Drives	87668														
Programmable Logic Controller	39436														
Sensors	39654														
Three-Phase AC Power Electronics	86362										●				
Thyristor Power Electronics	86363										●				
Hydropower Electricity Generation	86369										●				
Three-Phase Induction Motor Starters	88197										●				
Three-Phase Motor Drives	86368										●				
Principles of DFIG	86376													●	
Three-Phase PWM Rectifier/Inverter	86366														
BLDC Motors and Vector Control PMSM Drives	86373														
High-Voltage DC Transmission Systems	86380										●		●		●
Static Var Compensator (SVC)	86370												●		●
Static Synchronous Compensator (STATCOM	86371												●		●
Overcurrent and Overload Protection Using Protective Relays	52173														
Directional Relays	52174														

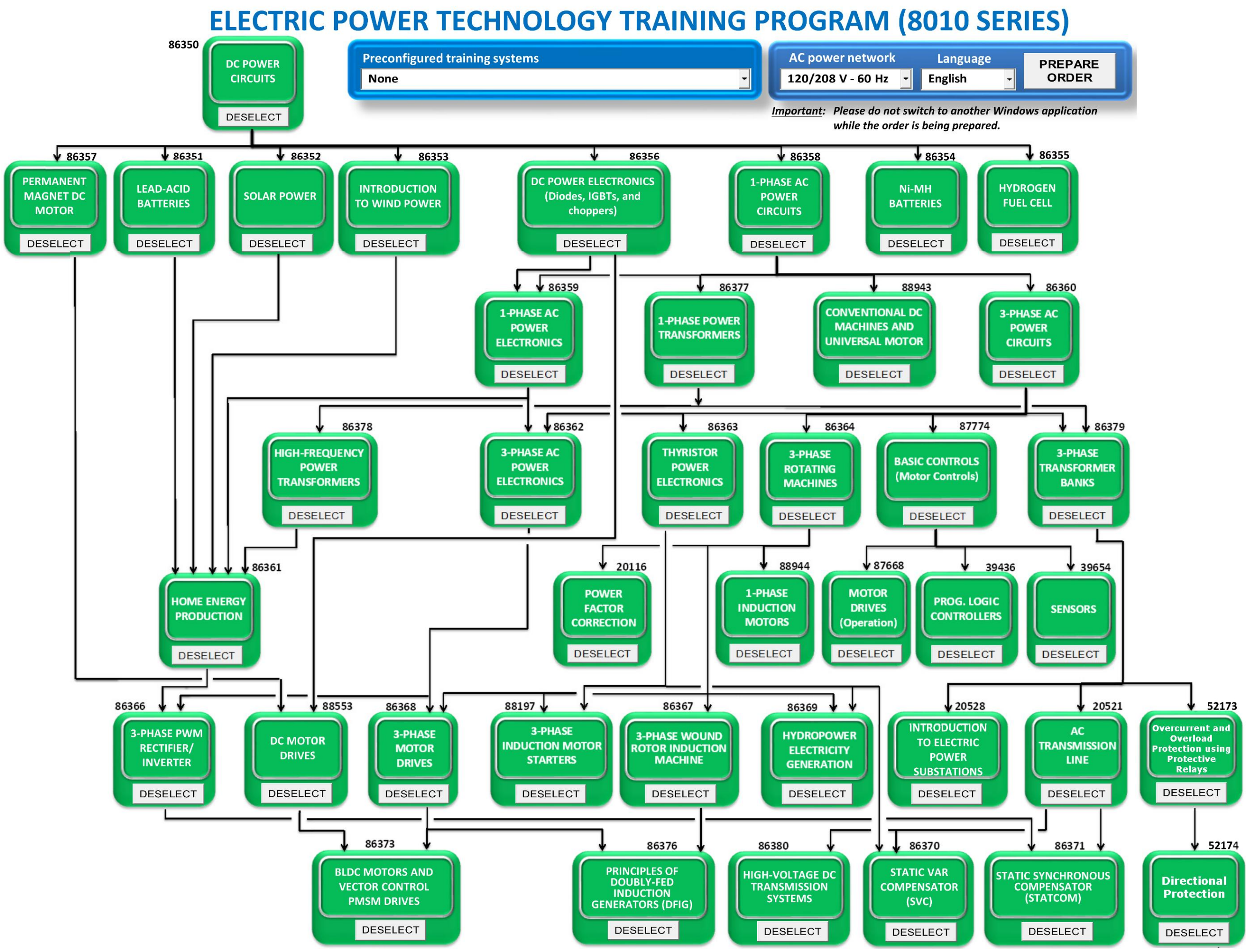
Custom Training Solutions

The modularity of the Electric Power Technology Training Program allows you to build your own training solution by selecting courses in the program that correspond to your specific needs. To build a custom training solution, refer to the Course Description section of this data sheet to learn about the topic coverage and prerequisites of each course in the Electric Power Technology Training Program, then select the courses that meet your specific training needs. The sales representative can easily determine the exact list of equipment required to perform the lab exercises associated with your selection of courses using the Custom Training Solutions application (shown on next page). A few examples of custom solutions for specific training needs are shown below.

Example 1 – Training solution dealing with Single-Phase AC Power Electronics

Course selection:

- DC Power Circuits (86350)
- DC Power Electronics (86356)
- Single-Phase AC Power Circuits (86358)


ELECTRIC POWER TECHNOLOGY TRAINING PROGRAM (8010 SERIES)

Preconfigured training systems: None

AC power network: 120/208 V - 60 Hz

Language: English

Important: *Please do not switch to another Windows application while the order is being prepared.*

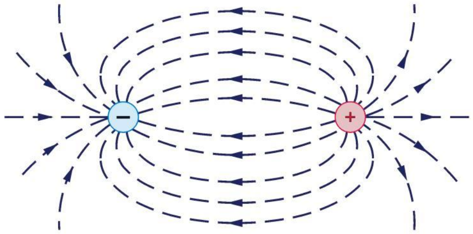
PREPARE ORDER
86350 DC POWER CIRCUITS DESELECT
86357 PERMANENT MAGNET DC MOTOR DESELECT
86351 LEAD-ACID BATTERIES DESELECT
86352 SOLAR POWER DESELECT
86353 INTRODUCTION TO WIND POWER DESELECT
86356 DC POWER ELECTRONICS (Diodes, IGBTs, and choppers) DESELECT
86358 1-PHASE AC POWER CIRCUITS DESELECT
86354 Ni-MH BATTERIES DESELECT
86355 HYDROGEN FUEL CELL DESELECT
86359 1-PHASE AC POWER ELECTRONICS DESELECT
86377 1-PHASE POWER TRANSFORMERS DESELECT
88943 CONVENTIONAL DC MACHINES AND UNIVERSAL MOTOR DESELECT
86360 3-PHASE AC POWER CIRCUITS DESELECT
86378 HIGH-FREQUENCY POWER TRANSFORMERS DESELECT
86362 3-PHASE AC POWER ELECTRONICS DESELECT
86363 THYRISTOR POWER ELECTRONICS DESELECT
86364 3-PHASE ROTATING MACHINES DESELECT
87774 BASIC CONTROLS (Motor Controls) DESELECT
86379 3-PHASE TRANSFORMER BANKS DESELECT
86361 HOME ENERGY PRODUCTION DESELECT
20116 POWER FACTOR CORRECTION DESELECT
88944 1-PHASE INDUCTION MOTORS DESELECT
87668 MOTOR DRIVES (Operation) DESELECT
39436 PROG. LOGIC CONTROLLERS DESELECT
39654 SENSORS DESELECT
86366 3-PHASE PWM RECTIFIER/ INVERTER DESELECT
88553 DC MOTOR DRIVES DESELECT
86368 3-PHASE MOTOR DRIVES DESELECT
88197 3-PHASE INDUCTION MOTOR STARTERS DESELECT
86367 3-PHASE WOUND ROTOR INDUCTION MACHINE DESELECT
86369 HYDROPOWER ELECTRICITY GENERATION DESELECT
20528 INTRODUCTION TO ELECTRIC POWER SUBSTATIONS DESELECT
20521 AC TRANSMISSION LINE DESELECT
52173 Overcurrent and Overload Protection using Protective Relays DESELECT
86373 BLDC MOTORS AND VECTOR CONTROL PMSM DRIVES DESELECT
86376 PRINCIPLES OF DOUBLY-FED INDUCTION GENERATORS (DFIG) DESELECT
86380 HIGH-VOLTAGE DC TRANSMISSION SYSTEMS DESELECT
86370 STATIC VAR COMPENSATOR (SVC) DESELECT
86371 STATIC SYNCHRONOUS COMPENSATOR (STATCOM) DESELECT
52174 Directional Protection DESELECT

Course Description

The Electric Power Technology Training Program consists of a wide selection of courses which are listed below.

- DC Power Circuits
- Lead-Acid Batteries
- Ni-MH Batteries
- Solar Power (photovoltaic)
- Introduction to Wind Power
- Permanent Magnet DC Motor
- Hydrogen Fuel Cell
- DC Power Electronics
- DC Motor Drives
- Single-Phase AC Power Circuits
- Single-Phase Power Transformers
- Conventional DC Machines and Universal Motor
- Single-Phase AC Power Electronics
- High-Frequency Power Transformers
- Home Energy Production
- Three-Phase AC Power Circuits
- Three-Phase Rotating Machines
- Power Factor Correction
- Single-Phase Induction Motors
- Three-Phase Wound-Rotor Induction Machine

DC Power Circuits (86350)



The DC Power Circuits course introduces the student to the fundamentals of electricity such as the direct current (dc), dc voltage, resistance, Ohm's Law, etc.

Topic Coverage (4 exercises)

- Voltage, Current, and Ohm's Law
- Equivalent Resistance
- Power in DC Circuits
- Series and Parallel Circuits

Prerequisites

- None

Lead-Acid Batteries (86351)

LEAD-ACID BATTERIES
0.1 A
PARALLEL CHARGING INPUT
+
15 V MAX.
RATING
EACH BATTERY:
12 V 2.3 Ah
MAX. CHARGE CURRENT: 0.92 A
MAX. DISCHARGE CURRENT: 5 A

The Lead-Acid Batteries course explains how a lead-acid battery produces electricity from a chemical reaction. The course familiarizes the student with the charge and discharge characteristics of lead-acid batteries. The student also learns the various methods of charging lead-acid batteries.

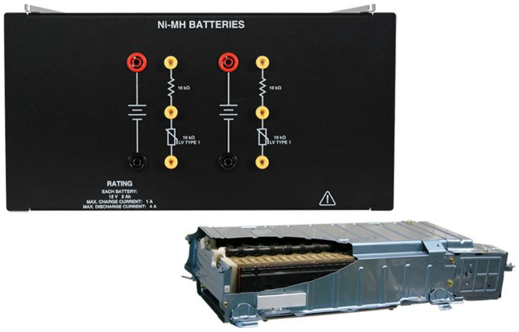
Topic Coverage (4 exercises)

- Battery Fundamentals
- Discharge Characteristics
- Battery Charging Fundamentals
- Battery Charging Methods

Prerequisites

- DC Power Circuits

Ni-MH Batteries (86354)


Ni-MH BATTERIES
10 kΩ
10 kΩ
10 kΩ
LV TYPE 1
10 kΩ
LV TYPE 1
RATING
EACH BATTERY:
12 V 2 Ah
MAX. CHARGE CURRENT: 1 A
MAX. DISCHARGE CURRENT: 4 A

The Ni-MH Batteries course explains how a nickel-metal hydride (Ni-MH) battery produces electricity from a chemical reaction. The course familiarizes the student with the charge and discharge characteristics of Ni-MH batteries. The student also learns the various methods of charging Ni-MH batteries, with emphasis on the various methods of terminating the charge (temperature cutoff, voltage drop, and rate of temperature increase)

Topic Coverage (4 exercises)

- Battery Fundamentals
- Battery Capacity Versus Discharge Rate
- Battery Charging Fundamentals
- Battery Charging Methods

Prerequisites

- DC Power Circuits

Solar Power (86352)

The Solar Power course familiarizes the student with the production of electricity using photovoltaic (PV) solar panels. The course begins by introducing the diode, the basic semiconductor component in PV solar panels. The student then learns how a solar panel produces electricity from solar power as well as how to store this electric energy in batteries to ensure electric power is available during cloudy periods. The student also learns how to connect PV panels in series and in parallel to increase the voltage and current produced, respectively, as well as how shading affects solar panel operation. Finally, the student learns how to set the orientation of solar panels so the maximum amount of energy is produced.

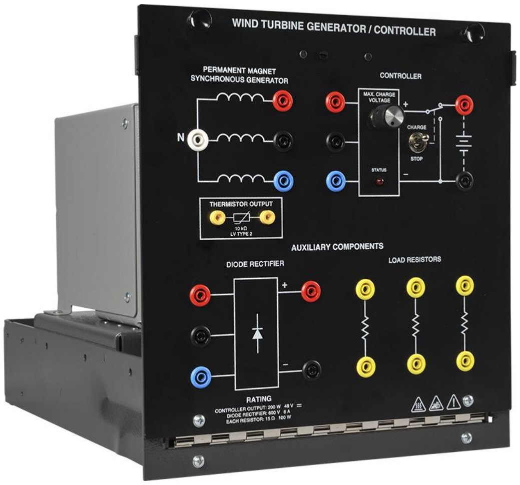
Topic Coverage (7 exercises)

- The Diode
- The Solar Panel (Photovoltaic Panel)
- Effect of Temperature on Solar Panel Performance
- Storing Energy from Solar Panels into Batteries
- Effect of Shading on Solar Panel Operation
- Solar Panel Orientation (optional)
- Solar Panel Performance versus Insolation (optional)

Prerequisites

- DC Power Circuits

Introduction to Wind Power (86353)


WIND TURBINE GENERATOR / CONTROLLER
PERMANENT MAGNET SYNCHRONOUS GENERATOR
N
CONTROLLER
MAX. CHARGE VOLTAGE
+
CHARGE
STOP
STATUS
–
THERMISTOR OUTPUT
10 kΩ
LV TYPE 2
AUXILIARY COMPONENTS
DIODE RECTIFIER
LOAD RESISTORS
+
–
RATING
CONTROLLER OUTPUT: 200 W 48 V ⎓
DIODE RECTIFIER: 600 V 6 A
EACH RESISTOR: 15 Ω 100 W

The Introduction to Wind Power course familiarizes the student with the small-scale production of electricity using a fixed-pitch, direct-drive wind turbine. The student learns how a wind turbine produces electricity from wind power as well as how to store this electric energy in batteries to ensure electric power is available when there is no wind or during low-wind periods. In lab exercises, the Wind Turbine Emulator is used to realistically emulate wind blowing on the rotor of a small wind turbine, and make the wind turbine generator operate exactly as if it would be subjected to actual wind.

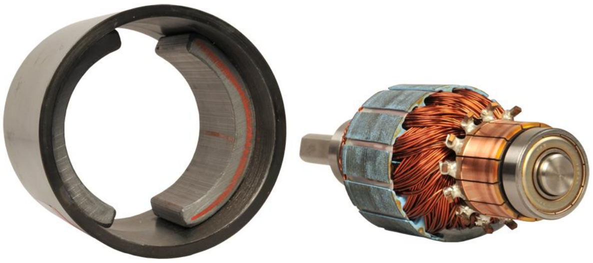
Topic Coverage (4 exercises)

- Voltage-Speed Characteristic of a Wind Turbine Generator
- Torque-Current Characteristic of a Wind Turbine Generator
- Power versus Wind Speed
- Storing the Energy Produced by a Wind Turbine into Batteries

Prerequisites

- DC Power Circuits

Permanent Magnet DC Motor (86357)



The Permanent Magnet DC Motor course covers the operating characteristics of a permanent magnet dc motor. In this course, students will learn the motor characteristics when used as a motor or as a generator.

- Topic Coverage (3 exercises)
- Prime Mover and Brake Operation
- Permanent Magnet DC Motor Operating as a Generator
- Permanent Magnet DC Motor Operating as a Motor

Prerequisites

- DC Power Circuits

Hydrogen Fuel Cell (86355)

HYDROGEN FUEL CELL
START-UP BATTERIES
SYSTEM CONTROL
POWER SUPPLY

The Hydrogen Fuel Cell course teaches foundational engineering principles of fuel cell systems. The course covers the structure and functioning principles, the thermodynamics theory, and the different characteristics of a real 50 W fuel cell system. Through numerous experiments, the students will also learn about the safety aspects of this type of technology.

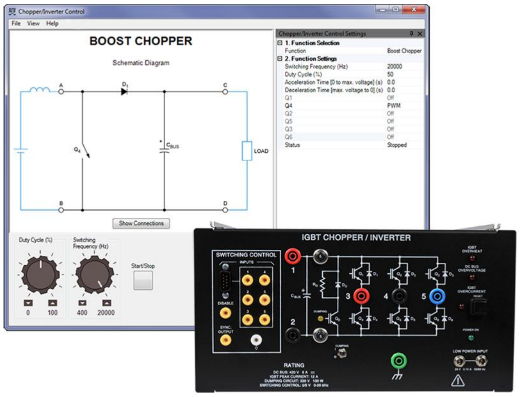
Topic Coverage (9 exercises)

- The Basic Functions of the Fuel Cell System
- The Characteristic Curve of a Fuel Cell
- Parameters Influencing the Characteristic Curve
- Determination of the Hydrogen Current Curve
- Efficiency of the Fuel Cell Stack
- Set-up of a Fuel Cell Power Supply
- Efficiency of a Fuel Cell Power Supply
- Fuel Cell Application I: Remote Traffic Light
- Fuel Cell Application II: Fuel Cell Car

Prerequisites

- DC Power Circuits

DC Power Electronics (86356)


Chopper/Inverter Control
File View Help
BOOST CHOPPER
Schematic Diagram
LOAD
Show Connections
Duty Cycle (%)
Switching Frequency (Hz)
Start/Stop
IGBT CHOPPER / INVERTER
SWITCHING CONTROL
RATING

Chopper/Inverter Control Settings

1. Function Selection

Function	Boost Chopper

2. Function Settings

Switching Frequency (Hz)	20000
Duty Cycle (%)	50
Acceleration Time [0 to max. voltage] (s)	0.0
Deceleration Time [max. voltage to 0] (s)	0.0
Q1	Off
Q4	PWM
Q2	Off
Q5	Off
Q3	Off
Q6	Off
Status	Stopped

The DC Power Electronics course introduces the student to power electronic components and circuits (choppers) required to manage dc power, such as the dc power stored in batteries or produced from wind power or solar power. The course first presents the diode and the switching transistor, the two main semiconductor components used in power electronics. Through the remainder of the course, the student becomes familiar with the main types of choppers, is introduced to high-speed power switching (voltage-type and current-type circuits, free-wheeling diodes, etc.), learns how to control ripple in choppers, and discovers how to build a battery charger using a buck chopper.

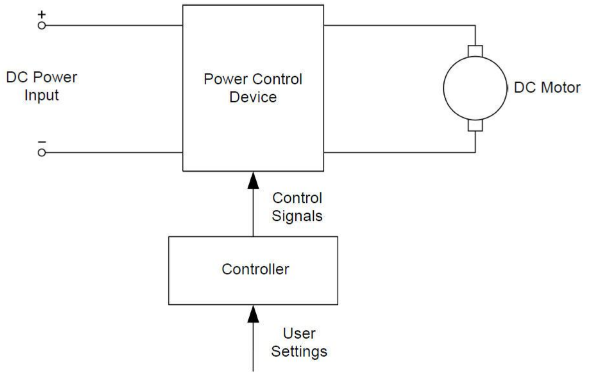
Topic Coverage (8 exercises)

- The Diode and Switching Transistor
- The Buck Chopper
- Introduction to High-Speed Power Switching
- Ripple in Choppers
- The Lead-Acid Battery Charger
- The Boost Chopper
- The Buck/Boost Chopper
- The Four-Quadrant Chopper

Prerequisites

- DC Power Circuits

DC Motor Drives (88553)


+
DC Power
Input
−
Power Control
Device
DC Motor
Control
Signals
Controller
User
Settings

The DC Motor Drives course familiarizes the student with the operation and use of PWM dc motor drives. Through the curriculum, students will learn the different concepts (e.g., motor coasting, regenerative braking, etc.) related to dc motor drives. They will also be able to demonstrate their ability to control the speed and torque of a dc motor.

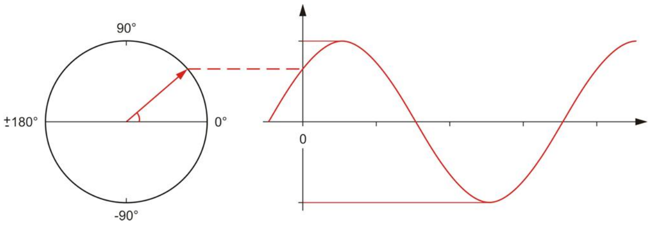
Topic Coverage (3 exercises)

- Basic PWM DC Motor Drive (Buck Chopper Drive)
- Bidirectional PWM DC Motor Drive with Regenerative Breaking (Four-Quadrant Chopper Drive)
- Speed Feedback and Current Control in PWM DC Motor Drives

Prerequisites

- DC Power Circuits
- Permanent Magnet DC Motor
- DC Power Electronics

Single-Phase AC Power Circuits (86358)



The Single-Phase Power Circuits course first introduces the student to the fundamentals of alternating current (ac) such as the sine wave, period and frequency, phase angle and phase shift, instantaneous and average power, etc. The student then becomes familiar with the inductor and capacitor. The course continues with more advanced topics such as the impedance, active power, reactive power, apparent power, and power triangle. The course concludes by teaching the student how to solve ac power circuits using the impedance calculation method or the power triangle method.

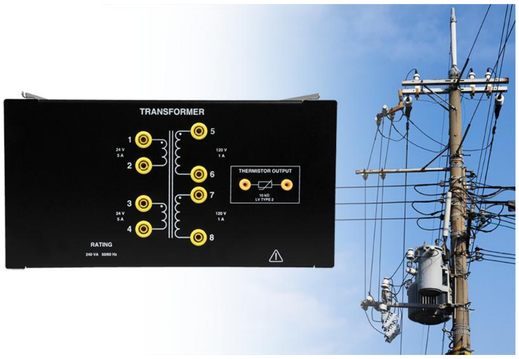
Topic Coverage (10 exercises)

- The Sine Wave
- Phase Angle and Phase Shift
- Instantaneous Power and Average Power
- Inductive Reactance
- Capacitive Reactance
- Impedance
- Active and Reactive Power
- Apparent Power and the Power Triangle
- Solving Simple AC Circuits using Circuit Impedance Calculation
- Solving AC Circuits Using the Power Triangle Method

Prerequisites

- DC Power Circuits

Single-Phase Power Transformers (86377)



The Single-Phase Power Transformers course covers, through theory and demonstrations, the operating characteristics of single-phase power transformers. Through measurements, students will learn the important characteristics of a power transformer, such as the turns ratio, voltage and current ratios, winding polarity, voltage regulation, power losses, and transformer ratings. The course also covers the effect which frequency has on the transformer rating as well as the operation and special characteristics of the autotransformer.

Topic Coverage (6 exercises)

- Voltage and Current Ratios
- Transformer Winding Polarity and Interconnection
- Transformer Losses, Efficiency, and Regulation
- Transformer Rating
- Effect of Frequency on Transformer Rating
- The Autotransformer

Prerequisites

- DC Power Circuits
- Single-Phase AC Power Circuits

Conventional DC Machines and Universal Motor (88943)

The Conventional DC Machines and Universal Motor course introduces the student to the operation and characteristics of the following rotating machines: seperately-excited, shunt, series, and compound dc motors, separately-excited, shunt, and compound dc generators, and universal motor. These machines, although still in use in numerous applications today, are less common in modern battery-powered applications (e.g., electric bicycles, mobility scooters, etc.) where power efficiency is at a premium. In such applications, the permanent magnet dc motor is often preferred because of its superior power efficiency.

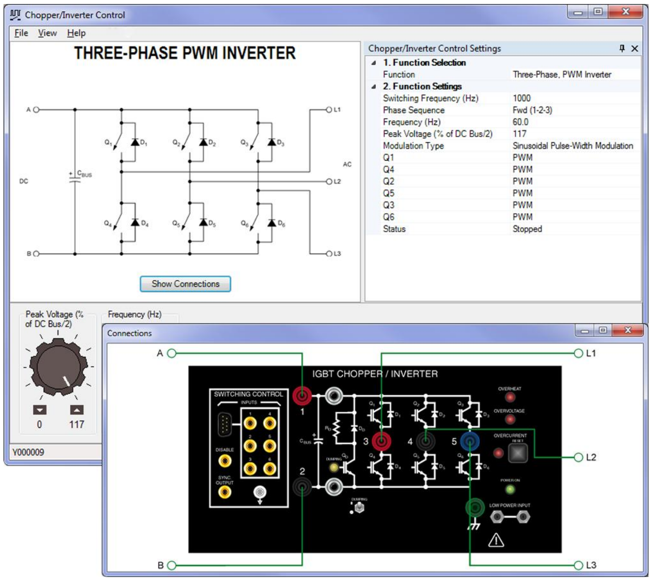
Topic Coverage (6 exercises)

- Prime Mover and Brake Operation
- The Separately-Excited DC Motor
- Separately-Excited, Series, Shunt, and Compound Motors
- Separately-Excited, Shunt, and Compound DC Generators
- Armature Reaction and Saturation Effect
- The Universal Motor

Prerequisites

- DC Power Circuits
- Single-Phase AC Power Circuits

Single-Phase AC Power Electronics (86359)


Chopper/Inverter Control
File View Help
THREE-PHASE PWM INVERTER
A
B
DC
AC
L1
L2
L3
Show Connections
Peak Voltage (% of DC Bus/2)
Frequency (Hz)
0
117
Y000009
Connections
IGBT CHOPPER / INVERTER
SWITCHING CONTROL
INPUTS
DISABLE
SYNC OUTPUT
OVERHEAT
OVERVOLTAGE
OVERCURRENT
POWER ON
LOW POWER INPUT
1
2
3
4
5

Chopper/Inverter Control Settings

1. Function Selection	
Function	Three-Phase, PWM Inverter
2. Function Settings	
Switching Frequency (Hz)	1000
Phase Sequence	Fwd (1-2-3)
Frequency (Hz)	60.0
Peak Voltage (% of DC Bus/2)	117
Modulation Type	Sinusoidal Pulse-Width Modulation
Q1	PWM
Q4	PWM
Q2	PWM
Q5	PWM
Q3	PWM
Q6	PWM
Status	Stopped

The Single-Phase AC Power Electronics course introduces the student to power electronic circuits (rectifiers and inverters) used to perform ac/dc power conversion in single-phase circuits. The course begins with the study of single-phase diode rectifiers. The student then becomes familiar with the operation of the single-phase inverter and the single-phase PWM inverter. The course concludes with the study of power flow in a single-phase PWM inverter.

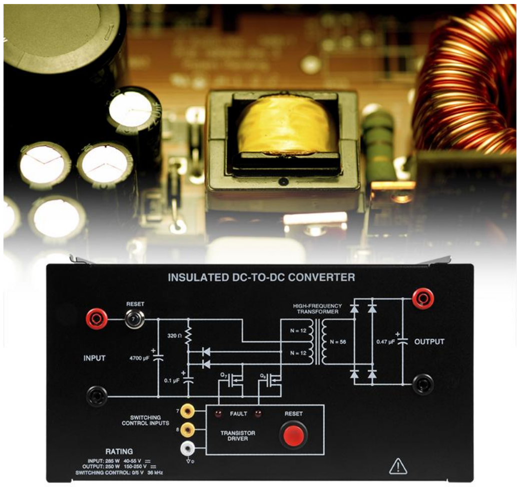
Topic Coverage (2 exercises)

- Power Diode Single-Phase Rectifiers
- The Single-Phase PWM Inverter

Prerequisites

- DC Power Circuits
- DC Power Electronics
- Single-Phase AC Power Circuits

High-Frequency Power Transformers (86378)


INSULATED DC-TO-DC CONVERTER
RESET
7
INPUT
HIGH-FREQUENCY TRANSFORMER
320 Ω
4700 µF
0.1 µF
N = 12
N = 56
N = 12
0.47 µF
OUTPUT
Q_7
Q_8
SWITCHING CONTROL INPUTS
7
8
FAULT
RESET
TRANSISTOR DRIVER
RATING
INPUT: 285 W 40-55 V
OUTPUT: 250 W 150-250 V
SWITCHING CONTROL: 0/5 V 36 kHz

The High-Frequency Power Transformers course demonstrates how high-frequency switching can be used to increase the power handling capability of power transformers. This type of power transformer is commonly used to perform dc-to-dc conversion in switched-mode power supplies (SMPS) as well as in grid-tied inverters used for home energy production.

Topic Coverage (1 exercise)

- High-Frequency Power Transformer Operation

Prerequisites

- DC Power Circuits
- Single-Phase AC Power Circuits
- Single-Phase Power Transformers

Home Energy Production (86361)

The Home Energy Production course explains how to produce ac power from dc power produced using renewable natural resources (e.g., wind, sunlight, etc.) or stored in batteries. The course first shows how to produce ac power for local use (typically at remote sites) from dc power produced from renewable resources and stored in batteries. The course continues by introducing the single-phase grid-tied inverter (i.e., the PWM rectifier/inverter), the essential device required to convert dc power into ac power that can fed the grid. Then the student learns how to feed the grid with ac power obtained from dc power produced from renewable resources. Finally, the student is introduced to large-scale energy storage, an important step in the implementation of the smart grid.

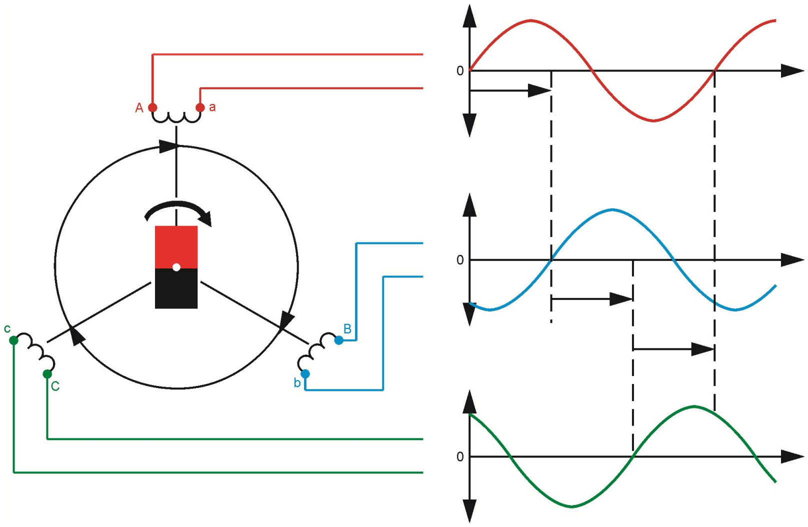
Topic Coverage (5 exercises)

- Stand-Alone Home Energy Production
- The Single-Phase Grid-Tied Inverter (PWM Rectifier/Inverter)
- Grid-Tied Home Energy Production Using a Solar or Wind Power Inverter without DC-to-DC Converter
- Grid-Tied Home Energy Production Using a Solar or Wind Power Inverter with DC-to-DC Converter
- Large-Scale Energy Storage: A Step in the Implementation of the Smart Grid

Prerequisites

- DC Power Circuits
- Lead-Acid Batteries
- Solar Power (photovoltaic)
- Introduction to Wind Power
- DC Power Electronics
- Single-Phase AC Power Circuits
- Single-Phase AC Power Electronics
- Single-Phase Power Transformers
- High-Frequency Power Transformers

Three-Phase AC Power Circuits (86360)



The Three-Phase AC Power Circuit course familiarizes the student with three-phase power systems. The course first introduces the student to the fundamentals of three-phase power systems such as the wye (star) and delta configurations, phase and line voltages, phase and line currents, phase balance, etc. The student then learns how to measure power in three-phase circuits using the two-wattmeter method as well as how to determine the power factor. Finally, the student learns what the phase sequence is and how to determine the phase sequence of a three-phase power system.

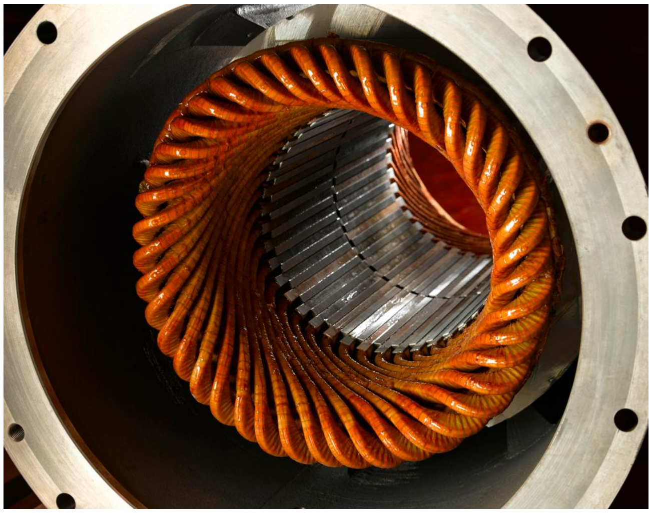
Topic Coverage (3 exercises)

- Three-Phase Circuits
- Three-Phase Power Measurement
- Phase Sequence

Prerequisites

- DC Power Circuits
- Single-Phase AC Power Circuits

Three-Phase Rotating Machines (86364)



The Three-Phase Rotating Machines course familiarizes the student with the various three-phase machines used in commercial and industrial motor applications, as well as for large-scale production of electricity from wind power, hydropower, etc. The course begins with fundamentals of rotating machines such as the torque, rotation speed, direction of rotation, motor power, power losses in motor, motor efficiency, etc. The student then studies the operation (both as a motor and a generator) of the following three-phase machines: squirrel-cage induction machine and synchronous machine.

Topic Coverage (8 exercises)

- Prime Mover and Brake Operation
- The Three-Phase Squirrel Cage Induction Motor
- Eddy-Current Brake and Asynchronous Generator
- The Three-Phase Synchronous Motor
- Synchronous Motor Pull-Out Torque
- Three-Phase Synchronous Generator No-Load Operation
- Voltage-Regulation Characteristics
- Generator Synchronization

Prerequisites

- DC Power Circuits
- Single-Phase AC Power Circuits
- Three-Phase AC Power Circuits

Power Factor Correction (20116)

The Power Factor Correction course familiarizes the student with the reasons for correcting the power factor in industrial applications, as well as with the different means to do so. The course begins by discussing the problematic of having a low power factor in industrial applications, for both the electrical power provider and the customer. It then covers how power factor correction is usually implemented in industrial applications with variable inductive loads (e.g., induction motors that start and stop). The course also introduces students to the two main types of power factor correction available: plant-wide and distributed. Finally, the principles of power factor correction are applied to both single-phase and three-phase ac power circuits.

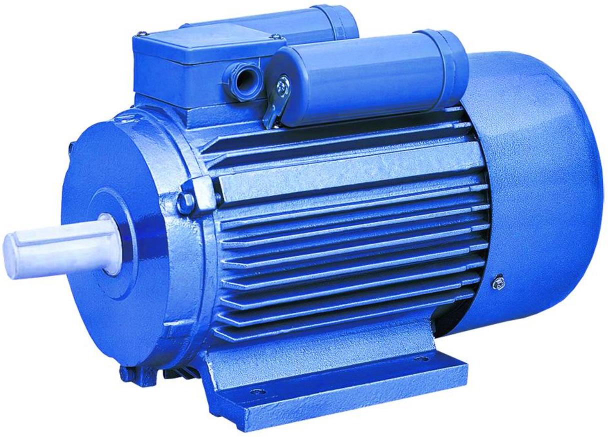
Topic Coverage (1 exercise)

- Power Factor Correction

Prerequisites

- DC Power Circuits
- Single-Phase AC Power Circuits
- Three-Phase AC Power Circuits
- Three-Phase Rotating Machines

Single-Phase Induction Motors (88944)



The Single-Phase Induction Motors course introduces the student to the operation and characteristics of the following two types of single-phase induction motor: capacitor-start induction motor and split-phase induction motor. These motors, although still in use in numerous applications today, are less common in modern applications where they are often replaced with three-phase induction motor drives (i.e., a three-phase squirrel-cage induction motor plus a variable-frequency, three-phase inverter) for added flexibility of operation and improved performance.

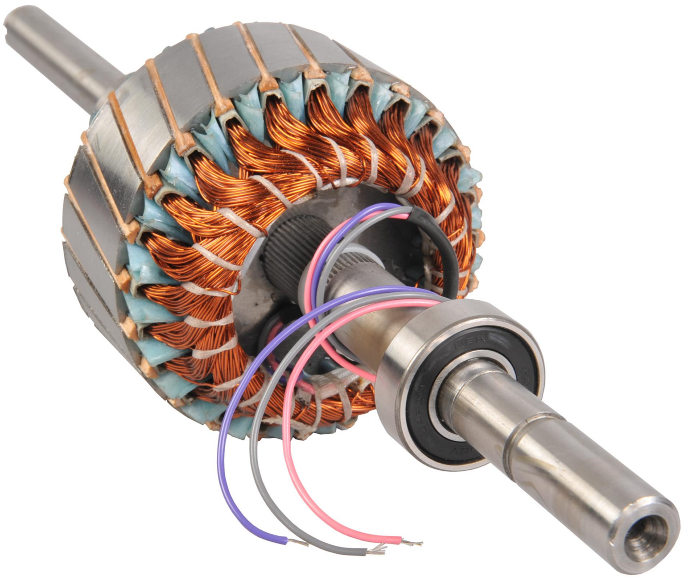
Topic Coverage

- Operation and Characteristics of Single-Phase Induction Motors

Prerequisites

- DC Power Circuits
- Single-Phase AC Power Circuits
- Three-Phase AC Power Circuits
- Three-Phase Rotating Machines

Three-Phase Wound-Rotor Induction Machine (86367)



The Three-Phase Wound-Rotor Induction Machine course introduces the student to the operation of three-phase wound-rotor induction machines. The student then learns the effects which varying the rotor resistor has on the starting current and torque of the machine. Through this process, the student also learns how to vary the rotation speed of a wound-rotor induction machine.

Topic Coverage (2 exercises)

- Three-Phase Wound-Rotor Induction Machine with a Short-Circuited Rotor
- Three-Phase Wound-Rotor Induction Machine with Rotor Resistance

Prerequisites

- DC Power Circuits
- Single-Phase AC Power Circuits
- Three-Phase AC Power Circuits
- Three-Phase Rotating Machines

Three-Phase Transformer Banks (86379)

The Three-Phase Transformer Banks course covers the operating characteristics of three-phase transformer banks. The course covers the winding connection (wye and delta configurations) and shows how to ensure proper phase relationships between the phase windings.

Topic Coverage (1 exercise)

- Three-Phase Transformer Configurations

Prerequisites

- DC Power Circuits
- Single-Phase AC Power Circuits
- Single-Phase Power Transformers
- Three-Phase AC Power Circuits

AC Transmission Lines (20521)

THREE-PHASE TRANSMISSION LINE
CAUTION
1
2
3
N
4
5
6
N
RATING

The AC Transmission Lines course introduces students to the characteristics and behavior of high-voltage ac transmission lines, as well as to the voltage compensation of these lines using switched shunt compensation (SSC). The student first studies the voltage regulation characteristics of a simplified ac transmission line. Students are then introduced to the fundamental characteristics, characteristic impedance, natural load, corrected PI equivalent circuit, and power-voltage curve of a high-voltage ac transmission line. Voltage compensation of a high-voltage ac transmission line using SSC is then covered in detail. Students learn the relationship between the active power transmitted by a voltage-compensated line and the phase shift between the voltages at both ends of the line, as well as how to determine the maximal transmissible power of a voltage-compensated line. Students then discover how line length affects the characteristics and voltage compensation of a high-voltage ac transmission line. The students then learn how to remedy to the negative effects of the line length using distributed SSC. Finally, students learn how to control the flow of active power in an ac transmission line using a phase-shifting transformer.

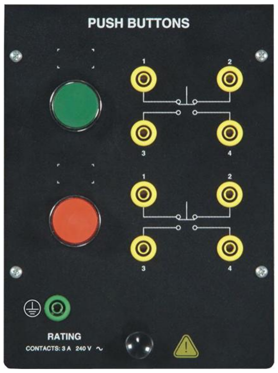
Topic Coverage (6 exercises)

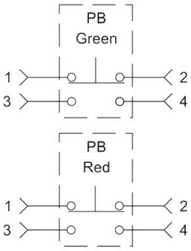
- Voltage Regulation Characteristics
- Characteristics of a High-Voltage AC Transmission Line
- Voltage Compensation of a High-Voltage AC Transmission Line Using Switched Shunt Compensation
- Effect of length on the Characteristics and Voltage Compensation of a High-Voltage AC Transmission Line
- Voltage Compensation of a Long, High-Voltage AC Transmission Line Using Distributed, Switched Shunt Compensation
- Control of the Active Power Flowing Through Voltage-Compensated AC Transmission Lines

Prerequisites

- DC Power Circuits
- Single-Phase AC Power Circuits
- Single-Phase Power Transformers
- Three-Phase AC Power Circuits
- Three-Phase Transformer Banks

Basic Controls (87774)





The Basic Controls course provides students with a basis of knowledge for further study in industrial controls. The course provides students with basic safety procedures and gives them an overview of industrial control devices, as well as of the graphical tools used to represent industrial control circuits. The course also presents basic motor starter and control circuits, the jogging and braking features of a control circuit, and the methods of starting a motor smoothly. Finally, the Basic Controls course introduces students to time relays.

Topic Coverage (6 exercises)

- Basic Principles of Motor Control
- Circuit Layout and Specifications
- Basic Control Circuits
- Jogging Control Circuits
- Reduced AC Voltage Starters
- Time Relay Circuits

Prerequisites

- DC Power Circuits
- Single-Phase AC Power Circuits
- Single-Phase Power Transformers
- Three-Phase AC Power Circuits

Motor Drives (87668)

The Motor Drives course introduces students to the operation of ac and dc drives. It covers a large variety of topics related to ac drives, such as volt per hertz characteristic, ramp and torque boost, protection mechanisms, braking and jogging, and remote controls. The course also covers topics related to dc drives, such as current limiting and IR compensation.

Topic Coverage (2 exercises)

- AC Drives
- DC Drives

Prerequisites

- DC Power Circuits
- Single-Phase AC Power Circuits
- Single-Phase Power Transformers
- Three-Phase AC Power Circuits
- Basic Controls

Programmable Logic Controller (39436)

PROGRAMMABLE LOGIC CONTROLLER
MOELLER
easy512-DC-R
+24 V
0 V
RATING
POWER INPUT: 2 W 24 V
INPUTS: 24 V
CONTACTS: 4 A 24 V
ANALOG INPUTS (I7,I8): 0-10 V

The Programmable Logic Controller course complements the exercises contained in the Basic Controls course. It provides students the knowledge necessary to realize motor controls with the help of a PLC. It introduces students to the PLC and to its main functions. It also includes PLC circuits that are equivalent to those realized in the Basic Controls course.

Topic Coverage (2 exercises)

- Programmable Logic Controller
- PLC Control Circuits

Prerequisites

- DC Power Circuits
- Single-Phase AC Power Circuits
- Single-Phase Power Transformers
- Three-Phase AC Power Circuits
- Basic Controls

Sensors (39654)

The Sensors course introduces students to sensors and to the terms commonly used in the sensor field. It covers the operation of a wide variety of switches, such as background suppression switches, polarized retroreflective photoelectric switches, capacitive proximity switches, inductive proximity switches, and limit switches. Two optional exercises familiarize students with the use of sensors and a limit switch in motor-operated circuits, as well as with the design of circuits using sensors, a PLC, and a motor based on project descriptions.

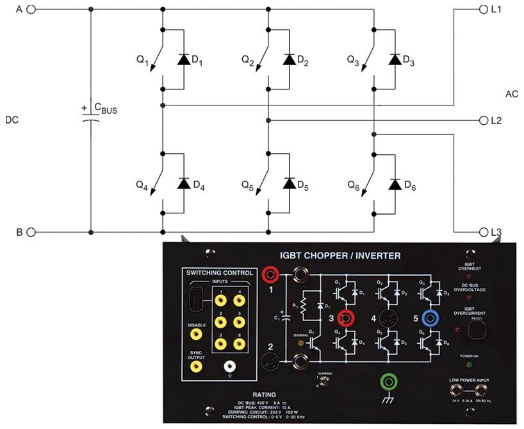
Topic Coverage (8 exercise)

- Introduction to sensors
- Background Suppression Photoelectric Switch
- Polarized Retroreflective Photoelectric Switch
- Capacitive Proximity Switch
- Inductive Proximity Switch
- Limit Switch
- Motor-Operated Circuits Using Sensors (optional)
- PLC-Controlled Circuits Using Sensors (optional)

Prerequisites

- DC Power Circuits
- Single-Phase AC Power Circuits
- Single-Phase Power Transformers
- Three-Phase AC Power Circuits
- Basic Controls

Three-Phase AC Power Electronics (86362)


A
B
DC
+
C_{BUS}
Q_1
D_1
Q_2
D_2
Q_3
D_3
Q_4
D_4
Q_5
D_5
Q_6
D_6
L1
L2
L3
AC
IGBT CHOPPER / INVERTER
SWITCHING CONTROL
INPUTS
DISABLE
SYNC OUTPUT
1
2
3
4
5
RATING
LOW POWER INPUT
POWER ON

The Three-Phase Power Electronics course introduces the student to power electronic circuits (rectifiers and inverters) used to perform ac/dc power conversion in three-phase circuits. The course begins with the study of three-phase diode rectifiers. The student then becomes familiar with the operation of the single-phase PWM inverter built with a dual-polarity dc bus. The course continues with the operation of the three-phase PWM inverter built with a single-polarity or dual-polarity dc bus. The course concludes with the study of the three-phase PWM inverter.

Topic Coverage (3 exercises)

- Power Diode Three-Phase Rectifiers
- The Single-Phase PWM Inverter with Dual-Polarity DC Bus
- The Three-Phase PWM Inverter

Prerequisites

- DC Power Circuits
- DC Power Electronics
- Single-Phase AC Power Circuits
- Single-Phase AC Power Electronics
- Three-Phase AC Power Circuits

Thyristor Power Electronics (86363)

POWER THYRISTORS
FIRING CONTROL
INPUTS
SYNC. OUTPUT
DISABLE
ISOLATORS AND AMPLIFIERS
TO THYRISTOR GATES
RATING
RESET
POWER ON
LOW POWER INPUT

The Thyristor Power Electronics course introduces the student to the power diode and thyristor, two electronic components used to control very large amounts of power in ac and dc power systems. The course begins with the study of both the single-phase and three-phase power diode rectifiers. The student is then introduced to the thyristor operation. The remainder of the course deals with the following applications of the power thyristor: solid state relay, single-phase and three-phase ac power control circuits using either phase angle control or burst fire control, and three-phase thyristor bridge. Both the rectifier and inverter modes of operation are discussed when studying the three-phase thyristor bridge.

Topic Coverage (7 exercises)

- Power Diode Single-Phase Rectifiers
- Power Diode Three-Phase Rectifiers
- The Power Thyristor
- The Solid State Relay
- Single-Phase AC Power Control
- Three-Phase AC Power Control
- Thyristor Three-Phase Rectifier/Inverter

Prerequisites

- DC Power Circuits
- Single-Phase AC Power Circuits
- Three-Phase AC Power Circuits

Hydropower Electricity Generation (86369)

The Hydropower Electricity Generation course examines the large-scale production of electricity from hydro power using a synchronous generator, a proven technology long used worldwide by power utilities. The course first introduces the student to the configuration of a typical hydropower plant. The student then learns how to adjust the voltage and frequency of the synchronous generator in a hydropower plant, as well as how to synchronize the generator using a synchro-check relay. The course concludes with a study of the automatic speed (frequency) and voltage regulation systems used in a hydropower plant. The course also includes an optional exercise dealing with the operation of hydropower generators connected in parallel as well as with load sharing.

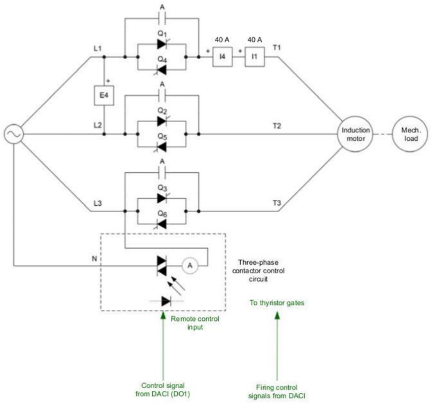
Topic Coverage (5 exercises)

- Generator Frequency and Voltage Control Principles
- Generator Synchronization Using a Synchro-Check Relay
- Generator Operation with Speed and Voltage Regulation
- Generator Speed and Voltage Regulation with Droop
- Generator Parallel Operation and Load Sharing (Optional)

Prerequisites

- DC Power Circuits
- Single-Phase AC Power Circuits
- Three-Phase AC Power Circuits
- Thyristor Power Electronics
- Three-Phase Rotating Machines

Three-Phase Induction Motor Starters (88197)


A
Q1
Q4
40 A
40 A
L1
T1
I4
I1
+
+
+
E4
A
Q2
Q5
L2
T2
Induction motor
Mech. load
A
Q3
Q6
L3
T3
N
A
Three-phase contactor control circuit
To thyristor gates
Remote control input
Control signal from DACI (DO1)
Firing control signals from DACI

The Three-phase Induction Motor Starters course is an introduction to direct on-line starters and soft starters. This course demonstrates the advantages and limitations of each type of starters. In particular, it shows how using a soft starter helps reducing inrush current and starting torque of induction motors.

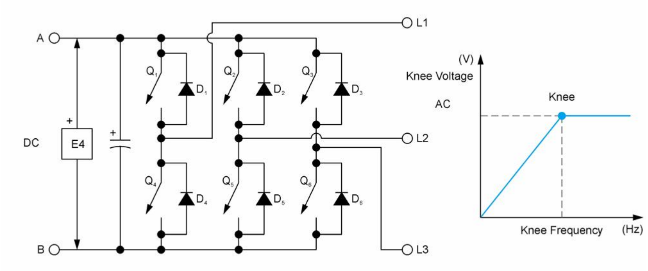
Topic Coverage (2 exercises)

- Motor Starters
- Advanced Soft Starters Features

Prerequisites

- DC Power Circuits
- Single-Phase AC Power Circuits
- Three-Phase AC Power Circuits
- Thyristor Power Electronics
- Three-Phase Rotating Machines

Three-Phase Motor Drives (86368)



The Three-Phase Motor Drives course teaches the fundamentals principles and operating characteristics of three-phase induction motor drives. The three-phase induction motor is rugged, requires little maintenance, and is low cost, making it attractive in numerous commercial and industrial applications. To control the rotational speed of an induction motor, a motor drive using variable frequency and voltage is necessary.

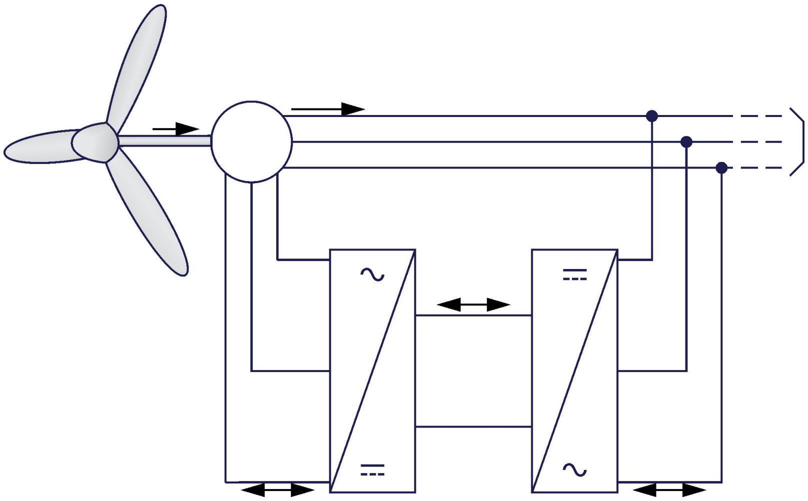
Topic Coverage (2 exercises)

- Three-Phase, Variable-Frequency Induction-Motor Drive
- Three-Phase, Variable-Frequency Induction-Motor Drive with Constant V/f ratio

Prerequisites

- DC Power Circuits
- DC Power Electronics
- Single-Phase AC Power Circuits
- Single-Phase AC Power Electronics
- Three-Phase AC Power Circuits
- Three-Phase AC Power Electronics
- Three-Phase Rotating Machines

Principles of Doubly-Fed Induction Generators (86376)



The Principles of Doubly-Fed Induction Generators (DFIG) course covers in detail the operation of the doubly-fed induction generator. This technology allows the generator to operate at different rotation speeds while keeping the frequency of the generated voltage and current fixed; a very useful feature when the generator is used in a wind turbine designed for large-scale production of electricity.

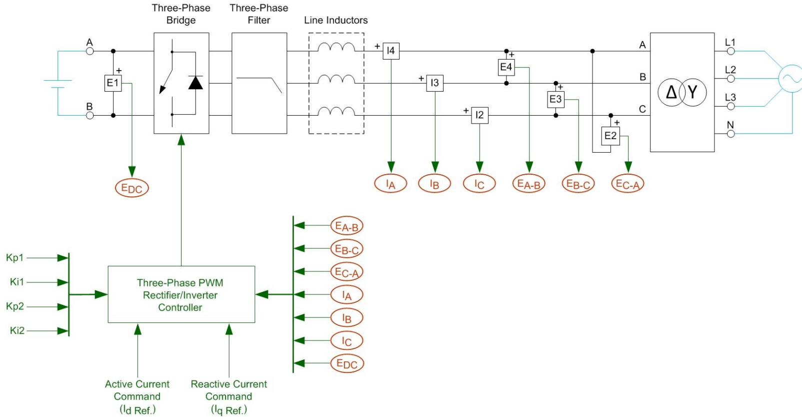
Topic Coverage (3 exercises)

- Three-Phase Wound-Rotor Induction Machine Used as a Synchronous Machine
- Doubly-Fed Induction Motors
- Doubly-Fed Induction Generators

Prerequisites

- DC Power Circuits
- DC Power Electronics
- Single-Phase AC Power Circuits
- Single-Phase AC Power Electronics
- Three-Phase AC Power Circuits
- Three-Phase AC Power Electronics
- Three-Phase Rotating Machines
- Three-Phase Motor Drives
- Three-Phase Wound-Rotor Induction Machine

Three-Phase PWM Rectifier/Inverter (86366)


Three-Phase Bridge
Three-Phase Filter
Line Inductors
A
B
C
E1
E2
E3
E4
I2
I3
I4
L1
L2
L3
N
Δ Y
EDC
IA
IB
IC
EA-B
EB-C
EC-A
Kp1
Ki1
Kp2
Ki2
Three-Phase PWM Rectifier/Inverter Controller
Active Current Command (Id Ref.)
Reactive Current Command (Iq Ref.)

The Three-Phase PWM Rectifier/Inverter course builds on the knowledge the student gained in previous power electronics courses and in the Home Energy Production course to deal with the operation and characteristics of the three-phase PWM rectifier/inverter (grid-tied inverter). The three-phase PWM rectifier/inverter is a key device in several applications such as the static synchronous compensator (STATCOM), large-scale production of electricity from solar power, permanent-magnet synchronous machine (PMSG) control, etc.

Topic Coverage (1 exercice)

- Operation of a Three-Phase PWM Rectifier/Inverter

Prerequisites

- DC Power Circuits
- DC Power Electronics
- Lead-Acid Batteries
- Solar Power (photovoltaic)
- Introduction to Wind Power
- Single-Phase AC Power Circuits
- Single-Phase AC Power Electronics
- Single-Phase Power Transformers
- Three-Phase AC Power Circuits
- Three-Phase AC Power Electronics
- High-Frequency Power Transformer
- Home Energy Production

BLDC Motors and Vector Control PMSM Drives (86373)

The BLDC Motor and Vector Control PMSM Drives course introduces the student to the permanent magnet synchronous machine (PMSM). This type of machine is used in a wide range of modern applications such as computers, household appliances, and electric vehicles. The course covers the operation and characteristics of two types of motor that use PMSM technology: the brushless dc (BLDC) motor and the PMSM drive. It also deals with the most common types of modulation used to implement BLDC motors (six-step 120° modulation and six-step PWM) and PMSM drives (vector control).

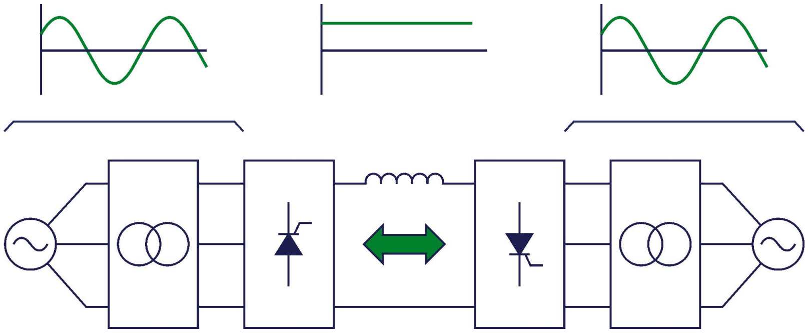
Topic Coverage (2 exercices)

- PMSM Control Using a Three-Phase, Six-Step 120° Modulation Inverter
- The BLDC Motor
- The Vector Control PMSM Drive

Prerequisites

- DC Power Circuits
- Lead-Acid Batteries
- Solar Power (photovoltaic)
- Introduction to Wind Power
- DC Power Electronics
- Single-Phase AC Power Circuits
- Single-Phase AC Power Electronics
- Single-Phase Power Transformers
- Three-Phase AC Power Circuits
- High-Frequency Power Transformers
- Three-Phase AC Power Electronics
- Three-Phase Rotating Machines
- Home Energy Production
- Three-Phase PWM Rectifier/Inverter
- Three-Phase Motor Drives

High-Voltage DC Transmission Systems (86380)



The High-Voltage Direct-Current (HVDC) Transmission Systems course deals with the operating characteristics of this type of power transmission system and the technology involved. HVDC transmission systems are used at several nodes of the grid to improve the flexibility and efficiency of electric power transmission, and thus, are important tools in building a smart grid. Typical applications of HVDC transmission systems are long-distance power transmission, underwater power transmission (submarine link), back-to-back link for easy interconnection of two independent ac power networks, etc.

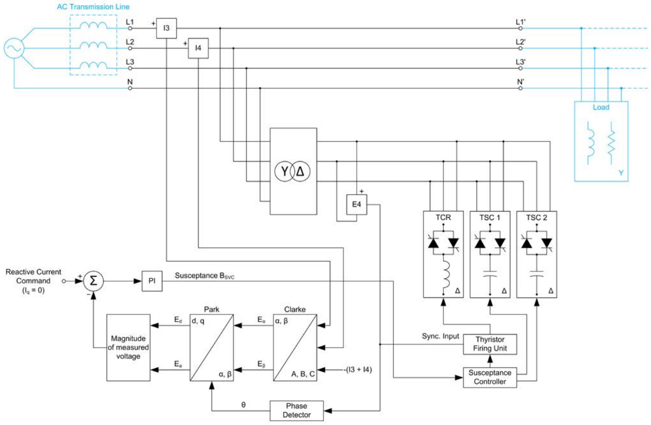
Topic Coverage (5 exercises)

- Voltage Regulation and Displacement Power Factor (DPF) in Thyristor Three-Phase Bridges
- Basic Operation of HVDC Transmission Systems
- DC Current Regulation and Power Flow Control in HVDC Transmission Systems
- Commutation Failure at the Inverter Bridge
- Harmonic Reduction using Thyristor 12-Pulse Converters

Prerequisites

- DC Power Circuits
- Single-Phase AC Power Circuits
- Single-Phase Power Transformers
- Three-Phase AC Power Circuits
- Thyristor Power Electronics
- Three-Phase Transformer Banks
- AC Transmission Lines

Static Var Compensator (86370)


AC Transmission Line
L1
L2
L3
N
I3
I4
L1'
L2'
L3'
N'
Load
Y
Y Δ
E4
TCR
TSC 1
TSC 2
Δ
Reactive Current Command ($I_q = 0$)
Σ
PI
Susceptance B_{SVC}
Park
Clarke
E_d
E_q
E_α
E_β
d, q
α, β
A, B, C
Magnitude of measured voltage
-(I3 + I4)
Sync. Input
Thyristor Firing Unit
Susceptance Controller
θ
Phase Detector

The Static Var Compensator (SVC) course deals with the operation of the SVC (i.e., thyristor-controlled reactor, thyristor-switched capacitors, and SVC controller) as well as with the automatic control of the voltage or the power factor in three-phase ac power systems. As part of the FACTS (Flexible AC Transmission Systems), the SVC technology is used by power utilities to maintain voltage quality for the distribution system as well as by industrial plants for dynamic power factor correction at their electric power entrance.

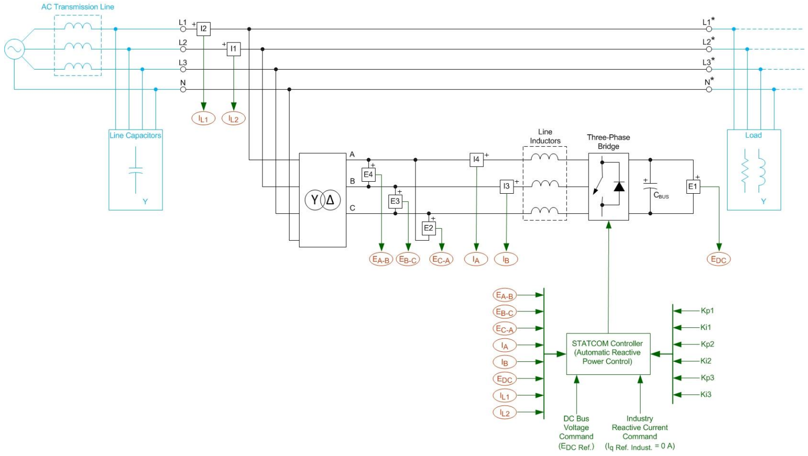
Topic Coverage (3 exercises)

- Main Components of a Static Var Compensator (SVC)
- Voltage Compensation of AC Transmission Lines using an SVC
- Dynamic Power Factor Correction Using an SVC

Prerequisites

- DC Power Circuits
- Single-Phase AC Power Circuits
- Single-Phase Power Transformers
- Three-Phase AC Power Circuits
- Thyristor Power Electronics
- Three-Phase Transformer Banks
- AC Transmission Lines

Static Synchronous Compensator (STATCOM) (86371)


AC Transmission Line
L1
L2
L3
N
I2
I1
IL1
IL2
Line Capacitors
Y
A
B
C
E4
E3
E2
I4
I3
Line Inductors
Three-Phase Bridge
CBUS
E1
L1*
L2*
L3*
N*
Load
Y
EA-B
EB-C
EC-A
IA
IB
EDC
STATCOM Controller (Automatic Reactive Power Control)
Kp1
Ki1
Kp2
Ki2
Kp3
Ki3
DC Bus Voltage Command (EDC Ref.)
Industry Reactive Current Command (Iq Ref. Indust. = 0 A)

This course deals with the static synchronous compensator (STATCOM), which mainly consists of a three-phase PWM rectifier/inverter that is used to exchange reactive power, and even active power, with the ac power network. This type of compensator, which is part of the FACTS (Flexible AC Transmission Systems), provides fast and accurate reactive power compensation in three-phase ac power systems. The STATCOM technology is used by power utilities to maintain voltage quality for the distribution system as well as by industrial plants for dynamic power factor correction at their electric power entrance.

Topic Coverage (2 exercises)

- Voltage compensation of AC transmission lines using a STATCOM
- Dynamic Power Factor Correction Using a STATCOM

Prerequisites

- DC Power Circuits
- Lead-Acid Batteries
- Solar Power (photovoltaic)
- Introduction to Wind Power
- DC Power Electronics
- Single-Phase AC Power Circuits
- Single-Phase AC Power Electronics
- Single-Phase Power Transformers
- High-Frequency Power Transformers
- Three-Phase AC Power Circuits
- Three-Phase Transformer Banks
- Home Energy Production
- Three-Phase PWM Rectifier/Inverter
- AC Transmission Lines

Introduction to Electric Power Substations (20528)

The Introduction to Electric Power Substations course introduces students to the operation of electric power substations. It begins by covering the main components of substations: buses, circuit breakers, and disconnecting switches. The course then fully describes and presents both advantages and disadvantages of two switching schemes commonly implemented in substations: the single-bus scheme and the double-bus, single-breaker scheme.

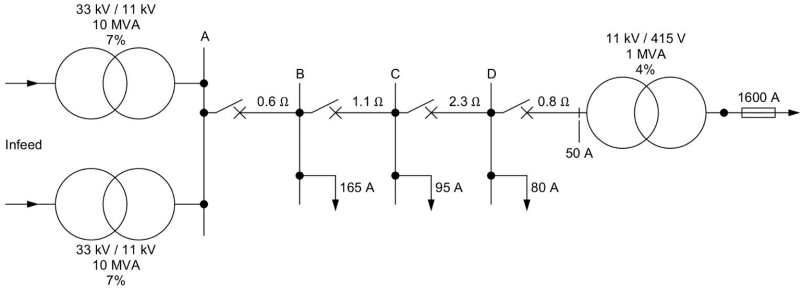
Topic Coverage (3 exercises)

- Circuit Breakers and Disconnecting Switches
- Single-Bus Switching Scheme
- Double-Bus, Single-Breaker Switching Scheme

Prerequisites

- DC Power Circuits
- Single-Phase AC Power Circuits
- Single-Phase Power Transformers
- Three-Phase AC Power Circuits
- Three-Phase Transformer Banks

Overcurrent and Overload Protection Using Protective Relays (52173)



The Overcurrent and Overload Protection Using Protective Relays course introduces students to the operation and settings of the instantaneous (ANSI device no. 50), definite-time (ANSI device no. 51DT), and inverse definite minimum time (ANSI device no. 51I) overcurrent relays. Students learn how to adjust the settings of an overcurrent relay to obtain a specific time-current characteristic, and explore applications where it is common to use overcurrent relays and high-voltage circuit breakers in conjunction to achieve overcurrent protection of electrical equipment. Among other things, a complete exercise is devoted to overcurrent protection of radial feeders, with emphasis on how to achieve proper discrimination through coordination of the overcurrent relay operation.

Students are also introduced to the operation and settings of the machine or transformer thermal relay (ANSI device no. 49) of the temperature sensor type and the thermal replica type. They learn how to combine protection functions in a numerical protective relay to achieve overcurrent and overload protection of an ac machine or a power transformer. Finally, students learn how to use the internal relay test system of a numerical protective relay to assess that the relay operates as expected.

Topic Coverage (3 exercises)

- Overcurrent Protection
- Overcurrent and Overload Protection of AC Machines and Power Transformers
- Overcurrent Protection of Radial Feeders

Prerequisites

- DC Power Circuits
- Single-Phase AC Power Circuits
- Single-Phase Power Transformers
- Three-Phase AC Power Circuits
- Three-Phase Transformer Banks

Directional Protection (52174)

The Directional Protection course introduces students to the operation and settings of the directional overcurrent relay (ANSI device no. 67). Students learn about directional overcurrent protection and directional comparison protection, two ways to protect power lines connected in parallel or multiple power lines forming a ring bus. They also learn how directional comparison protection uses a communication link between two directional overcurrent relays to implement a blocking scheme that allows fast clearing of faults.

Students are then introduced to the operation and settings of the directional power relay (ANSI device no. 32). They learn how directional power protection can be used to implement motoring protection, a protection that prevents damage to the prime mover of a synchronous generator when it stops driving the generator. They also learn how directional power protection can be used to implement loss-of-excitation protection, a protection that prevents damage to a synchronous generator resulting from sustained operation as an asynchronous generator following a loss of excitation.

Topic Coverage (3 exercises)

- Directional Overcurrent Protection
- Directional Comparison Protection
- Directional Power Protection

Prerequisites

- DC Power Circuits
- Single-Phase AC Power Circuits
- Single-Phase Power Transformers
- Three-Phase AC Power Circuits
- Three-Phase Transformer Banks
- Overcurrent and Overload Protection Using Protective Relays

List of Available Training Systems

Qty	Description	Model number
1	DC and AC Power Circuits Training System	579281 (8010-10)
1	Solar Power Training System	579284 (8010-20)
1	Small-Scale Wind Power Electricity Generation Training System	579287 (8010-30)
1	Lead-Acid Batteries Training System	579290 (8010-40)
1	Basic Renewable Energy Training System	579294 (8010-50)
1	DC Power Electronics Training System	579298 (8010-60)
1	Home Energy Production Training System	579301 (8010-70)

Qty	Description	Model number
1	Hydrogen Fuel Cell Training System	579307 (8010-80)
1	Electromechanical Training System	579308 (8010-90)
1	Power Electronics Training System	579314 (8010-A0)
1	AC Power Transmission Training System	579320 (8010-B0)
1	Smart Grid Technologies Training System	579325 (8010-C0)
1	DFIG Principles Training System	579328 (8010-D0)
1	Power Transmission Smart Grid Technologies Training System	579331 (8010-E0)
1	Smart Grid Training System	8117310 (8010-F0)
1	Electric Power Generation Training System	8108668 (8010-G0)
1	BLDC Motors and Vector Control PMSM Drives Training System	8108674 (8010-J0)
1	Electric Power Substations Training System	8108677 (8010-K0)
1	Numerical Protective Relays Training System	8108680 (8010-L0)

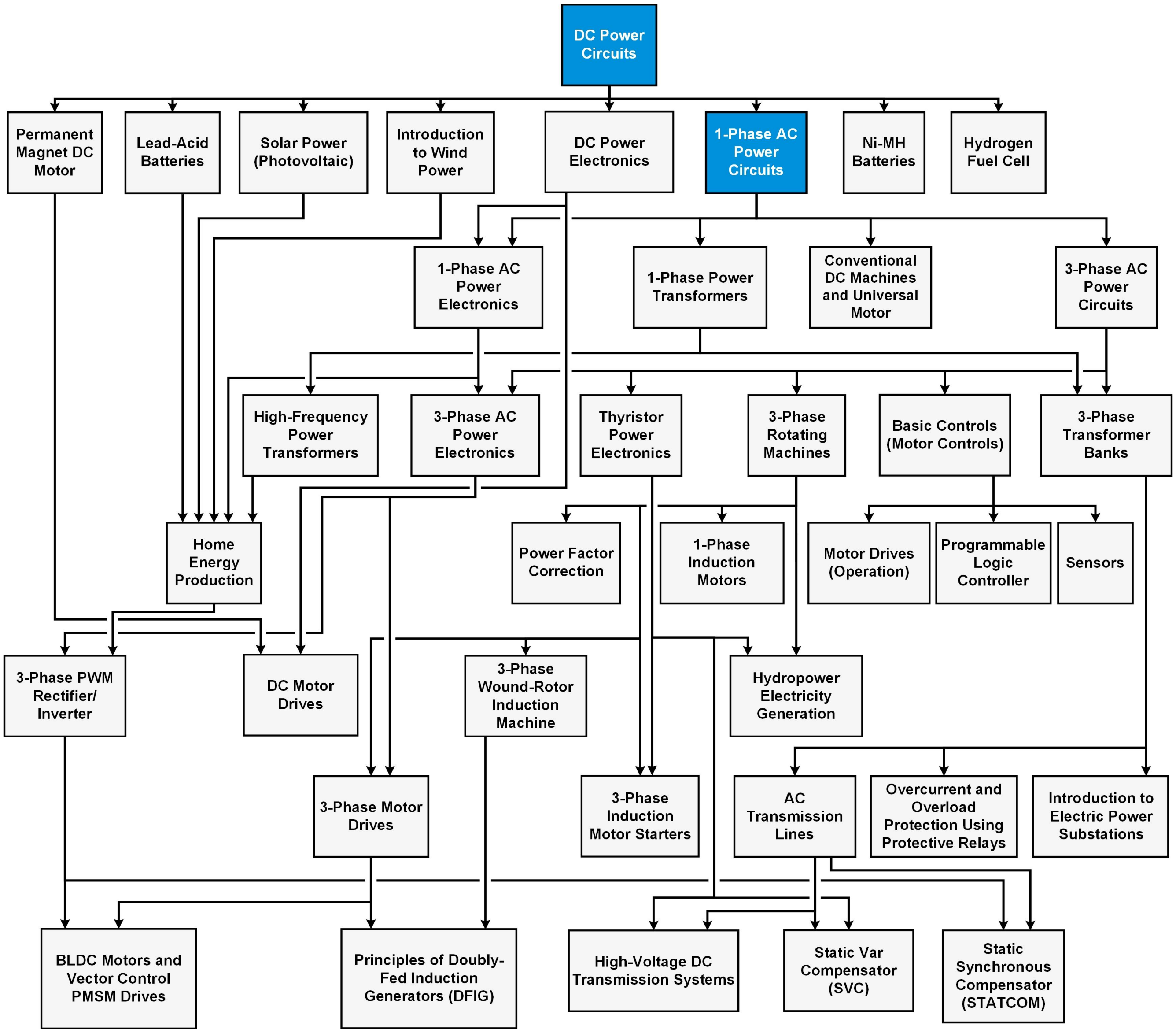
Available Training Systems

DC and AC Power Circuits Training System
579281 (8010-10)

The DC and AC Power Circuits Training System combines a modular design approach with computer-based data acquisition and control to introduce students to the fundamentals of electricity, such as direct current (dc), alternating current (ac), voltage, resistance, and Ohm's Law. The training system is designed to operate at a low voltage to ensure the safety of students beginning their training in electric power technology.

The DC and AC Power Circuits Training System is part of the Electric Power Technology Training Systems, Series 8010. Each training system in Series 8010 is based on the Electric Power Technology Training Program and provides a turn-key solution dealing with some aspects of the wide field of electrical energy. The exhaustive courseware provided with each training system covers all the theory required to perform the laboratory exercises, while review questions and unit tests allow students to test the knowledge they have gained.

The Electric Power Technology Training Program is highly modular in both courseware and hardware. Because of this, courses and equipment from the program are available as required, either individually or in the context of a specific training system. The program covers several different subjects in the field of electrical energy, such as rotating machines, electrical power transmission, power electronics, home energy production from renewable resources (wind and sunlight), large-scale electricity production from hydropower and wind power, smart-grid technologies (SVC, STATCOM, HVDC transmission, etc.), storage of electrical energy in batteries, and drive systems for small electric vehicles and cars.


DC Power Circuits
Permanent Magnet DC Motor
Lead-Acid Batteries
Solar Power (Photovoltaic)
Introduction to Wind Power
DC Power Electronics
1-Phase AC Power Circuits
Ni-MH Batteries
Hydrogen Fuel Cell
1-Phase AC Power Electronics
1-Phase Power Transformers
Conventional DC Machines and Universal Motor
3-Phase AC Power Circuits
High-Frequency Power Transformers
3-Phase AC Power Electronics
Thyristor Power Electronics
3-Phase Rotating Machines
Basic Controls (Motor Controls)
3-Phase Transformer Banks
Home Energy Production
Power Factor Correction
1-Phase Induction Motors
Motor Drives (Operation)
Programmable Logic Controller
Sensors
3-Phase PWM Rectifier/ Inverter
DC Motor Drives
3-Phase Wound-Rotor Induction Machine
Hydropower Electricity Generation
3-Phase Motor Drives
3-Phase Induction Motor Starters
AC Transmission Lines
Overcurrent and Overload Protection Using Protective Relays
Introduction to Electric Power Substations
BLDC Motors and Vector Control PMSM Drives
Principles of Doubly-Fed Induction Generators (DFIG)
High-Voltage DC Transmission Systems
Static Var Compensator (SVC)
Static Synchronous Compensator (STATCOM)

The above chart shows all courses in the Electric Power Technology Training Program. Blue boxes highlight courses included in the training system covered in this datasheet, while dark grey boxes, if any, highlight courses that can be optionally added to this training system.

Courseware

Each course in the training system includes a full-color student manual providing all the theoretical matter required, guided lab-exercise procedures to be performed with the training equipment, and review questions that test the knowledge gained by the student. Whenever possible, each course is built to bring the student to actual applications as soon as possible. A full-color instructor guide providing all lab results and answers to questions is also included with each course.

Modular Approach

The modular approach for designing the training program and lab equipment enables instructors to start building their electrical-energy laboratory with a basic package of courses and equipment and add new courses and equipment over time without needless duplication of equipment.

All lab equipment consists of modules that can be inserted into a workstation. Module dimensions vary between two standard EMS sizes: full-size and half-size. Symbols and diagrams representing the electrical components in each module are clearly silk-screened on the front panel. Standard, color-coded safety banana jacks are used to provide access to the various components in each module.

elearning Formats

The courseware is also available in three eLearning formats for users preferring a computer-based approach:

- Model 21001- E: eSeries format, facilitated by the Mind-Sight eLearning system.
- Model 21001-F: SCORM-based format, designed to be hosted by a third-party, SCORM 1.2 compliant management system.
- Model 21001-G: Stand-alone format, available on CD-ROM. This format runs on a web browser and does not require any management system.

Please refer to our website at www.labvolt.com for more information about the Mind-Sight, SCORM, and Stand-Alone eLearning formats.

Features & Benefits

- The training system teaches simply and effectively the basic principles of electrical power for both direct current (dc) and alternating current (ac).
- The course curriculum of the Electric Power Technology Training Program is highly flexible and allows a multitude of different customized training solutions.
- The courseware includes student manuals and instructor guides with all the theory required to perform the hands-on experiments.
- All workstations, modules, and components are very sturdy to ensure a prolonged service life in a demanding environment such as a training laboratory.
- The modular design approach of the training equipment allows a large variety of courses to be performed using a small number of modules, without unnecessary duplication of equipment.
- All electrical components can be interconnected without electric shock hazard since all live parts of the connection leads are concealed and insulated.
- All electrical symbols representing the components used in a laboratory exercise are clearly silk-screened on the front panel of the modules.
- The training system includes two highly versatile USB peripherals:
  - Four-Quadrant Dynamometer/Power Supply, Model 8960-2. This module is used as a dc and ac power source.
  - Data Acquisition and Control Interface, Model 9063. This module gives access to a large variety of computer-based measuring instruments via the LVDAC-EMS software.
- Software upgrades for LVDAC-EMS and firmware upgrades for the Four-Quadrant Dynamometer/Power Supply and Data Acquisition and Control Interface are available for download free of charge on the Festo Didactic website.

List of Equipment

Qty	Description	Model number
1	DC Power Circuits (Student Manual)	579339 (86350-00)
1	DC Power Circuits (Instructor Guide)	579341 (86350-10)
1	Single-Phase AC Power Circuits (Student Manual)	579366 (86358-00)
1	Single-Phase AC Power Circuits (Instructor Guide)	579368 (86358-10)
1	Three-Module Workstation	579483 (8131-00)
1	Resistive Load	763359 (8311-00)
1	Inductive Load	763362 (8321-00)
1	Capacitive Load	763366 (8331-00)
1	Connection Lead Set	579638 (8951-L0)
1	Four-Quadrant Dynamometer / Power Supply with Manual and Computer-Based Control	579648 (8960-C0)
1	Data Acquisition and Control Interface	579680 (9063-B0)
1	AC 24 V Wall Mount Power Supply	579696 (30004-20)

List of Manuals

Description	Manual number
DC Power Circuits (Workbook)	579339 (86350-00)
DC Power Circuits (Workbook (Instructor))	579341 (86350-10)
Single-Phase AC Power Circuits (Workbook)	579366 (86358-00)
Single-Phase AC Power Circuits (Workbook (Instructor))	579368 (86358-10)
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)

Table of Contents of the Manual(s)

DC Power Circuits (Workbook) (579339 (86350-00))

- 1 Voltage, Current, and Ohm’s Law
- 2 Equivalent Resistance
- 3 Power in DC Circuits
- 4 Series and Parallel Circuits

Single-Phase AC Power Circuits (Workbook) (579366 (86358-00))

- 1-1 The Sine Wave
- 1-2 Phase Angle and Phase Shift
- 1-3 Instantaneous Power and Average Power
- 2-1 Inductive Reactance
- 2-2 Capacitive reactance

- 2-3 Impedance
- 3-1 Active and Reactive Power
- 3-2 Apparent Power and the Power Triangle
- 4-1 Solving Simple AC Circuits Using Circuit Impedance Calculation
- 4-2 Solving AC Circuits Using the Power Triangle Method

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

- 1 General Safety Recommendations
- 2 System Power Requirements
- 3 Quick Start Installation Guide
- 4 Equipment Installation
- 5 Modules Handling, Installation, and Removal
- 6 Equipment Maintenance
- A Connection of the Power Supply to the AC Power Network
- B Description, Specifications, and Operation of the EMS Modules

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Digital Multimeter	579782 (8946-20) [1]

Software

Qty	Description	Model number
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 1 User Online, 1 year	586971 (8972-00) [2]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 5 Users Online, 1 year	586974 (8972-A0) [3]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 10 Users Online, 1 year	586977 (8972-B0) [4]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 15 Users Online, 1 year	586980 (8972-C0) [5]

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[1] The data acquisition already includes this function and many more, but the DC Circuits manual references using multimeters.

[2] Simulation software that covers these topics as well as transformers, motors, generators and transmission lines.

[3] Simulation software that covers these topics as well as transformers, motors, generators and transmission lines.

[4] Simulation software that covers these topics as well as transformers, motors, generators and transmission lines.

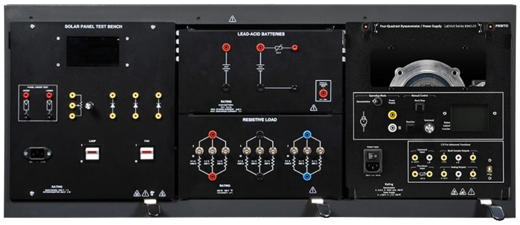
[5] Simulation software that covers these topics as well as transformers, motors, generators and transmission lines.

Qty	Description	Model number
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 20 Users Online, 1 year	586983 (8972-D0) [6]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 25 Users Online, 1 year	586986 (8972-E0) [7]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 30 Users Online, 1 year	586989 (8972-F0) [8]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 35 Users Online, 1 year	586992 (8972-G0) [9]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 40 Users Online, 1 year	586995 (8972-H0) [10]

System Specifications

Parameter	Value
Power Requirements	
Service Installation	A standard single-phase ac outlet
Computer Requirements	A currently available personal computer with USB 2.0 ports, running under one of the following operating systems: Windows® 7 or Windows® 8.
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment
Dimensions (H x W x D)	900 x 930 x 530 mm (35.4 x 36.6 x 20.9 in)
Net Weight	TBE
EMS Modules	
Full-Size Dimensions (H x W x D)	308 x 287 x 440 mm (12.1 x 11.3 x 17.3 in)
Half-Size Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)

Solar Power Training System
579284 (8010-20)



The Solar Power Training System uses a modular design approach to introduce students to the production of electrical energy from solar power, with emphasis on the use and operation of photovoltaic panels. The Solar Power Training System mainly consists of a solar panel test bench and a monocrystalline silicon solar panel. By installing the solar panel in the solar panel test bench, students can conduct several indoor experiments on solar panel operation and performance using the artificial light source of the test bench. Students can also install the solar panel on a tripod to perform outdoor experiments using sunlight.

The Solar Power Training System is part of the Electric Power Technology Training Systems, Series 8010. Each training system in Series 8010 is based on the Electric Power Technology Training Program and provides a turn-key solution dealing with some aspects of the wide field of electrical energy. The exhaustive courseware provided with each training system covers all the theory required to perform the laboratory exercises, while review questions and unit tests allow students to test the knowledge they have gained.

The Electric Power Technology Training Program is highly modular in both courseware and hardware. Because of this, courses and equipment from the program are available as required, either individually or in the context of a specific training system. The program covers several different subjects in the field of electrical energy, such as rotating machines, electrical power transmission, power electronics, home energy production from renewable resources (wind and sunlight), large-scale electricity production from hydropower and wind power, smart-grid technologies (SVC, STATCOM, HVDC transmission, etc.), storage of electrical energy in batteries, and drive systems for small electric vehicles and cars.

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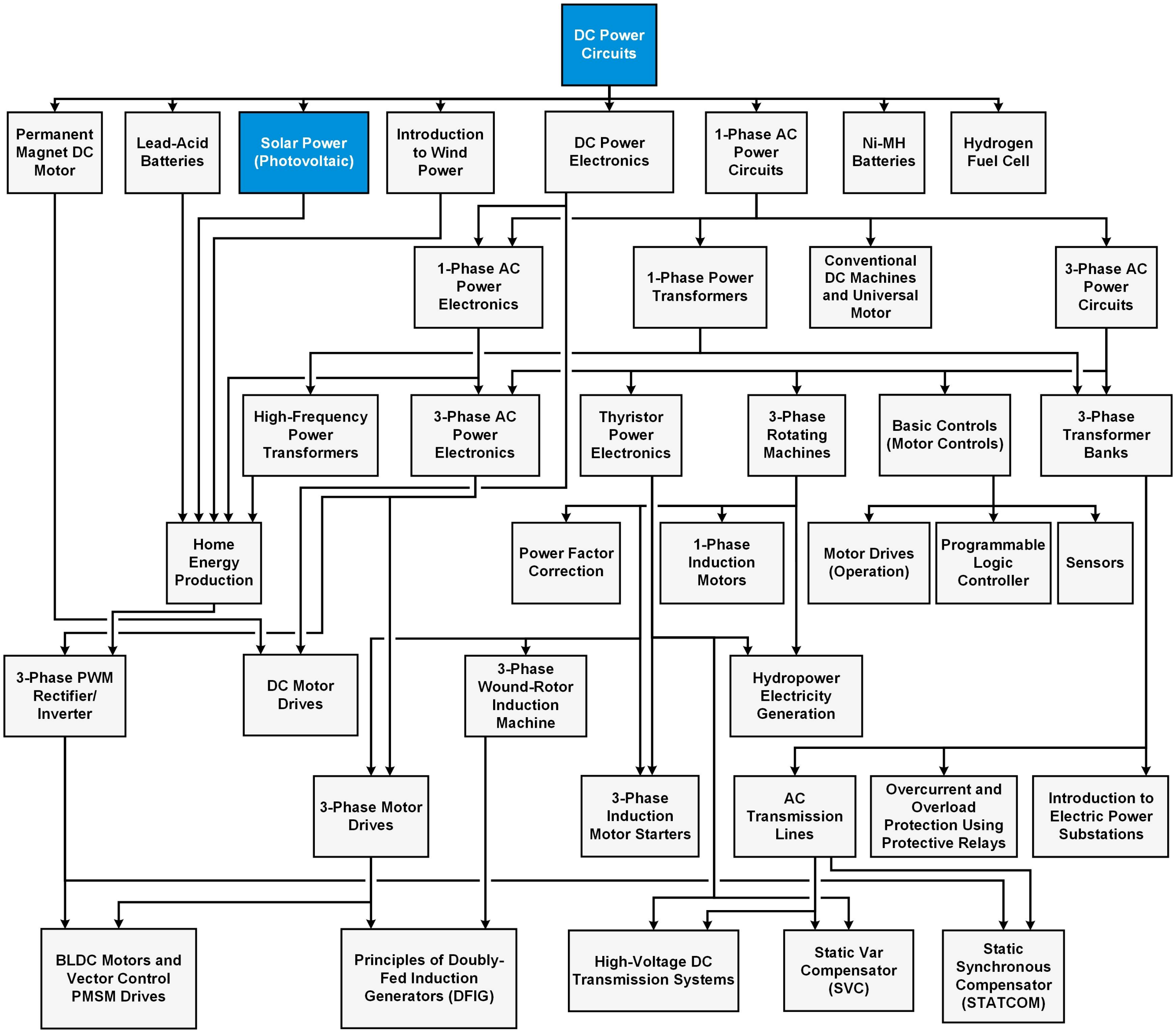
[6] Simulation software that covers these topics as well as transformers, motors, generators and transmission lines.

[7] Simulation software that covers these topics as well as transformers, motors, generators and transmission lines.

[8] Simulation software that covers these topics as well as transformers, motors, generators and transmission lines.

[9] Simulation software that covers these topics as well as transformers, motors, generators and transmission lines.

[10] Simulation software that covers these topics as well as transformers, motors, generators and transmission lines.


DC Power Circuits
Permanent Magnet DC Motor
Lead-Acid Batteries
Solar Power (Photovoltaic)
Introduction to Wind Power
DC Power Electronics
1-Phase AC Power Circuits
Ni-MH Batteries
Hydrogen Fuel Cell
1-Phase AC Power Electronics
1-Phase Power Transformers
Conventional DC Machines and Universal Motor
3-Phase AC Power Circuits
High-Frequency Power Transformers
3-Phase AC Power Electronics
Thyristor Power Electronics
3-Phase Rotating Machines
Basic Controls (Motor Controls)
3-Phase Transformer Banks
Home Energy Production
Power Factor Correction
1-Phase Induction Motors
Motor Drives (Operation)
Programmable Logic Controller
Sensors
3-Phase PWM Rectifier/ Inverter
DC Motor Drives
3-Phase Wound-Rotor Induction Machine
Hydropower Electricity Generation
3-Phase Motor Drives
3-Phase Induction Motor Starters
AC Transmission Lines
Overcurrent and Overload Protection Using Protective Relays
Introduction to Electric Power Substations
BLDC Motors and Vector Control PMSM Drives
Principles of Doubly-Fed Induction Generators (DFIG)
High-Voltage DC Transmission Systems
Static Var Compensator (SVC)
Static Synchronous Compensator (STATCOM)

The above chart shows all courses in the Electric Power Technology Training Program. Blue boxes highlight courses included in the training system covered in this datasheet, while dark grey boxes, if any, highlight courses that can be optionally added to this training system.

Courseware

Each course in the training system includes a full-color student manual providing all the theoretical matter required, guided lab-exercise procedures to be performed with the training equipment, and review questions that test the knowledge gained by the student. Whenever possible, each course is built to bring the student to actual applications as soon as possible. A full-color instructor guide providing all lab results and answers to questions is also included with each course.

Modular Design Approach

The modular approach for designing the training program and lab equipment enables instructors to start building their electrical-energy laboratory with a basic package of courses and equipment and add new courses and equipment over time without needless duplication of equipment.

All lab equipment consists of modules that can be inserted into a workstation. Module dimensions vary between two standard EMS sizes: full-size and half-size. Symbols and diagrams representing the electrical components in each module are clearly silk-screened on the front panel. Standard, color-coded safety banana jacks are used to provide access to the various components in each module.

Features & Benefits

- The training system allows easy experimentation with the operation of solar panels and the storage of electrical energy in batteries.
- Solar panel experiments can be performed both indoors, using the solar panel test bench as light source, or outdoors, using sunlight.
- The course curriculum of the Electric Power Technology Training Program is highly flexible and allows a multitude of different customized training solutions.
- The courseware includes student manuals and instructor guides with all the theory required to perform the hands-on experiments.
- All workstations, modules, and components are very sturdy to ensure a prolonged service life in a demanding environment such as a training laboratory.
- The modular design approach of the training equipment allows a large variety of courses to be performed using a small number of modules, without unnecessary duplication of equipment.
- All electrical components can be interconnected without electric shock hazard since all live parts of the connection leads are concealed and insulated.
- All electrical symbols representing the components used in a laboratory exercise are clearly silk-screened on the front panel of the modules.

List of Equipment

Qty	Description	Model number
1	DC Power Circuits (Student Manual)	579339 (86350-00)
1	DC Power Circuits (Instructor Guide)	579341 (86350-10)
1	Solar Power (Student Manual)	579347 (86352-00)
1	Solar Power (Instructor Guide)	579349 (86352-10)
1	Three-Module Workstation	579483 (8131-00)
1	Resistive Load	763359 (8311-00)
1	Lead-Acid Batteries	763374 (8801-00)

Qty	Description	Model number
1	Solar Panel Test Bench	579594 (8805-00)
1	Monocrystalline Silicon Solar Panel	579600 (8806-00)
1	Connection Lead Set	579638 (8951-L0)
1	Four-Quadrant Dynamometer/Power Supply with manual control	579641 (8960-B0)

List of Manuals

Description	Manual number
DC Power Circuits (Workbook)	579339 (86350-00)
DC Power Circuits (Workbook (Instructor))	579341 (86350-10)
Solar Power (Workbook)	579347 (86352-00)
Solar Power (Workbook (Instructor))	579349 (86352-10)
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)

Table of Contents of the Manual(s)

DC Power Circuits (Workbook) (579339 (86350-00))

- 1 Voltage, Current, and Ohm's Law
- 2 Equivalent Resistance
- 3 Power in DC Circuits
- 4 Series and Parallel Circuits

Solar Power (Workbook) (579347 (86352-00))

- 1 The Diode
- 2 The Solar Panel (Photovoltaic Panel)
- 3 Effect of Temperature on Solar Panel Performance
- 4 Storing Energy from Solar Panels into Batteries
- 5 Effect of Shading on Solar Panel Operation
- 6 Solar Panel Orientation
- 7 Solar Panel Performance Versus Insolation

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

- 1 General Safety Recommendations
- 2 System Power Requirements
- 3 Quick Start Installation Guide
- 4 Equipment Installation
- 5 Modules Handling, Installation, and Removal
- 6 Equipment Maintenance
- A Connection of the Power Supply to the AC Power Network
- B Description, Specifications, and Operation of the EMS Modules

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Digital Multimeter	579782 (8946-20) [11]
1	Pyranometer	579784 (8989-00)
1	Heavy-Duty Tripod	583216 (40208-10)

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[11] The data acquisition already includes this function and many more, but the DC Circuits manual references using multimeters.

System Specifications

Parameter	Value
Power Requirements	
Service Installation	A standard single-phase ac outlet
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment
Dimensions (H x W x D)	900 x 930 x 530 mm (35.4 x 36.6 x 20.9 in)
Net Weight	TBE
EMS Modules	
Full-Size Dimensions (H x W x D)	308 x 287 x 440 mm (12.1 x 11.3 x 17.3 in)
Half-Size Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)

Small-Scale Wind Power Electricity Generation Training System
579287 (8010-30)

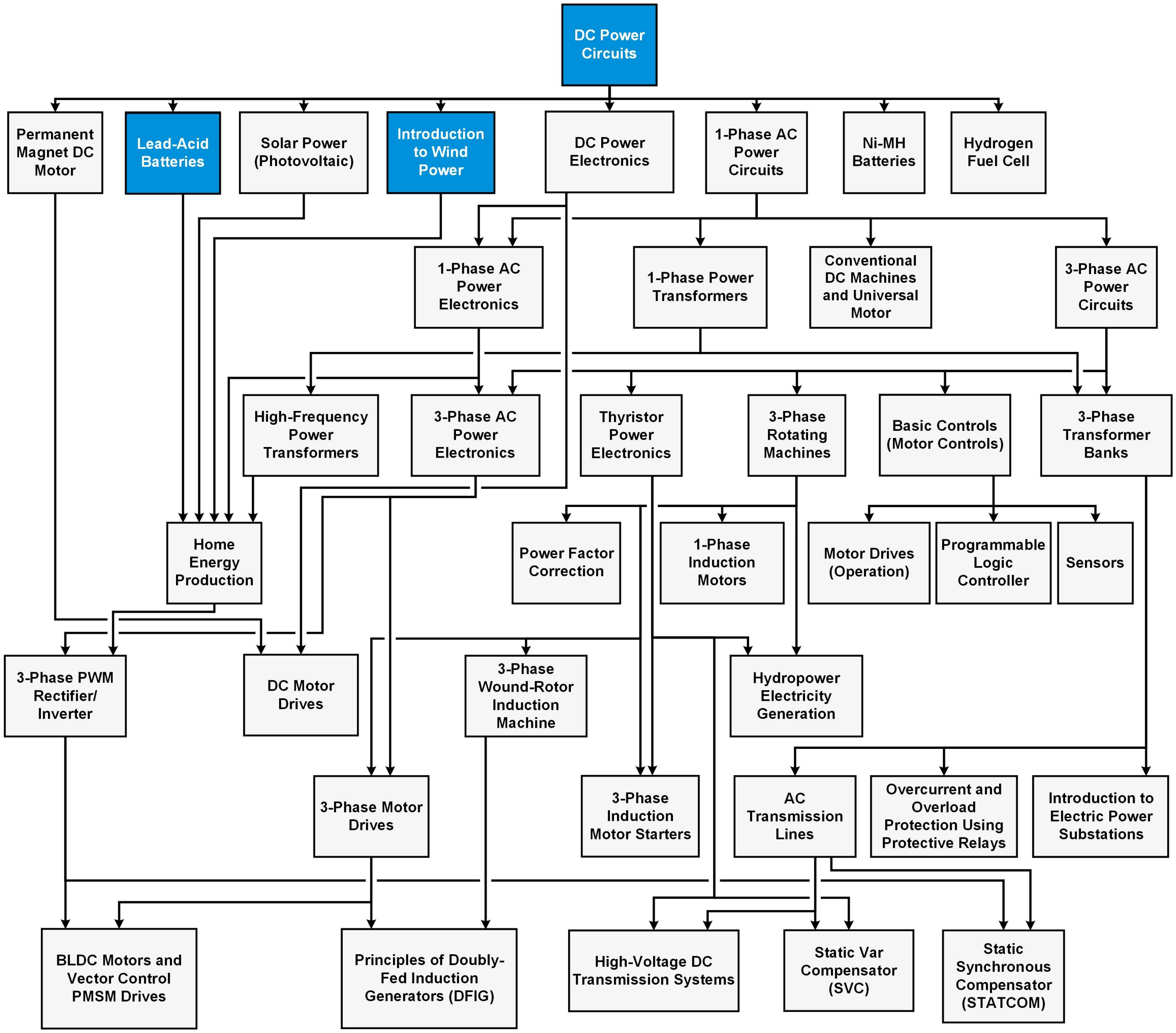
FOUR-QUADRANT DYNAMOMETER / POWER SUPPLY
WIND TURBINE GENERATOR / CONTROLLER
LEAD-ACID BATTERY PACK
RESISTIVE LOAD

The Small-Scale Wind Power Electricity Generation Training System enables students to study the complete process of wind power electricity generation directly in the classroom. The training system also covers the storage of electrical energy in batteries to ensure that it is available when there is no wind or during low wind periods.

The training system features the Wind Turbine Generator/ Controller, Model 8216, and the Four-Quadrant Dynamometer/Power Supply, Model 8960-2. The Four-Quadrant Dynamometer/Power Supply is used as a prime mover in order to drive the wind turbine generator. By varying the rotation speed of the prime mover and the current through the generator windings, students can measure the generator parameters for different speeds and load values. The prime mover is also used to emulate wind blowing on the blades of a wind turbine rotor. In this mode of operation, the prime mover's torque-speed characteristic is identical to the torque-speed characteristic that would be obtained at the wind turbine rotor for different wind speeds. This allows students to plot the typical curves of the wind turbine. Finally, the wind turbine controller can be used to adjust the charge current of a storage battery in order to maximize the amount of energy stored in the battery at any wind speed.

The Small-Scale Wind Power Electricity Generation Training System is part of the Electric Power Technology Training Systems, Series 8010. Each training system in Series 8010 is based on the Electric Power Technology Training Program and provides a turn-key solution dealing with some aspects of the wide field of electrical energy. The exhaustive courseware provided with each training system covers all the theory required to perform the laboratory exercises, while review questions and unit tests allow students to test the knowledge they have gained.

The Electric Power Technology Training Program is highly modular in both courseware and hardware. Because of this, courses and equipment from the program are available as required, either individually or in the context of a specific training system. The program covers several different subjects in the field of electrical energy, such as rotating machines, electrical power transmission, power electronics, home energy production from renewable resources (wind and sunlight), large-scale electricity production from hydropower and wind power, smart-grid technologies (SVC, STATCOM, HVDC transmission, etc.), storage of electrical energy in batteries, and drive systems for small electric vehicles and cars.


DC Power Circuits
Permanent Magnet DC Motor
Lead-Acid Batteries
Solar Power (Photovoltaic)
Introduction to Wind Power
DC Power Electronics
1-Phase AC Power Circuits
Ni-MH Batteries
Hydrogen Fuel Cell
1-Phase AC Power Electronics
1-Phase Power Transformers
Conventional DC Machines and Universal Motor
3-Phase AC Power Circuits
High-Frequency Power Transformers
3-Phase AC Power Electronics
Thyristor Power Electronics
3-Phase Rotating Machines
Basic Controls (Motor Controls)
3-Phase Transformer Banks
Home Energy Production
Power Factor Correction
1-Phase Induction Motors
Motor Drives (Operation)
Programmable Logic Controller
Sensors
3-Phase PWM Rectifier/ Inverter
DC Motor Drives
3-Phase Wound-Rotor Induction Machine
Hydropower Electricity Generation
3-Phase Motor Drives
3-Phase Induction Motor Starters
AC Transmission Lines
Overcurrent and Overload Protection Using Protective Relays
Introduction to Electric Power Substations
BLDC Motors and Vector Control PMSM Drives
Principles of Doubly-Fed Induction Generators (DFIG)
High-Voltage DC Transmission Systems
Static Var Compensator (SVC)
Static Synchronous Compensator (STATCOM)

The above chart shows all courses in the Electric Power Technology Training Program. Blue boxes highlight courses included in the training system covered in this datasheet, while dark grey boxes, if any, highlight courses that can be optionally added to this training system.

Courseware

Each course in the training system includes a full-color student manual providing all the theoretical matter required, guided lab-exercise procedures to be performed with the training equipment, and review questions that test the knowledge gained by the student. Whenever possible, each course is built to bring the student to actual applications as soon as possible. A full-color instructor guide providing all lab results and answers to questions is also included with each course.

Modular Design Approach

The modular approach for designing the training program and lab equipment enables instructors to start building their electrical-energy laboratory with a basic package of courses and equipment and add new courses and equipment over time without needless duplication of equipment.

All lab equipment consists of modules that can be inserted into a workstation. Module dimensions vary between two standard EMS sizes: full-size and half-size. Symbols and diagrams representing the electrical components in each module are clearly silk-screened on the front panel. Standard, color-coded safety banana jacks are used to provide access to the various components in each module.

Features & Benefits

- The training system teaches the basic principles of wind power electricity generation directly in the laboratory.
- Wind speed and air density are simulated in the training system using a user-friendly and highly-configurable wind emulator.
- All main components found in real wind turbines can be accessed separately in the Wind Turbine Generator/Controller, Model 8216.
- The course curriculum of the Electric Power Technology Training Program is highly flexible and allows a multitude of different customized training solutions.
- The courseware includes student manuals and instructor guides with all the theory required to perform the hands-on experiments.
- All workstations, modules, and components are very sturdy to ensure a prolonged service life in a demanding environment such as a training laboratory.
- The modular design approach of the training equipment allows a large variety of courses to be performed using a small number of modules, without unnecessary duplication of equipment.
- All electrical components can be interconnected without electric shock hazard since all live parts of the connection leads are concealed and insulated.
- All electrical symbols representing the components used in a laboratory exercise are clearly silk-screened on the front panel of the modules.
- The training system includes a highly versatile USB peripheral:
  - Four-Quadrant Dynamometer/Power Supply, Model 8960-2. This module is used as a dc power source, as well as to simulate different wind conditions through a large variety of configurable parameters.
- Firmware upgrades for the Four-Quadrant Dynamometer/Power Supply are available for download free of charge on the Festo Didactic website.

List of Equipment

Qty	Description	Model number
1	DC Power Circuits (Student Manual)	579339 (86350-00)
1	DC Power Circuits (Instructor Guide)	579341 (86350-10)
1	Lead-Acid Batteries (Student Manual)	579343 (86351-00)
1	Lead-Acid Batteries (Instructor Guide)	579345 (86351-10)
1	Introduction to Wind Power (Student Manual)	579351 (86353-00)
1	Introduction to Wind Power (Instructor Guide)	579353 (86353-10)
1	Three-Module Workstation	579483 (8131-00)
1	Wind Turbine Generator/Controller	579487 (8216-00)
1	Resistive Load	763359 (8311-00)
1	Lead-Acid Batteries	763374 (8801-00)
1	Lead-Acid Battery Pack	579591 (8802-10)
1	Timing Belt	579637 (8942-00)
1	Connection Lead Set	579638 (8951-L0)
1	Four-Quadrant Dynamometer/Power Supply	579655 (8960-D0)

List of Manuals

Description	Manual number
DC Power Circuits (Workbook)	579339 (86350-00)
DC Power Circuits (Workbook (Instructor))	579341 (86350-10)
Lead-Acid Batteries (Workbook)	579343 (86351-00)
Lead-Acid Batteries (Workbook (Instructor))	579345 (86351-10)
Introduction to Wind Power (Workbook)	579351 (86353-00)
Introduction to Wind Power (Workbook (Instructor))	579353 (86353-10)
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)

Table of Contents of the Manual(s)

DC Power Circuits (Workbook) (579339 (86350-00))

- 1 Voltage, Current, and Ohm's Law
- 2 Equivalent Resistance
- 3 Power in DC Circuits
- 4 Series and Parallel Circuits

Lead-Acid Batteries (Workbook) (579343 (86351-00))

- 1 Battery Fundamentals
- 2 Discharge Characteristics
- 3 Battery Charging Fundamentals
- 4 Battery Charging Methods

Introduction to Wind Power (Workbook) (579351 (86353-00))

- 1 Voltage-Versus-Speed Characteristic of a Wind Turbine
- 2 Torque-Versus-Current Characteristic of a Wind Turbine
- 3 Power Versus Wind Speed
- 4 Storing the Energy Produced by Wind Turbines in Batteries

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

- 1 General Safety Recommendations
- 2 System Power Requirements
- 3 Quick Start Installation Guide
- 4 Equipment Installation
- 5 Modules Handling, Installation, and Removal
- 6 Equipment Maintenance
- A Connection of the Power Supply to the AC Power Network
- B Description, Specifications, and Operation of the EMS Modules

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Digital Multimeter	579782 (8946-20) [12]

System Specifications

Parameter	Value
Power Requirements	
Service Installation	A standard single-phase ac outlet
Computer Requirements	A currently available personal computer with USB 2.0 ports, running under one of the following operating systems: Windows® 7 or Windows® 8.
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment
Dimensions (H x W x D)	900 x 930 x 530 mm (35.4 x 36.6 x 20.9 in)
Net Weight	TBE
EMS Modules	
Full-Size Dimensions (H x W x D)	308 x 287 x 440 mm (12.1 x 11.3 x 17.3 in)
Half-Size Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)

Lead-Acid Batteries Training System
579290 (8010-40)

The Lead-Acid Batteries Training System introduces students to the operation of lead-acid batteries and covers voltage regulation, internal resistance, capacity, depth of discharge, and cycle life of lead-acid batteries. Hands-on experiments cover both the discharge characteristics and the most popular charging methods of lead-acid batteries.

The Lead-Acid Batteries Training System equipment includes the Lead-Acid Batteries, Model 8801, and the Four-Quadrant Dynamometer/Power Supply, Model 8960-2. The Four-Quadrant Dynamometer / Power Supply is a multifunctional module that is used in the Lead-Acid Batteries course to charge and discharge the batteries. Its operation is controlled by the LVDAC-EMS software, which also provides the instrumentation required to measure, collect, and record the experimental data.

The Lead-Acid Batteries Training System is part of the Electric Power Technology Training Systems, Series 8010. Each training system in Series 8010 is based on the Electric Power Technology Training Program and provides a turn-key solution dealing with some aspects of the wide field of electrical energy. The exhaustive courseware provided with each training system covers all the theory required to perform the laboratory exercises, while review questions and unit tests allow students to test the knowledge they have gained.

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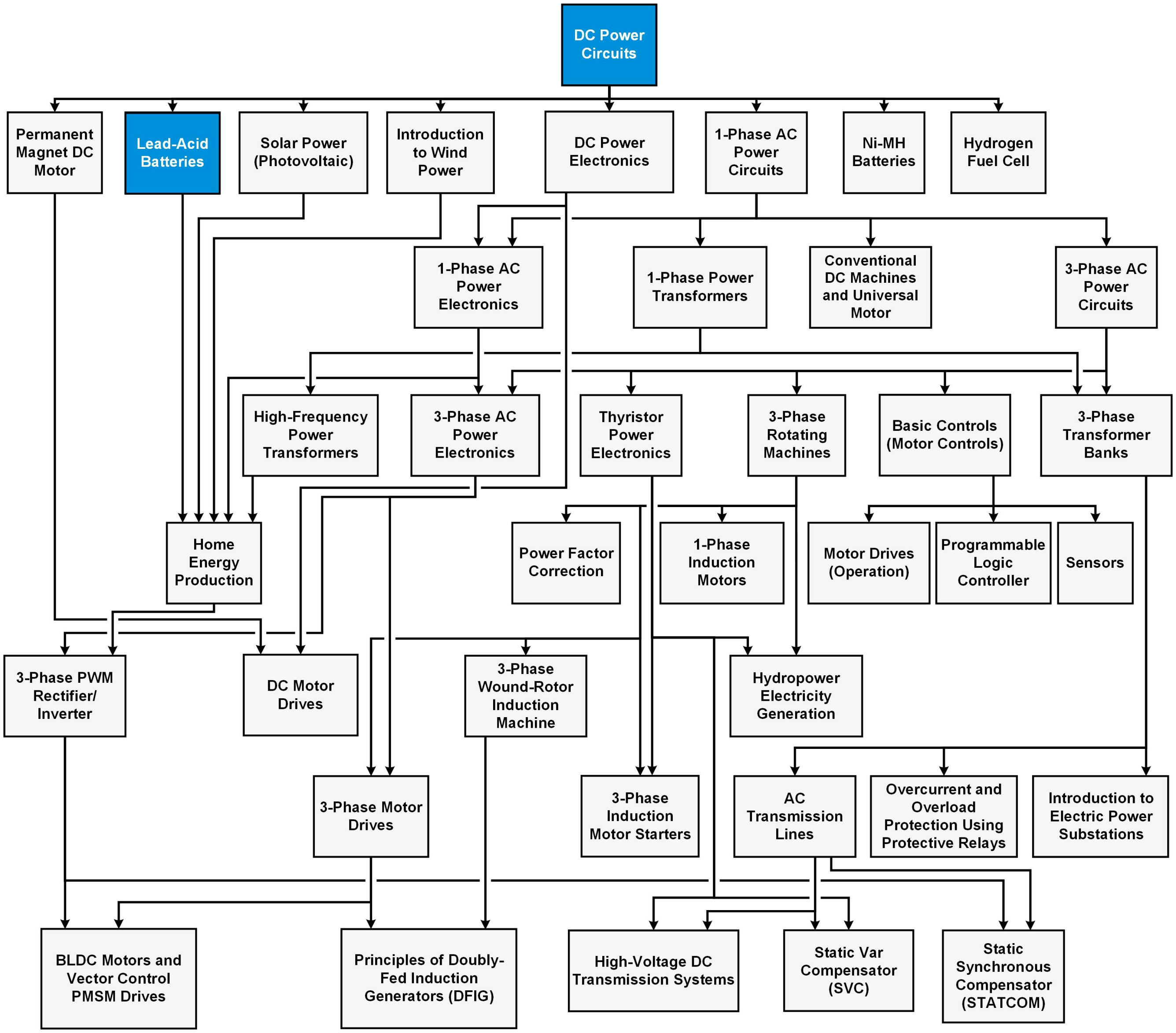
[12] The data acquisition already includes this function and many more, but the DC Circuits manual references using multimeters.

The Electric Power Technology Training Program is highly modular in both courseware and hardware. Because of this, courses and equipment from the program are available as required, either individually or in the context of a specific training system. The program covers several different subjects in the field of electrical energy, such as rotating machines, electrical power transmission, power electronics, home energy production from renewable resources (wind and sunlight), large-scale electricity production from hydropower and wind power, smart-grid technologies (SVC, STATCOM, HVDC transmission, etc.), storage of electrical energy in batteries, and drive systems for small electric vehicles and cars.


DC Power Circuits
Permanent Magnet DC Motor
Lead-Acid Batteries
Solar Power (Photovoltaic)
Introduction to Wind Power
DC Power Electronics
1-Phase AC Power Circuits
Ni-MH Batteries
Hydrogen Fuel Cell
1-Phase AC Power Electronics
1-Phase Power Transformers
Conventional DC Machines and Universal Motor
3-Phase AC Power Circuits
High-Frequency Power Transformers
3-Phase AC Power Electronics
Thyristor Power Electronics
3-Phase Rotating Machines
Basic Controls (Motor Controls)
3-Phase Transformer Banks
Home Energy Production
Power Factor Correction
1-Phase Induction Motors
Motor Drives (Operation)
Programmable Logic Controller
Sensors
3-Phase PWM Rectifier/ Inverter
DC Motor Drives
3-Phase Wound-Rotor Induction Machine
Hydropower Electricity Generation
3-Phase Motor Drives
3-Phase Induction Motor Starters
AC Transmission Lines
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BLDC Motors and Vector Control PMSM Drives
Principles of Doubly-Fed Induction Generators (DFIG)
High-Voltage DC Transmission Systems
Static Var Compensator (SVC)
Static Synchronous Compensator (STATCOM)

The above chart shows all courses in the Electric Power Technology Training Program. Blue boxes highlight courses included in the training system covered in this datasheet, while dark grey boxes, if any, highlight courses that can be optionally added to this training system.

Courseware

Each course in the training system includes a full-color student manual providing all the theoretical matter required, guided lab-exercise procedures to be performed with the training equipment, and review questions that test the knowledge gained by the student. Whenever possible, each course is built to bring the student to actual applications as soon as possible. A full-color instructor guide providing all lab results and answers to questions is also included with each course.

Modular Design Approach

The modular approach for designing the training program and lab equipment enables instructors to start building their electrical-energy laboratory with a basic package of courses and equipment and add new courses and equipment over time without needless duplication of equipment.

All lab equipment consists of modules that can be inserted into a workstation. Module dimensions vary between two standard EMS sizes: full-size and half-size. Symbols and diagrams representing the electrical components in each module are clearly silk-screened on the front panel. Standard, color-coded safety banana jacks are used to provide access to the various components in each module.

Features & Benefits

- The training system teaches the principles of lead-acid battery operation during both charge and discharge.
- The course curriculum of the Electric Power Technology Training Program is highly flexible and allows a multitude of different customized training solutions.
- The courseware includes student manuals and instructor guides with all the theory required to perform the hands-on experiments.
- All workstations, modules, and components are very sturdy to ensure a prolonged service life in a demanding environment such as a training laboratory.
- The modular design approach of the training equipment allows a large variety of courses to be performed using a small number of modules, without unnecessary duplication of equipment.
- All electrical components can be interconnected without electric shock hazard since all live parts of the connection leads are concealed and insulated.
- All electrical symbols representing the components used in a laboratory exercise are clearly silk-screened on the front panel of the modules.
- The training system includes a highly versatile USB peripheral:
  - Four-Quadrant Dynamometer/Power Supply, Model 8960-2. This module is used as a dc power source and a battery charger/discharger with a large variety of configurable parameters. It can also be used as an overnight battery float charger.

- Firmware upgrades for the Four-Quadrant Dynamometer/Power Supply are available for download free of charge on the Festo Didactic website.

List of Equipment

Qty	Description	Model number
1	DC Power Circuits (Student Manual)	579339 (86350-00)
1	DC Power Circuits (Instructor Guide)	579341 (86350-10)
1	Lead-Acid Batteries (Student Manual)	579343 (86351-00)
1	Lead-Acid Batteries (Instructor Guide)	579345 (86351-10)
1	Three-Module Workstation	579483 (8131-00)
1	Resistive Load	763359 (8311-00)
1	Lead-Acid Batteries	763374 (8801-00)
1	Connection Lead Set	579638 (8951-L0)
1	Four-Quadrant Dynamometer/Power Supply	579662 (8960-E0)

List of Manuals

Description	Manual number
DC Power Circuits (Workbook)	579339 (86350-00)
DC Power Circuits (Workbook (Instructor))	579341 (86350-10)
Lead-Acid Batteries (Workbook)	579343 (86351-00)
Lead-Acid Batteries (Workbook (Instructor))	579345 (86351-10)
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)

Table of Contents of the Manual(s)

DC Power Circuits (Workbook) (579339 (86350-00))

- 1 Voltage, Current, and Ohm’s Law
- 2 Equivalent Resistance
- 3 Power in DC Circuits
- 4 Series and Parallel Circuits

Lead-Acid Batteries (Workbook) (579343 (86351-00))

- 1 Battery Fundamentals
- 2 Discharge Characteristics
- 3 Battery Charging Fundamentals
- 4 Battery Charging Methods

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

- 1 General Safety Recommendations
- 2 System Power Requirements
- 3 Quick Start Installation Guide
- 4 Equipment Installation
- 5 Modules Handling, Installation, and Removal
- 6 Equipment Maintenance
- A Connection of the Power Supply to the AC Power Network
- B Description, Specifications, and Operation of the EMS Modules

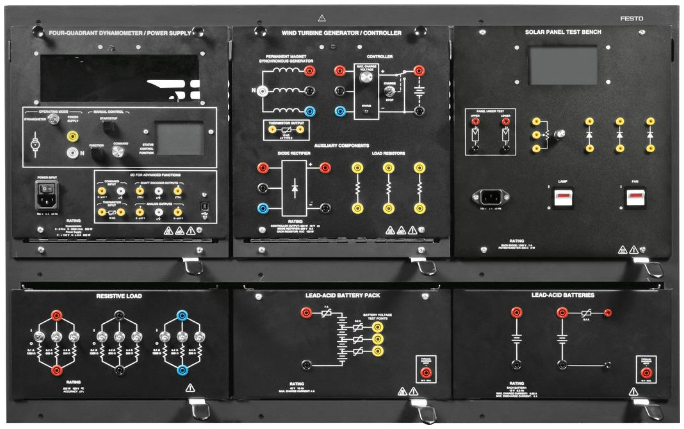
Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Digital Multimeter	579782 (8946-20) [13]

System Specifications

Parameter	Value
Power Requirements	
Service Installation	A standard single-phase ac outlet
Computer Requirements	A currently available personal computer with USB 2.0 ports, running under one of the following operating systems: Windows® 7 or Windows® 8.
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment
Dimensions (H x W x D)	900 x 930 x 530 mm (35.4 x 36.6 x 20.9 in)
Net Weight	TBE
EMS Modules	
Full-Size Dimensions (H x W x D)	308 x 287 x 440 mm (12.1 x 11.3 x 17.3 in)
Half-Size Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)

Basic Renewable Energy Training System
579294 (8010-50)



The Basic Renewable Energy Training System provides in-depth coverage of basic renewable energy systems. It provides an introduction to dc power circuits, and covers in detail the principles behind the production of electrical energy from both solar power and wind power. Finally, the training system introduces students to the storage of electrical energy produced from renewable resources into lead-acid batteries for future consumption.

The Basic Renewable Energy Training System is part of the Electric Power Technology Training Systems, Series 8010. Each training system in Series 8010 is based on the Electric Power Technology Training Program and provides a turn-key solution dealing with some aspects of the wide field of electrical energy. The exhaustive courseware provided with each training system covers all the theory required to perform the laboratory exercises, while review questions and unit tests allow students to test the knowledge they have gained.

The Electric Power Technology Training Program is highly modular in both courseware and hardware. Because of this, courses and equipment from the program are available as required, either individually or in the context of a specific training system. The program covers several different subjects in the field of electrical energy, such as rotating machines, electrical power transmission, power electronics, home energy production from renewable resources (wind and sunlight), large-scale electricity production from hydropower and wind power, smart-grid technologies (SVC, STATCOM, HVDC transmission, etc.), storage of electrical energy in batteries, and drive systems for small electric vehicles and cars.

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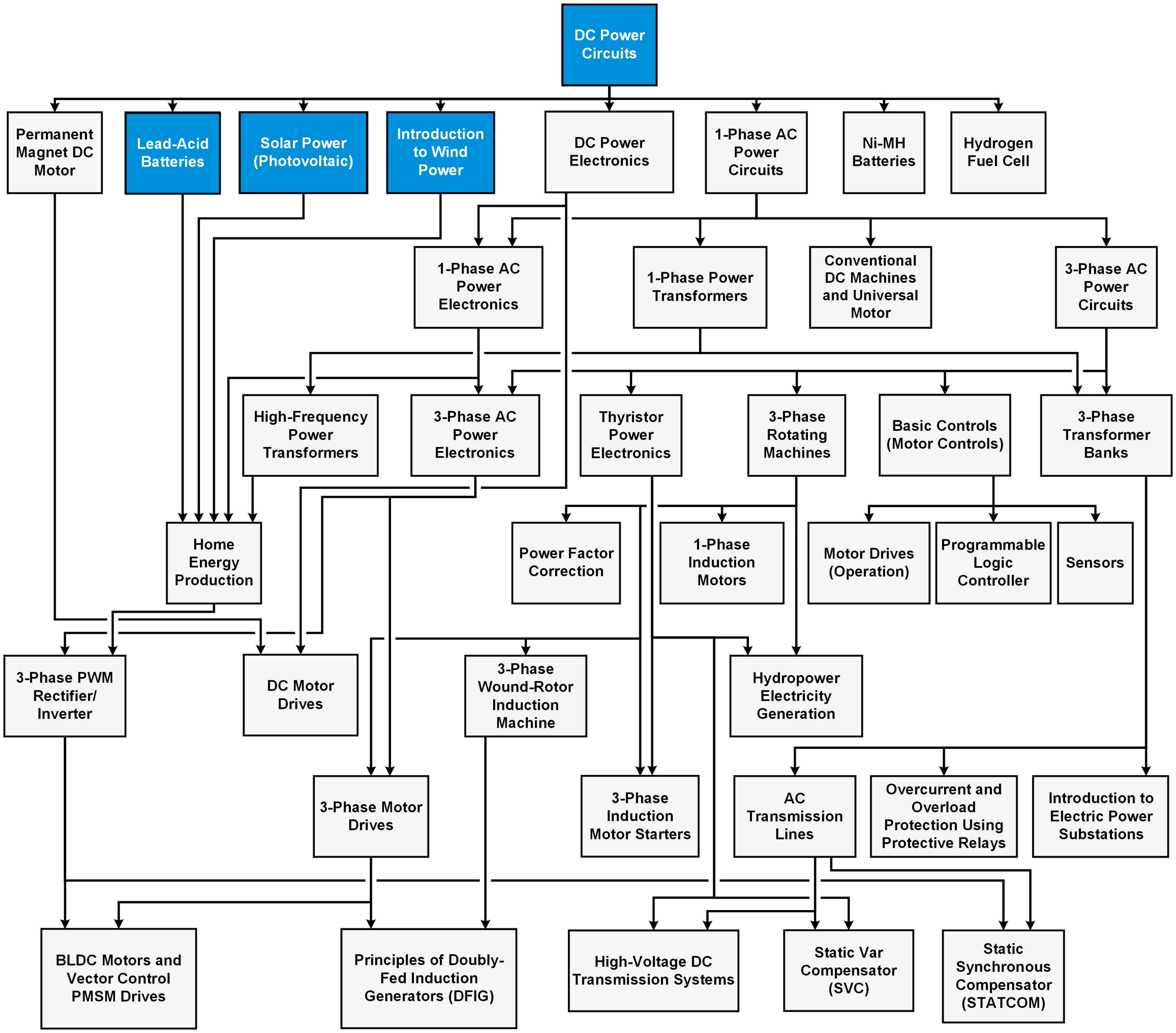
[13] The data acquisition already includes this function and many more, but the DC Circuits manual references using multimeters.


DC Power Circuits
Permanent Magnet DC Motor
Lead-Acid Batteries
Solar Power (Photovoltaic)
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Ni-MH Batteries
Hydrogen Fuel Cell
1-Phase AC Power Electronics
1-Phase Power Transformers
Conventional DC Machines and Universal Motor
3-Phase AC Power Circuits
High-Frequency Power Transformers
3-Phase AC Power Electronics
Thyristor Power Electronics
3-Phase Rotating Machines
Basic Controls (Motor Controls)
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3-Phase Wound-Rotor Induction Machine
Hydropower Electricity Generation
3-Phase Motor Drives
3-Phase Induction Motor Starters
AC Transmission Lines
Overcurrent and Overload Protection Using Protective Relays
Introduction to Electric Power Substations
BLDC Motors and Vector Control PMSM Drives
Principles of Doubly-Fed Induction Generators (DFIG)
High-Voltage DC Transmission Systems
Static Var Compensator (SVC)
Static Synchronous Compensator (STATCOM)

The above chart shows all courses in the Electric Power Technology Training Program. Blue boxes highlight courses included in the training system covered in this datasheet, while dark grey boxes, if any, highlight courses that can be optionally added to this training system.

Courseware

Each course in the training system includes a full-color student manual providing all the theoretical matter required, guided lab-exercise procedures to be performed with the training equipment, and review questions that test the knowledge gained by the student. Whenever possible, each course is built to bring the student to actual applications as soon as possible. A full-color instructor guide providing all lab results and answers to questions is also included with each course.

Modular Design Approach

The modular approach for designing the training program and lab equipment enables instructors to start building their electrical-energy laboratory with a basic package of courses and equipment and add new courses and equipment over time without needless duplication of equipment.

All lab equipment consists of modules that can be inserted into a workstation. Module dimensions vary between two standard EMS sizes: full-size and half-size. Symbols and diagrams representing the electrical components in each module are clearly silk-screened on the front panel. Standard, color-coded safety banana jacks are used to provide access to the various components in each module.

Features & Benefits

- The training system teaches the principles of electricity generation from renewable energy sources (solar power and wind power), as well as its subsequent storage in lead-acid batteries.
- The course curriculum of the Electric Power Technology Training Program is highly flexible and allows a multitude of different customized training solutions.
- The courseware includes student manuals and instructor guides with all the theory required to perform the hands-on experiments.
- All workstations, modules, and components are very sturdy to ensure a prolonged service life in a demanding environment such as a training laboratory.
- The modular design approach of the training equipment allows a large variety of courses to be performed using a small number of modules, without unnecessary duplication of equipment.
- All electrical components can be interconnected without electric shock hazard since all live parts of the connection leads are concealed and insulated.
- All electrical symbols representing the components used in a laboratory exercise are clearly silk-screened on the front panel of the modules.
- The training system includes a highly versatile USB peripheral:
  - Four-Quadrant Dynamometer/Power Supply, Model 8960-2. This module is used as a dc power source and a battery charger/discharger with a large variety of configurable parameters. It is also used to simulate different wind conditions through a large variety of configurable parameters.
- Firmware upgrades for the Four-Quadrant Dynamometer/Power Supply are available for download free of charge on the Festo Didactic website.

List of Equipment

Qty	Description	Model number
1	DC Power Circuits (Student Manual)	579339 (86350-00)
1	DC Power Circuits (Instructor Guide)	579341 (86350-10)
1	Lead-Acid Batteries (Student Manual)	579343 (86351-00)
1	Lead-Acid Batteries (Instructor Guide)	579345 (86351-10)

Qty	Description	Model number
1	Solar Power (Student Manual)	579347 (86352-00)
1	Solar Power (Instructor Guide)	579349 (86352-10)
1	Introduction to Wind Power (Student Manual)	579351 (86353-00)
1	Introduction to Wind Power (Instructor Guide)	579353 (86353-10)
1	Three-Module Workstation	579483 (8131-00)
1	Wind Turbine Generator/Controller	579487 (8216-00)
1	Resistive Load	763359 (8311-00)
1	Lead-Acid Batteries	763374 (8801-00)
1	Lead-Acid Battery Pack	579591 (8802-10)
1	Solar Panel Test Bench	579594 (8805-00)
1	Monocrystalline Silicon Solar Panel	579600 (8806-00)
1	Timing Belt	579637 (8942-00)
1	Connection Lead Set	579638 (8951-L0)
1	Four-Quadrant Dynamometer/Power Supply	579655 (8960-D0)

List of Manuals

Description	Manual number
DC Power Circuits (Workbook)	579339 (86350-00)
DC Power Circuits (Workbook (Instructor))	579341 (86350-10)
Lead-Acid Batteries (Workbook)	579343 (86351-00)
Lead-Acid Batteries (Workbook (Instructor))	579345 (86351-10)
Solar Power (Workbook)	579347 (86352-00)
Solar Power (Workbook (Instructor))	579349 (86352-10)
Introduction to Wind Power (Workbook)	579351 (86353-00)
Introduction to Wind Power (Workbook (Instructor))	579353 (86353-10)
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)

Table of Contents of the Manual(s)

DC Power Circuits (Workbook) (579339 (86350-00))

- 1 Voltage, Current, and Ohm’s Law
- 2 Equivalent Resistance
- 3 Power in DC Circuits
- 4 Series and Parallel Circuits

Lead-Acid Batteries (Workbook) (579343 (86351-00))

- 1 Battery Fundamentals
- 2 Discharge Characteristics
- 3 Battery Charging Fundamentals
- 4 Battery Charging Methods

Solar Power (Workbook) (579347 (86352-00))

- 1 The Diode
- 2 The Solar Panel (Photovoltaic Panel)

- 3 Effect of Temperature on Solar Panel Performance
- 4 Storing Energy from Solar Panels into Batteries
- 5 Effect of Shading on Solar Panel Operation
- 6 Solar Panel Orientation
- 7 Solar Panel Performance Versus Insolation

Introduction to Wind Power (Workbook) (579351 (86353-00))

- 1 Voltage-Versus-Speed Characteristic of a Wind Turbine
- 2 Torque-Versus-Current Characteristic of a Wind Turbine
- 3 Power Versus Wind Speed
- 4 Storing the Energy Produced by Wind Turbines in Batteries

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

- 1 General Safety Recommendations
- 2 System Power Requirements
- 3 Quick Start Installation Guide
- 4 Equipment Installation
- 5 Modules Handling, Installation, and Removal
- 6 Equipment Maintenance
- A Connection of the Power Supply to the AC Power Network
- B Description, Specifications, and Operation of the EMS Modules

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Digital Multimeter	579782 (8946-20) [14]

Software

Qty	Description	Model number
1	SCADA for LVDAC-EMS	8094377 (8973-00) [15]
1	Software Development Kit (SDK)	581459 (9069-90) [16]

System Specifications

Parameter	Value
Power Requirements	
Service Installation	A standard single-phase ac outlet
Computer Requirements	A currently available personal computer with USB 2.0 ports, running under one of the following operating systems: Windows® 7 or Windows® 8.
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment
Dimensions (H x W x D)	900 x 930 x 530 mm (35.4 x 36.6 x 20.9 in)
Net Weight	TBE
EMS Modules	
Full-Size Dimensions (H x W x D)	308 x 287 x 440 mm (12.1 x 11.3 x 17.3 in)
Half-Size Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)

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[14] The data acquisition already includes this function and many more, but the DC Circuits manual references using multimeters.

[15] Software allowing the monitoring of up to 5 Stations through OPC.

[16] Additional firmware for the Data Acquisition.

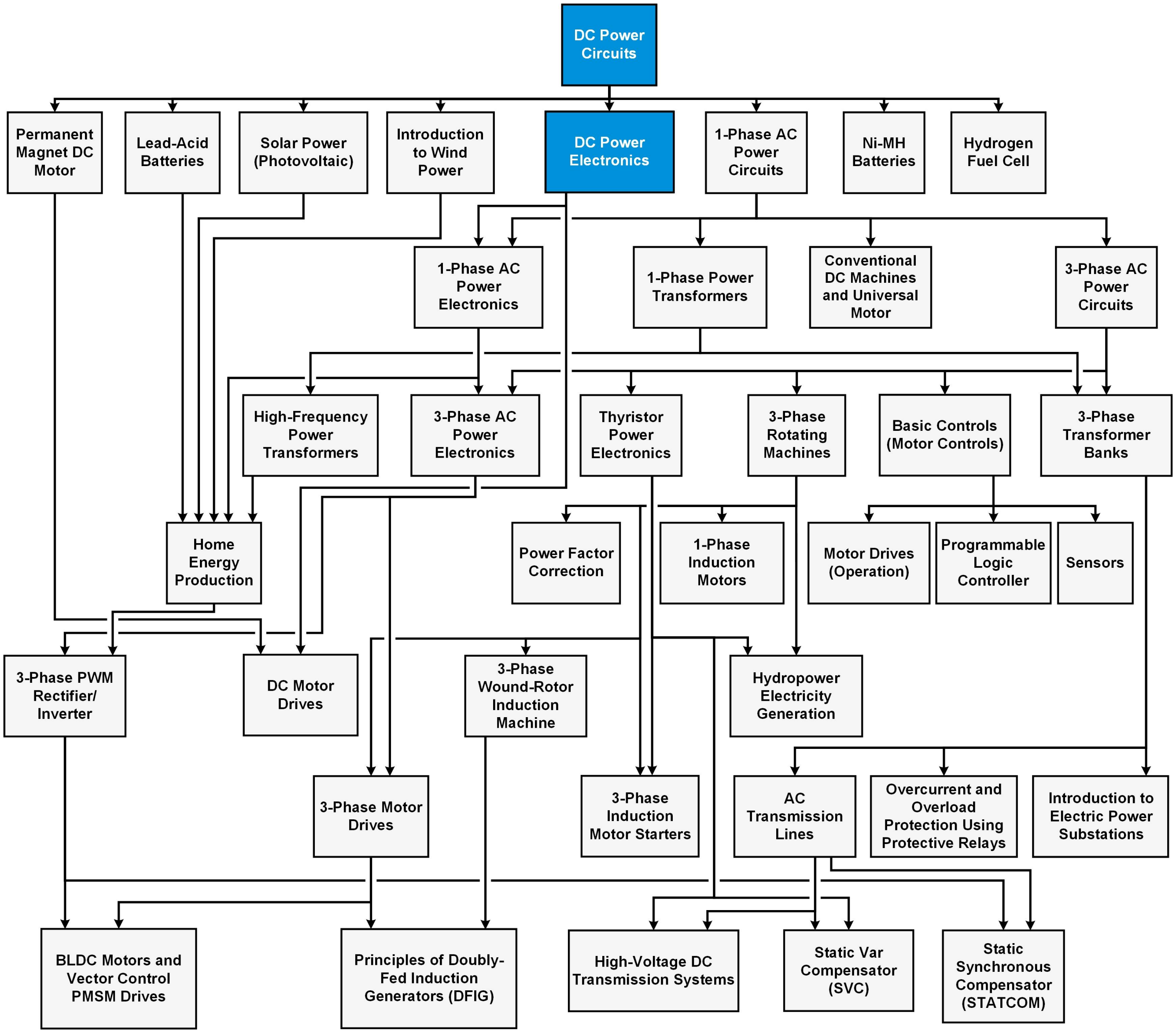
DC Power Electronics Training System
579298 (8010-60)

The DC Power Electronics Training System provides a comprehensive study of the diode and switching transistor, two semiconductor components that are widely used in power electronics circuits. It also provides in-depth coverage of various types of chopper, a power electronics device used in many dc power circuits (e.g., dc motor drives, battery chargers, dc-to-dc converters, etc.).

The training system equipment mainly consists of the IBGT Chopper/Inverter, Model 8837-B, and the Four-Quadrant Dynamometer/Power Supply, Model 8960-2. The IBGT Chopper/Inverter consists of insulated-gate bipolar transistors (IGBT) and diodes used to build various types of choppers. The Four-Quadrant Dynamometer/ Power Supply is a highly versatile module used in the DC Power Electronics course as a voltage source and battery charger. The operation of these modules is controlled via the LVDAC-EMS software, which also provides the instrumentation required to measure and record the experimental data.

The DC Power Electronics Training System is part of the Electric Power Technology Training Systems, Series 8010. Each training system in Series 8010 is based on the Electric Power Technology Training Program and provides a turn-key solution dealing with some aspects of the wide field of electrical energy. The exhaustive courseware provided with each training system covers all the theory required to perform the laboratory exercises, while review questions and unit tests allow students to test the knowledge they have gained.

The Electric Power Technology Training Program is highly modular in both courseware and hardware. Because of this, courses and equipment from the program are available as required, either individually or in the context of a specific training system. The program covers several different subjects in the field of electrical energy, such as rotating machines, electrical power transmission, power electronics, home energy production from renewable resources (wind and sunlight), large-scale electricity production from hydropower and wind power, smart-grid technologies (SVC, STATCOM, HVDC transmission, etc.), storage of electrical energy in batteries, and drive systems for small electric vehicles and cars.


DC Power Circuits
Permanent Magnet DC Motor
Lead-Acid Batteries
Solar Power (Photovoltaic)
Introduction to Wind Power
DC Power Electronics
1-Phase AC Power Circuits
Ni-MH Batteries
Hydrogen Fuel Cell
1-Phase AC Power Electronics
1-Phase Power Transformers
Conventional DC Machines and Universal Motor
3-Phase AC Power Circuits
High-Frequency Power Transformers
3-Phase AC Power Electronics
Thyristor Power Electronics
3-Phase Rotating Machines
Basic Controls (Motor Controls)
3-Phase Transformer Banks
Home Energy Production
Power Factor Correction
1-Phase Induction Motors
Motor Drives (Operation)
Programmable Logic Controller
Sensors
3-Phase PWM Rectifier/ Inverter
DC Motor Drives
3-Phase Wound-Rotor Induction Machine
Hydropower Electricity Generation
3-Phase Motor Drives
3-Phase Induction Motor Starters
AC Transmission Lines
Overcurrent and Overload Protection Using Protective Relays
Introduction to Electric Power Substations
BLDC Motors and Vector Control PMSM Drives
Principles of Doubly-Fed Induction Generators (DFIG)
High-Voltage DC Transmission Systems
Static Var Compensator (SVC)
Static Synchronous Compensator (STATCOM)

The above chart shows all courses in the Electric Power Technology Training Program. Blue boxes highlight courses included in the training system covered in this datasheet, while dark grey boxes, if any, highlight courses that can be optionally added to this training system.

Courseware

Each course in the training system includes a full-color student manual providing all the theoretical matter required, guided lab-exercise procedures to be performed with the training equipment, and review questions that test the knowledge gained by the student. Whenever possible, each course is built to bring the student to actual applications as soon as possible. A full-color instructor guide providing all lab results and answers to questions is also included with each course.

Modular Design Approach

The modular approach for designing the training program and lab equipment enables instructors to start building their electrical-energy laboratory with a basic package of courses and equipment and add new courses and equipment over time without needless duplication of equipment.

All lab equipment consists of modules that can be inserted into a workstation. Module dimensions vary between two standard EMS sizes: full-size and half-size. Symbols and diagrams representing the electrical components in each module are clearly silk-screened on the front panel. Standard, color-coded safety banana jacks are used to provide access to the various components in each module.

Features & Benefits

- The training system teaches the principles of dc power electronics, as well as the operation of various dc power electronics devices, through clear, easy-to-follow theory presentations and simple, demonstrative hands-on exercises.
- The course curriculum of the Electric Power Technology Training Program is highly flexible and allows a multitude of different customized training solutions.
- The courseware includes student manuals and instructor guides with all the theory required to perform the hands-on experiments.
- All workstations, modules, and components are very sturdy to ensure a prolonged service life in a demanding environment such as a training laboratory.
- The modular design approach of the training equipment allows a large variety of courses to be performed using a small number of modules, without unnecessary duplication of equipment.
- All electrical components can be interconnected without electric shock hazard since all live parts of the connection leads are concealed and insulated.
- All electrical symbols representing the components used in a laboratory exercise are clearly silk-screened on the front panel of the modules.
- The training system includes two highly versatile USB peripherals:
  - Four-Quadrant Dynamometer/Power Supply, Model 8960-2. This module is used as a dc power source and a battery charger/discharger with a large variety of configurable parameters. The module can also be used as an overnight battery float charger.
  - Data Acquisition and Control Interface, Model 9063. This module gives access to a large variety of computer-based measuring instruments and is used to control the various dc power electronics devices. Both of these functions are implemented via the LVDAC-EMS software.
- Software upgrades for LVDAC-EMS and firmware upgrades for the Four-Quadrant Dynamometer/Power Supply and Data Acquisition and Control Interface are available for download free of charge on the Festo Didactic website.

List of Equipment

Qty	Description	Model number
1	DC Power Circuits (Student Manual)	579339 (86350-00)
1	DC Power Circuits (Instructor Guide)	579341 (86350-10)
1	DC Power Electronics (Student Manual)	579358 (86356-00)
1	DC Power Electronics (Instructor Guide)	579360 (86356-10)
1	Three-Module Workstation	579483 (8131-00)
1	Resistive Load	763359 (8311-00)
1	Filtering Inductors/Capacitors	579523 (8325-A0)
1	Lead-Acid Battery Pack	579591 (8802-10)
1	IGBT Chopper/Inverter	579623 (8837-B0)
1	Connection Lead Set	579638 (8951-L0)
1	Four-Quadrant Dynamometer/Power Supply	579662 (8960-E0)
1	Data Acquisition and Control Interface	579683 (9063-C0)
1	AC 24 V Wall Mount Power Supply	579696 (30004-20)

List of Manuals

Description	Manual number
DC Power Circuits (Workbook)	579339 (86350-00)
DC Power Circuits (Workbook (Instructor))	579341 (86350-10)
DC Power Electronics (Workbook)	579358 (86356-00)
DC Power Electronics (Workbook (Instructor))	579360 (86356-10)
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)

Table of Contents of the Manual(s)

DC Power Circuits (Workbook) (579339 (86350-00))

- 1 Voltage, Current, and Ohm’s Law
- 2 Equivalent Resistance
- 3 Power in DC Circuits
- 4 Series and Parallel Circuits

DC Power Electronics (Workbook) (579358 (86356-00))

- 1 The Diode and Switching Transistor
- 2 The Buck Chopper
- 3 Introduction to High-Speed Power Switching
- 4 Ripple in Choppers
- 5 The Lead-Acid Battery Charger
- 6 The Boost Chopper
- 7 The Buck/Boost Chopper
- 8 The Four-Quadrant Chopper

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

- 1 General Safety Recommendations
- 2 System Power Requirements

- 3 Quick Start Installation Guide
- 4 Equipment Installation
- 5 Modules Handling, Installation, and Removal
- 6 Equipment Maintenance
- A Connection of the Power Supply to the AC Power Network
- B Description, Specifications, and Operation of the EMS Modules

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

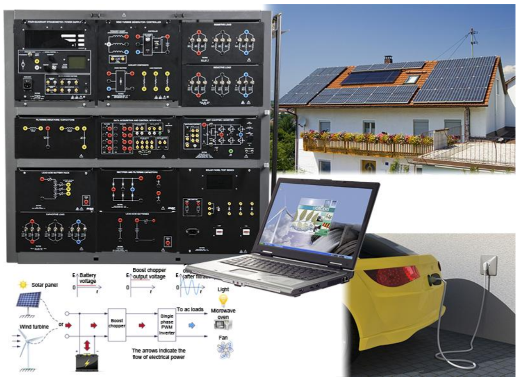
Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Digital Multimeter	579782 (8946-20) [17]

System Specifications

Parameter	Value
Power Requirements	
Service Installation	A standard single-phase ac outlet
Computer Requirements	A currently available personal computer with USB 2.0 ports, running under one of the following operating systems: Windows® 7 or Windows® 8.
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment
Dimensions (H x W x D)	900 x 930 x 530 mm (35.4 x 36.6 x 20.9 in)
Net Weight	TBE
EMS Modules	
Full-Size Dimensions (H x W x D)	308 x 287 x 440 mm (12.1 x 11.3 x 17.3 in)
Half-Size Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)

Home Energy Production Training System
579301 (8010-70)


Solar panel
Battery voltage
Boost chopper output voltage
Wind turbine
or
Boost chopper
Single phase PWM inverter
To ac loads
Light
Microwave oven
Fan
The arrows indicate the flow of electrical power

The Home Energy Production Training System combines a modular design approach with computer-based data acquisition and control to provide unrivaled training in home energy production systems. The system features the Four-Quadrant Dynamometer/Power Supply and the Data Acquisition and Control Interface, two state-of-the-art USB peripherals that greatly enhance the learning experience of students.

Training begins with the following four courses:

- DC Power Circuits

- Lead-Acid Batteries

- Solar Power

- Introduction to Wind Power

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[17] The data acquisition already includes this function and many more, but the DC Circuits manual references using multimeters.

These courses introduce students to the fundamentals of dc power circuits, to the storage of electrical energy in lead-acid batteries, and to the generation of electrical energy from wind and sunlight, the two renewable resources most commonly used for home energy production. Training continues with the following two courses dealing with ac power:

- Single-Phase AC Power Circuits
- Single-Phase Power Transformers

These courses teach students the fundamentals of ac power circuits and power transformers, and are necessary to understand the principles of grid-tied home energy production. Students then continue with the following three courses:

- DC Power Electronics
- Single-Phase AC Power Electronics
- High-Frequency Power Transformers

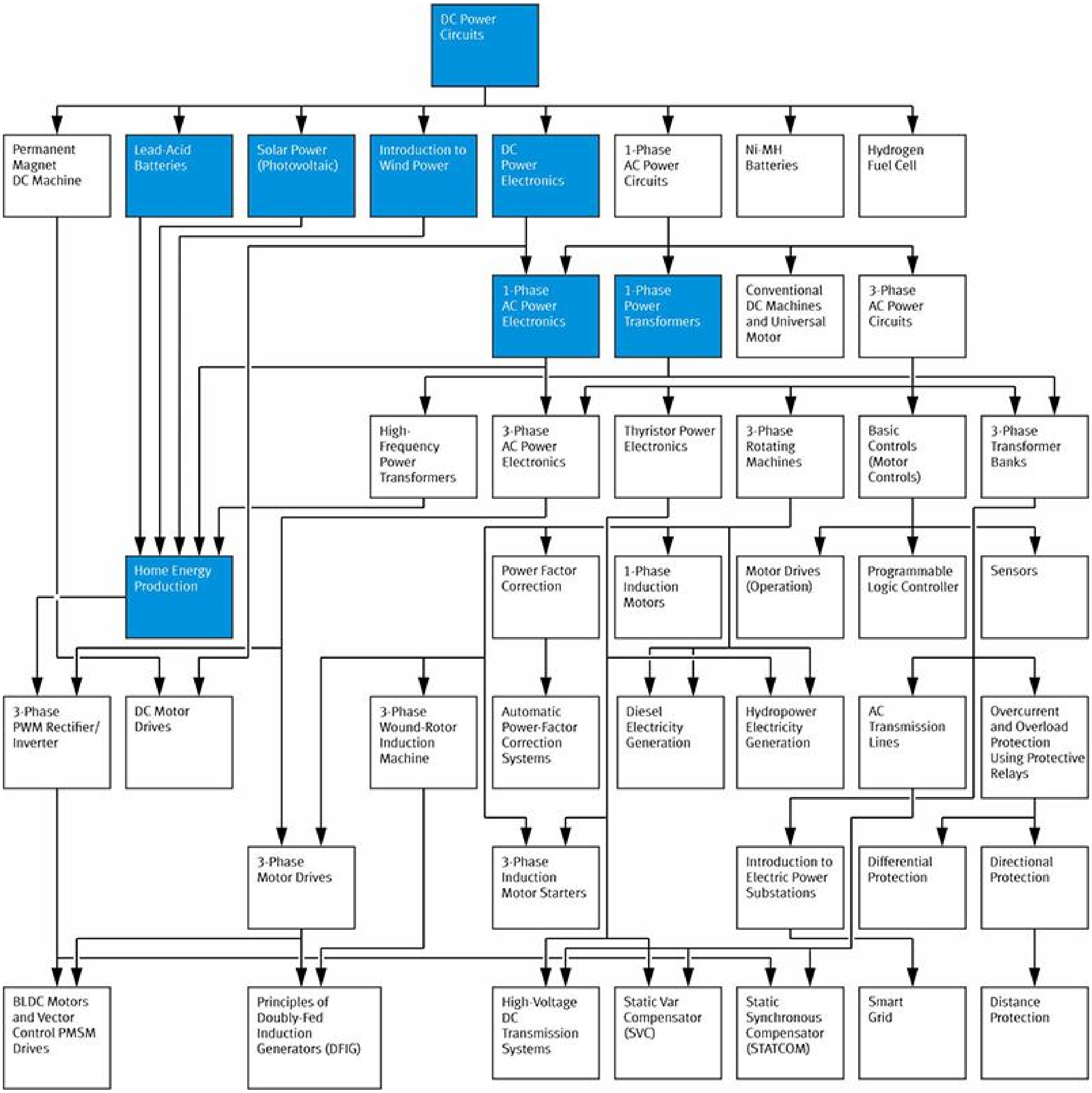
These courses familiarize students with the different power electronics devices used for home energy production, such as choppers, inverters, dc-to-dc converters, and high-frequency power transformers. After completion of the above courses, students finally possess all knowledge required to proceed with the main course of the training system:

- Home Energy Production

This course familiarizes students with the fundamentals of home energy production. It integrates all the different notions which students have acquired in the previous courses to cover both stand-alone home energy production and grid-tied home energy production. The course also explains and demonstrates how home energy production is an important contributor to the implementation of a smart grid, a concept of ever growing importance in today's electric power networks.

The Home Energy Production Training System is part of the Electric Power Technology Training Systems, Series 8010. Each training system in Series 8010 is based on the Electric Power Technology Training Program and provides a turn-key solution dealing with some aspects of the wide field of electrical energy. The exhaustive courseware provided with each training system covers all the theory required to perform the laboratory exercises, while review questions and unit tests allow students to test the knowledge they have gained.

The Electric Power Technology Training Program is highly modular in both courseware and hardware. Because of this, courses and equipment from the program are available as required, either individually or in the context of a specific training system. The program covers several different subjects in the field of electrical energy, such as rotating machines, electrical power transmission, power electronics, home energy production from renewable resources (wind and sunlight), large-scale electricity production from hydropower and wind power, smart-grid technologies (SVC, STATCOM, HVDC transmission, etc.), storage of electrical energy in batteries, and drive systems for small electric vehicles and cars.


DC Power Circuits
Permanent Magnet DC Machine
Lead-Acid Batteries
Solar Power (Photovoltaic)
Introduction to Wind Power
DC Power Electronics
1-Phase AC Power Circuits
Ni-MH Batteries
Hydrogen Fuel Cell
1-Phase AC Power Electronics
1-Phase Power Transformers
Conventional DC Machines and Universal Motor
3-Phase AC Power Circuits
High-Frequency Power Transformers
3-Phase AC Power Electronics
Thyristor Power Electronics
3-Phase Rotating Machines
Basic Controls (Motor Controls)
3-Phase Transformer Banks
Home Energy Production
Power Factor Correction
1-Phase Induction Motors
Motor Drives (Operation)
Programmable Logic Controller
Sensors
3-Phase PWM Rectifier/ Inverter
DC Motor Drives
3-Phase Wound-Rotor Induction Machine
Automatic Power-Factor Correction Systems
Diesel Electricity Generation
Hydropower Electricity Generation
AC Transmission Lines
Overcurrent and Overload Protection Using Protective Relays
3-Phase Motor Drives
3-Phase Induction Motor Starters
Introduction to Electric Power Substations
Differential Protection
Directional Protection
BLDC Motors and Vector Control PMSM Drives
Principles of Doubly-Fed Induction Generators (DFIG)
High-Voltage DC Transmission Systems
Static Var Compensator (SVC)
Static Synchronous Compensator (STATCOM)
Smart Grid
Distance Protection

The above chart shows all courses in the Electric Power Technology Training Program. Blue boxes highlight courses included in the training system covered in this datasheet, while dark grey boxes, if any, highlight courses that can be optionally added to this training system.

Courseware

Each course in the training system includes a full-color student manual providing all the theoretical matter required, guided lab-exercise procedures to be performed with the training equipment, and review questions that test the knowledge gained by the student. Whenever possible, each course is built to bring the student to actual applications as soon as possible. A full-color instructor guide providing all lab results and answers to questions is also included with each course.

Modular Design Approach

The modular approach for designing the training program and lab equipment enables instructors to start building their electrical-energy laboratory with a basic package of courses and equipment and add new courses and equipment over time without needless duplication of equipment.

All lab equipment consists of modules that can be inserted into a workstation. Module dimensions vary between two standard EMS sizes: full-size and half-size. Symbols and diagrams representing the electrical components in each module are clearly silk-screened on the front panel. Standard, color-coded safety banana jacks are used to provide access to the various components in each module.

Features & Benefits

- The training system teaches the principles of home energy production directly in the laboratory. To this end, students follow a complete curriculum that includes these topics:
  - An introduction to the fundamentals of electricity, beginning with dc power circuits.
  - Courses that cover the principles of electricity generation from renewable energy sources (solar power and wind power), as well as its subsequent storage in lead-acid batteries.
  - More advanced courses that cover different electrical concepts and necessary to home energy production, such as dc power electronics, single-phase ac power circuits, and high-frequency power transformers.
  - A comprehensive course covering in detail the production of energy at home from renewable resources.
- The course curriculum of the Electric Power Technology Training Program is highly flexible and allows a multitude of different customized training solutions.
- The courseware includes student manuals and instructor guides with all the theory required to perform the hands-on experiments.
- All workstations, modules, and components are very sturdy to ensure a prolonged service life in a demanding environment such as a training laboratory.
- The modular design approach of the training equipment allows a large variety of courses to be performed using a small number of modules, without unnecessary duplication of equipment.
- All electrical components can be interconnected without electric shock hazard since all live parts of the connection leads are concealed and insulated.
- All electrical symbols representing the components used in a laboratory exercise are clearly silk-screened on the front panel of the modules.
- The training system includes two highly versatile USB peripherals:
  - Four-Quadrant Dynamometer/Power Supply, Model 8960-2. This module is used as a dc and ac power source. It can also be used as a battery charger/discharger, a solar panel emulator, and a wind emulator, all with a large variety of configurable parameters.
  - Data Acquisition and Control Interface, Model 9063. This module gives access to a large variety of computer-based measuring instruments and is used to control the various dc power electronics

devices necessary to home energy production. All functions are implemented via the LVDAC-EMS software.

- The training system also includes three highly versatile power electronics modules controlled using the Data Acquisition and Control Interface:
  - Insulated DC-to-DC Converter, Model 8835. This module is used to implement a solar/wind power inverter with HF transformer topology.
  - IGBT Chopper/Inverter, Model 8837-B. This module is used to implement various types of choppers and inverters.
  - Rectifier and Filtering Capacitors, Model 8842-A. This module is used to implement various types of power diode rectifiers.
- Software upgrades for LVDAC-EMS and firmware upgrades for the Four-Quadrant Dynamometer/Power Supply and Data Acquisition and Control Interface are available for download free of charge on the Festo Didactic website.

List of Equipment

Qty	Description	Model number
1	DC Power Circuits (Student Manual)	579339 (86350-00)
1	DC Power Circuits (Instructor Guide)	579341 (86350-10)
1	Lead-Acid Batteries (Student Manual)	579343 (86351-00)
1	Lead-Acid Batteries (Instructor Guide)	579345 (86351-10)
1	Solar Power (Student Manual)	579347 (86352-00)
1	Solar Power (Instructor Guide)	579349 (86352-10)
1	Introduction to Wind Power (Student Manual)	579351 (86353-00)
1	Introduction to Wind Power (Instructor Guide)	579353 (86353-10)
1	DC Power Electronics (Student Manual)	579358 (86356-00)
1	DC Power Electronics (Instructor Guide)	579360 (86356-10)
1	Single-Phase AC Power Circuits (Student Manual)	579366 (86358-00)
1	Single-Phase AC Power Circuits (Instructor Guide)	579368 (86358-10)
1	Single-Phase AC Power Electronics (Student Manual)	579370 (86359-00)
1	Single-Phase AC Power Electronics (Instructor Guide)	579372 (86359-10)
1	Home Energy Production (Student Manual)	579385 (86361-00)
1	Home Energy Production (Instructor Guide)	579387 (86361-10)
1	Single-Phase Power Transformer (Student Manual)	579437 (86377-00)
1	Single-Phase Power Transformer (Instructor Guide)	579439 (86377-10)
1	Tabletop Workstation	579484 (8134-20)
1	Wind Turbine Generator/Controller	579487 (8216-00)
1	Resistive Load	763359 (8311-00)
1	Inductive Load	763362 (8321-00)
1	Filtering Inductors/Capacitors	579523 (8325-A0)
1	Capacitive Load	763366 (8331-00)
1	Transformer	763371 (8353-00)
1	AC Power Network Interface	579581 (8622-00)
1	Lead-Acid Batteries	763374 (8801-00)
1	Lead-Acid Battery Pack	579591 (8802-10)
1	Solar Panel Test Bench	579594 (8805-00)
1	Monocrystalline Silicon Solar Panel	579600 (8806-00)
1	Insulated DC-to-DC Converter	579618 (8835-00)

Qty	Description	Model number
1	IGBT Chopper/Inverter	579623 (8837-B0)
1	Rectifier and Filtering Capacitors	579630 (8842-A0)
1	Timing Belt	579637 (8942-00)
1	Connection Lead Set	579638 (8951-L0)
1	Four-Quadrant Dynamometer/Power Supply	579669 (8960-F0)
1	Data Acquisition and Control Interface	579689 (9063-E0)
1	AC 24 V Wall Mount Power Supply	579696 (30004-20)

List of Manuals

Description	Manual number
DC Power Circuits (Workbook)	579339 (86350-00)
DC Power Circuits (Workbook (Instructor))	579341 (86350-10)
Lead-Acid Batteries (Workbook)	579343 (86351-00)
Lead-Acid Batteries (Workbook (Instructor))	579345 (86351-10)
Solar Power (Workbook)	579347 (86352-00)
Solar Power (Workbook (Instructor))	579349 (86352-10)
Introduction to Wind Power (Workbook)	579351 (86353-00)
Introduction to Wind Power (Workbook (Instructor))	579353 (86353-10)
DC Power Electronics (Workbook)	579358 (86356-00)
DC Power Electronics (Workbook (Instructor))	579360 (86356-10)
Single-Phase AC Power Circuits (Workbook)	579366 (86358-00)
Single-Phase AC Power Circuits (Workbook (Instructor))	579368 (86358-10)
Single-Phase AC Power Electronics (Workbook)	579370 (86359-00)
Single-Phase AC Power Electronics (Workbook (Instructor))	579372 (86359-10)
Home Energy Production (Workbook)	579385 (86361-00)
Home Energy Production (Workbook (Instructor))	579387 (86361-10)
Single-Phase Power Transformers (Workbook)	579437 (86377-00)
Single-Phase Power Transformers (Workbook (Instructor))	579439 (86377-10)
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)

Table of Contents of the Manual(s)

DC Power Circuits (Workbook) (579339 (86350-00))

- 1 Voltage, Current, and Ohm’s Law
- 2 Equivalent Resistance
- 3 Power in DC Circuits
- 4 Series and Parallel Circuits

Lead-Acid Batteries (Workbook) (579343 (86351-00))

- 1 Battery Fundamentals
- 2 Discharge Characteristics
- 3 Battery Charging Fundamentals
- 4 Battery Charging Methods

Solar Power (Workbook) (579347 (86352-00))

- 1 The Diode

- 2 The Solar Panel (Photovoltaic Panel)
- 3 Effect of Temperature on Solar Panel Performance
- 4 Storing Energy from Solar Panels into Batteries
- 5 Effect of Shading on Solar Panel Operation
- 6 Solar Panel Orientation
- 7 Solar Panel Performance Versus Insolation

Introduction to Wind Power (Workbook) (579351 (86353-00))

- 1 Voltage-Versus-Speed Characteristic of a Wind Turbine
- 2 Torque-Versus-Current Characteristic of a Wind Turbine
- 3 Power Versus Wind Speed
- 4 Storing the Energy Produced by Wind Turbines in Batteries

DC Power Electronics (Workbook) (579358 (86356-00))

- 1 The Diode and Switching Transistor
- 2 The Buck Chopper
- 3 Introduction to High-Speed Power Switching
- 4 Ripple in Choppers
- 5 The Lead-Acid Battery Charger
- 6 The Boost Chopper
- 7 The Buck/Boost Chopper
- 8 The Four-Quadrant Chopper

Single-Phase AC Power Circuits (Workbook) (579366 (86358-00))

- 1-1 The Sine Wave
- 1-2 Phase Angle and Phase Shift
- 1-3 Instantaneous Power and Average Power
- 2-1 Inductive Reactance
- 2-2 Capacitive reactance
- 2-3 Impedance
- 3-1 Active and Reactive Power
- 3-2 Apparent Power and the Power Triangle
- 4-1 Solving Simple AC Circuits Using Circuit Impedance Calculation
- 4-2 Solving AC Circuits Using the Power Triangle Method

Single-Phase AC Power Electronics (Workbook) (579370 (86359-00))

- 1 Power Diode Single-Phase Rectifiers

- 2 The Single-Phase PWM Inverter

Home Energy Production (Workbook) (579385 (86361-00))

- 1 Stand-Alone Home Energy Production
- 2 Single-Phase Grid-Tied Inverter (PWM Rectifier/Inverter)
- 3 Grid-Tied Home Energy Production Using a Solar or Wind Power Inverter without DC-to-DC Converter
- 4 Grid-Tied Home Energy Production Using a Solar or Wind Power Inverter with DC-to-DC Converter
- 5 Large-Scale Energy Storage: A Step in the Implementation of the Smart Grid

Single-Phase Power Transformers (Workbook) (579437 (86377-00))

- 1 Voltage and Current Ratios
- 2 Transformer Winding Polarity and Interconnection
- 3 Transformer Losses, Efficiency, and Regulation
- 4 Transformer Rating
- 5 Effect of Frequency on Transformer Rating
- 6 The Autotransformer

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

- 1 General Safety Recommendations
- 2 System Power Requirements
- 3 Quick Start Installation Guide
- 4 Equipment Installation
- 5 Modules Handling, Installation, and Removal
- 6 Equipment Maintenance
- A Connection of the Power Supply to the AC Power Network
- B Description, Specifications, and Operation of the EMS Modules

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Digital Multimeter	579782 (8946-20) [18]
1	Heavy-Duty Tripod	583216 (40208-10) [19]

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[18] The data acquisition already includes this function and many more, but the DC Circuits manual references using multimeters.

[19] Required for only one exercise.

Software

Qty	Description	Model number
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 1 User Online, 1 year	586971 (8972-00) [20]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 5 Users Online, 1 year	586974 (8972-A0) [21]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 10 Users Online, 1 year	586977 (8972-B0) [22]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 15 Users Online, 1 year	586980 (8972-C0) [23]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 20 Users Online, 1 year	586983 (8972-D0) [24]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 25 Users Online, 1 year	586986 (8972-E0) [25]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 30 Users Online, 1 year	586989 (8972-F0) [26]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 35 Users Online, 1 year	586992 (8972-G0) [27]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 40 Users Online, 1 year	586995 (8972-H0) [28]
1	SCADA for LVDAC-EMS	8094377 (8973-00) [29]
1	Software Development Kit (SDK)	581459 (9069-90) [30]

System Specifications

Parameter	Value
Power Requirements	
Service Installation	A standard single-phase ac outlet
Computer Requirements	A currently available personal computer with USB 2.0 ports, running under one of the following operating systems: Windows® 7 or Windows® 8.
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment
Dimensions (H x W x D)	900 x 930 x 530 mm (35.4 x 36.6 x 20.9 in)
Net Weight	TBE
EMS Modules	
Full-Size Dimensions (H x W x D)	308 x 287 x 440 mm (12.1 x 11.3 x 17.3 in)
Half-Size Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)

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[20] Simulation software that covers DC, single-phase and 3 phase circuits as well as motors and generators and transmission lines. Doesn't cover Solar, Wind, nor Power Electronics.

[21] Simulation software that covers DC, single-phase and 3 phase circuits as well as motors and generators and transmission lines. Doesn't cover Solar, Wind, nor Power Electronics.

[22] Simulation software that covers DC, single-phase and 3 phase circuits as well as motors and generators and transmission lines. Doesn't cover Solar, Wind, nor Power Electronics.

[23] Simulation software that covers DC, single-phase and 3 phase circuits as well as motors and generators and transmission lines. Doesn't cover Solar, Wind, nor Power Electronics.

[24] Simulation software that covers DC, single-phase and 3 phase circuits as well as motors and generators and transmission lines. Doesn't cover Solar, Wind, nor Power Electronics.

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[26] Simulation software that covers DC, single-phase and 3 phase circuits as well as motors and generators and transmission lines. Doesn't cover Solar, Wind, nor Power Electronics.

[27] Simulation software that covers DC, single-phase and 3 phase circuits as well as motors and generators and transmission lines. Doesn't cover Solar, Wind, nor Power Electronics.

[28] Simulation software that covers DC, single-phase and 3 phase circuits as well as motors and generators and transmission lines. Doesn't cover Solar, Wind, nor Power Electronics.

[29] Software allowing the monitoring of up to 5 Stations through OPC.

[30] Additional firmware for the Data Acquisition.

Hydrogen Fuel Cell Training System
579307 (8010-80)

The Hydrogen Fuel Cell Training System provides a realistic representation of the basic functions of a 50 W hydrogen fuel cell system. It is ideal for teaching the basic engineering principles of fuel cell systems. Realistic, extensive experimenting capabilities and optimized instructional materials make this a comprehensive instruction package. Through practical experiments, students acquire a sound competence in working with fuel cell systems.

The modular design of the Hydrogen Fuel Cell Training System enables flexibility in setup complexity – from simple experiments for teaching basic principles to complex experiments for experienced students. The components and curriculum of the Hydrogen Fuel Cell Training System are offered through a partnership with Heliocentris, the world's leading authority on fuel cells used in education. The system is suitable for hands-on learning in diverse fields of study and occupations, such as:

- Electrical engineering
- Energy engineering
- Process engineering
- Mechanical engineering
- Automotive engineering

The Hydrogen Fuel Cell Training System includes numerous prepared experiments, enabling students to examine the design and functions of a real fuel cell system. It is developed especially for educational purposes, the system being designed for maximum safety and ease of use, even by inexperienced users. With this training system, students explore the engineering principles of a hydrogen fuel cell system, as well as advanced general principles related to the system, including:

- Structure and functioning principles
- Thermodynamics
- Characteristic curves and efficiency ratings
- Power electronics

The Hydrogen Fuel Cell Training System is part of the Electric Power Technology Training Systems, Series 8010. Each training system in Series 8010 is based on the Electric Power Technology Training Program and provides a turn-key solution dealing with some aspects of the wide field of electrical energy. The exhaustive courseware provided with each training system covers all the theory required to perform the laboratory exercises, while review questions and unit tests allow students to test the knowledge they have gained.

The Electric Power Technology Training Program is highly modular in both courseware and hardware. Because of this, courses and equipment from the program are available as required, either individually or in the context of a specific training system. The program covers several different subjects in the field of electrical energy, such as rotating machines, electrical power transmission, power electronics, home energy production from renewable resources (wind and sunlight), large-scale electricity production from hydropower and wind power, smart-grid technologies (SVC, STATCOM, HVDC transmission, etc.), storage of electrical energy in batteries, and drive systems for small electric vehicles and cars.

Exercises

Theory:

- Introduction to the operation of a fuel cell system
- Characteristic curve and output curve of the fuel cell
- Dependence of output on air supply and temperature
- Hydrogen/current characteristic curve of the fuel cell
- Efficiency analyses of the fuel cell stack

Safety:

The Hydrogen Fuel Cell Training System is designed for maximum technical safety. Developed especially for universities and vocational institutions, the system is designed for safe and easy operation by inexperienced and experienced users. In case of overloads or irregularities, the trainer shuts down automatically and locks the hydrogen supply. Therefore, you can take the system to its limits without the risk of safety hazards or damage.

Practice:

- Set-up and operation of an autonomous power supply
- Efficiency of the fuel cell system
- Sample application of independent power supply: How long can a fuel cell supply an autonomous consumer?
- Sample application for fuel cell car: Determination of the fuel consumption based on the load profile

Features & Benefits

- Different test points with digital meters throughout the process for better understanding
- The training system teaches the principles of hydrogen fuel cell operation during both charge and discharge directly in the laboratory.
- The hydrogen fuel cell modules are safe to use and present no risk to system users. The modules are easy to setup by following the procedure detailed in the manuals.
- Sequential loads and fully adjustable loads allow study of hydrogen fuel cell system operation.
- A variety of test points with digital meters are included in the hydrogen fuel cell modules to observe the different processes taking place.
- The course curriculum of the Electric Power Technology Training Program is highly flexible and allows a multitude of different customized training solutions.
- The courseware includes student manuals and instructor guides with all the theory required to perform the hands-on experiments.
- All workstations, modules, and components are very sturdy to ensure a prolonged service life in a demanding environment such as a training laboratory.
- The modular design approach of the training equipment allows a large variety of courses to be performed using a small number of modules, without unnecessary duplication of equipment.
- All electrical components can be interconnected without electric shock hazard since all live parts of the connection leads are concealed and insulated.
- All electrical symbols representing the components used in a laboratory exercise are clearly silk-screened on the front panel of the modules.

List of Equipment

Qty	Description	Model number
1		579355 (86355-00)
1		579356 (86355-10)
1	Three-Module Workstation	579483 (8131-00)
1	Traffic Lights	579574 (8380-00)
1	Electronic Load	579575 (8381-00)
1	Hydrogen Fuel Cell	579593 (8803-00)
1	Hydrogen Cylinder Connection Kit	780548 (52863-00)
1	Hydrogen Storage Canister	579699 (87948-00)

List of Manuals

Description	Manual number
Hydrogen Fuel Cell (Workbook)	579355 (86355-00)
Hydrogen Fuel Cell (Workbook (Instructor))	579356 (86355-10)
Hydrogen Fuel Cell (User Guide)	579357 (86355-E0)
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)

Table of Contents of the Manual(s)

Hydrogen Fuel Cell (Workbook) (579355 (86355-00))

- 3.1 The basic functions of the fuel cell system
- 3.2 The characteristic curve of a fuel cell
- 3.3 Parameters influencing the characteristic curve
- 3.4 Determination of the hydrogen current curve
- 3.5 Efficiency of the fuel cell stack
- 3.6 Set-up of a fuel cell power supply
- 3.7 Efficiency of a fuel cell power supply
- 3.8 Fuel cell application I: Remote traffic light
- 3.9 Fuel cell application II: Fuel cell car

Hydrogen Fuel Cell (User Guide) (579357 (86355-E0))

- 1 Warnings and Safety Instructions
- 1-1 Restricted use
- 1-2 Sources of danger
- 1-3 Authorized operators
- 1-4 Workplace
- 1-5 Safety information about using hydrogen
- 1-6 Safety precautions in an emergency
- 2 Product overview
- 2-1 Basic package
- 2-2 Off-grid package
- 3 Fuel Cell Module FC50
- 3-1 Use
- 3-2 Overview and parts list
- 3-3 Basic functions
- 3-4 Technical data
- 3-5 Hydrogen source

- 3-6 Start-up
- 3-7 Shutting down
- 3-8 Factors affecting operation
- 3-9 Improper modes of operation
- 3-10 Error messages and causes
- 3-11 Maintenance
- 4 Electronic Load Module EL200
- 4-1 Use
- 4-2 Overview and parts list
- 4-3 Basic function
- 4-4 Technical data
- 4-5 Start-up
- 4-6 Manual operation
- 4-7 Computer-assisted operation
- 4-8 Shutting down
- 4-9 Improper modes of operation
- 4-10 Possible malfunctions
- 5 Voltage Converter Module VC100
- 5-1 Use
- 5-2 Overview and parts list
- 5-3 Basic functions
- 5-4 Technical data
- 5-5 Start-up
- 5-6 Maintenance
- 6 Traffic Light Module TL10
- 6-1 Use
- 6-2 Overview
- 6-3 Technical data
- 7 Control software
- 7-1 System requirements
- 7-2 Installation
- 7-3 Running an FC50 Program
- 7-4 Control window (left side)
- 7-5 Warm-up panel
- 7-6 User Interface program
- 7-7 Experiment programs
- 7-8 Automated Experiment programs
- 7-9 Troubleshooting
- 8 Hydrogen Supply I: Connection set for compressed gas cylinders
- 8-1 Use
- 8-2 Overview and parts list
- 8-3 Special safety considerations for handling compressed hydrogen cylinders
- 8-4 Technical data
- 8-5 Basic function
- 8-6 Installation
- 8-7 Pausing and shutting down
- 8-8 Maintenance and repair
- 9 Hydrogen Supply II: Metal hydride storage, with refilling kit

- 9-1 Use
- 9-2 Overview and parts list
- 9-3 Special safety considerations for metal hydride storage canisters
- 9-4 Special safety considerations for handling compressed hydrogen cylinders
- 9-5 In case of fire
- 9-6 Technical data
- 9-7 Basic function
- 9-8 Shipping state, installation and first use of the metal hydride canister
- 9-9 Refilling the metal hydride storage canister with hydrogen
- 9-10 Installation of the metal hydride storage canister on its panel
- 9-11 Using hydrogen from the metal hydride storage canister
- 9-12 Pausing and shutting down
- 9-13 Maintenance and repair
- 10 Hydrogen Supply III: Hydrogen generator with metal hydride storage
- 10-1 Use
- 10-2 Special safety considerations for the hydrogen generator
- 10-3 Overview, scope of supply and operation
- 11 Warranty and complaints

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

- 1 General Safety Recommendations
- 2 System Power Requirements
- 3 Quick Start Installation Guide
- 4 Equipment Installation
- 5 Modules Handling, Installation, and Removal
- 6 Equipment Maintenance
- A Connection of the Power Supply to the AC Power Network
- B Description, Specifications, and Operation of the EMS Modules

System Specifications

Parameter	Value
Power Requirements	
Service Installation	A standard single-phase ac outlet
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment
Dimensions (H x W x D)	900 x 930 x 530 mm (35.4 x 36.6 x 20.9 in)
Net Weight	TBE
EMS Modules	
Full-Size Dimensions (H x W x D)	308 x 287 x 440 mm (12.1 x 11.3 x 17.3 in)
Half-Size Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)

Electromechanical Training System
579308 (8010-90)

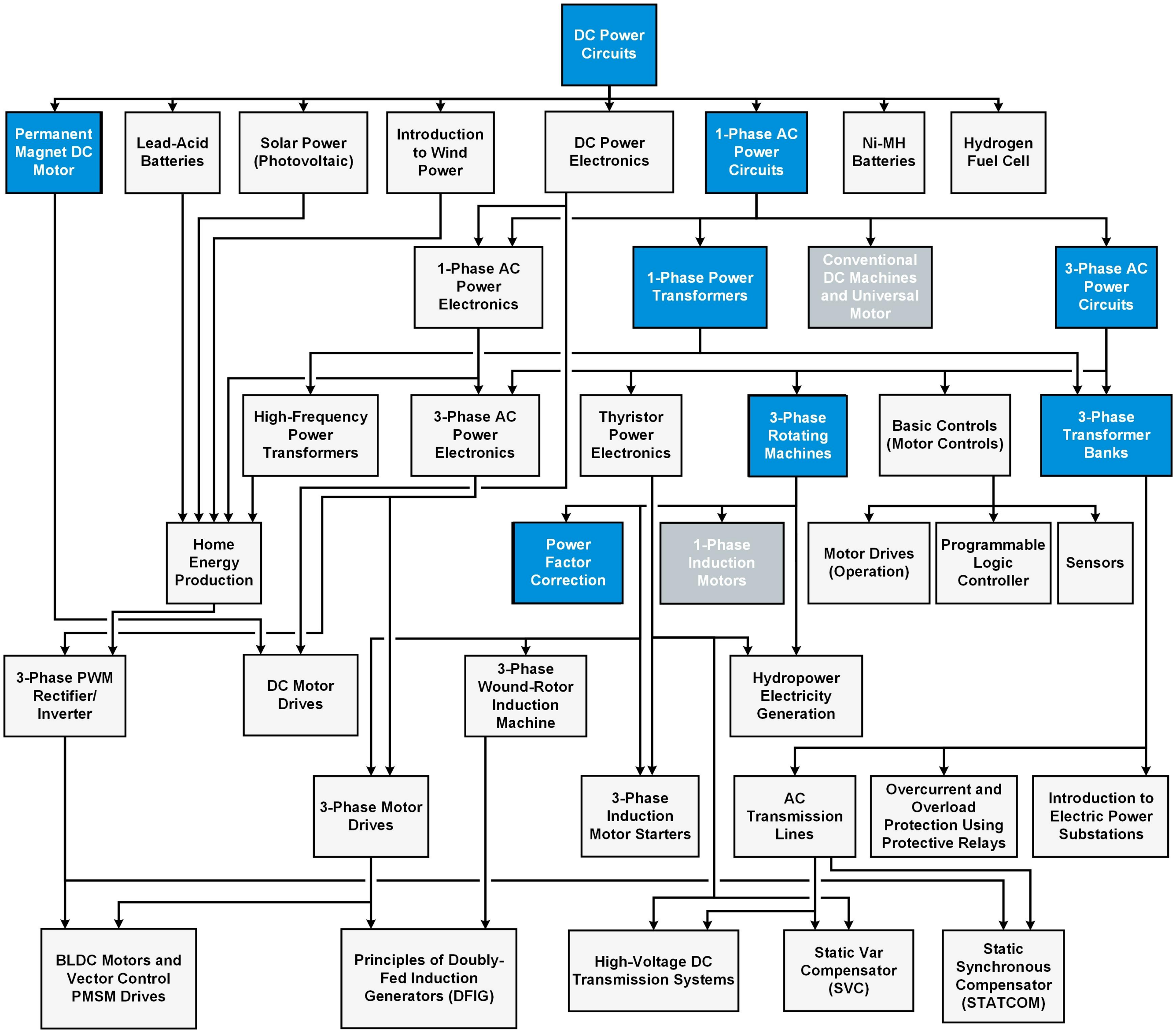
The Electromechanical Training System combines a modular design approach with computer-based data acquisition and control to provide unrivaled training in electromechanical systems. Training is oriented toward today's competence requirements, including electricity fundamentals (i.e., dc power circuits), single-phase and three-phase ac power circuits, power transformers, three-phase transformer banks, permanent magnet dc motors, three-phase rotating machines (induction machine and synchronous machine), and power factor correction. The system features the Four-Quadrant Dynamometer/Power Supply, and the Data Acquisition and Control Interface, two state-of-the-art USB peripherals that greatly enhance the learning experience of students.

The courseware in the Electromechanical Training System provides students with a sound knowledge of basic electric power technology, including the operation of the permanent magnet dc motor, three-phase induction machine, and three-phase synchronous machine, three rotating machines that are commonly used in numerous applications today.

Two other rotating machine courses from the Electric Power Technology Training Program can be optionally added to the Electromechanical Training System. These courses complete student training in rotating machinery by adding knowledge of the following conventional rotating machines: separately excited, shunt, series, and compound dc motors, separately excited, shunt, and compound dc generators, universal motor, and single-phase induction motor (capacitor-start and split-phase types). These machines, although still in use today, are less common in modern applications.

The Electromechanical Training System is part of the Electric Power Technology Training Systems, Series 8010. Each training system in Series 8010 is based on the Electric Power Technology Training Program and provides a turn-key solution dealing with some aspects of the wide field of electrical energy. The exhaustive courseware provided with each training system covers all the theory required to perform the laboratory exercises, while review questions and unit tests allow students to test the knowledge they have gained.

The Electric Power Technology Training Program is highly modular in both courseware and hardware. Because of this, courses and equipment from the program are available as required, either individually or in the context of a specific training system. The program covers several different subjects in the field of electrical energy, such as rotating machines, electrical power transmission, power electronics, home energy production from renewable resources (wind and sunlight), large-scale electricity production from hydropower and wind power, smart-grid technologies (SVC, STATCOM, HVDC transmission, etc.), storage of electrical energy in batteries, and drive systems for small electric vehicles and cars.


DC Power Circuits
Permanent Magnet DC Motor
Lead-Acid Batteries
Solar Power (Photovoltaic)
Introduction to Wind Power
DC Power Electronics
1-Phase AC Power Circuits
Ni-MH Batteries
Hydrogen Fuel Cell
1-Phase AC Power Electronics
1-Phase Power Transformers
Conventional DC Machines and Universal Motor
3-Phase AC Power Circuits
High-Frequency Power Transformers
3-Phase AC Power Electronics
Thyristor Power Electronics
3-Phase Rotating Machines
Basic Controls (Motor Controls)
3-Phase Transformer Banks
Home Energy Production
Power Factor Correction
1-Phase Induction Motors
Motor Drives (Operation)
Programmable Logic Controller
Sensors
3-Phase PWM Rectifier/ Inverter
DC Motor Drives
3-Phase Wound-Rotor Induction Machine
Hydropower Electricity Generation
3-Phase Motor Drives
3-Phase Induction Motor Starters
AC Transmission Lines
Overcurrent and Overload Protection Using Protective Relays
Introduction to Electric Power Substations
BLDC Motors and Vector Control PMSM Drives
Principles of Doubly-Fed Induction Generators (DFIG)
High-Voltage DC Transmission Systems
Static Var Compensator (SVC)
Static Synchronous Compensator (STATCOM)

The above chart shows all courses in the Electric Power Technology Training Program. Blue boxes highlight courses included in the training system covered in this datasheet, while dark grey boxes, if any, highlight courses that can be optionally added to this training system.

Courseware

Each course in the training system includes a full-color student manual providing all the theoretical matter required, guided lab-exercise procedures to be performed with the training equipment, and review questions that test the knowledge gained by the student. Whenever possible, each course is built to bring the student to actual applications as soon as possible. A full-color instructor guide providing all lab results and answers to questions is also included with each course.

Modular Design Approach

The modular approach for designing the training program and lab equipment enables instructors to start building their electrical-energy laboratory with a basic package of courses and equipment and add new courses and equipment over time without needless duplication of equipment.

All lab equipment consists of modules that can be inserted into a workstation. Module dimensions vary between two standard EMS sizes: full-size and half-size. Symbols and diagrams representing the electrical components in each module are clearly silk-screened on the front panel. Standard, color-coded safety banana jacks are used to provide access to the various components in each module.

Features & Benefits

- The training system teaches the principles of three-phase rotating machines. To this end, students follow a complete curriculum that includes these topics:
    - An introduction to the fundamentals of electricity, beginning with dc power circuits and ac power circuits.
    - More advanced courses that cover different concepts and devices important to the study of three-phase rotating machines, such as single-phase and three-phase ac power circuits, single-phase and three-phase power transformers, and power factor correction.
    - Courses that cover the operation of different rotating machines, such as permanent-magnet dc motors, induction machines, and synchronous machines.
    - Optional courses that cover less common machines, such as conventional dc machines, universal motors, and single-phase induction motors.
- The course curriculum of the Electric Power Technology Training Program is highly flexible and allows a multitude of different customized training solutions.
- The courseware includes student manuals and instructor guides with all the theory required to perform the hands-on experiments.
- All workstations, modules, and components are very sturdy to ensure a prolonged service life in a demanding environment such as a training laboratory.
- The modular design approach of the training equipment allows a large variety of courses to be performed using a small number of modules, without unnecessary duplication of equipment.
- All electrical components can be interconnected without electric shock hazard since all live parts of the connection leads are concealed and insulated.
- All electrical symbols representing the components used in a laboratory exercise are clearly silk-screened on the front panel of the modules.
- The training system includes two highly versatile USB peripherals:
    - Four-Quadrant Dynamometer/Power Supply, Model 8960-2. This module is used as a dc and ac power source. it can also be mechanically coupled to all rotating machines to operate as a prime mover or brake.

  - Data Acquisition and Control Interface, Model 9063. This module gives access to a large variety of computer-based measuring instruments via the LVDAC-EMS software.
- Software upgrades for LVDAC-EMS and firmware upgrades for the Four-Quadrant Dynamometer/Power Supply and Data Acquisition and Control Interface are available for download free of charge on the Festo Didactic website.

List of Equipment

Qty	Description	Model number
1	Permanent Magnet DC Motor (Instructor Guide)	8113732 (81137-32)
1	Permanent Magnet DC Motor (Student Manual)	8113734 (81137-34)
1	Power Factor Correction (Student Manual)	579334 (20116-00)
1	Power Factor Correction (Instructor Guide)	579335 (20116-10)
1	DC Power Circuits (Student Manual)	579339 (86350-00)
1	DC Power Circuits (Instructor Guide)	579341 (86350-10)
1	Single-Phase AC Power Circuits (Student Manual)	579366 (86358-00)
1	Single-Phase AC Power Circuits (Instructor Guide)	579368 (86358-10)
1	Three-Phase AC Power Circuits (Student Manual)	579374 (86360-00)
1	Three-Phase AC Power Circuits (Instructor Guide)	579378 (86360-10)
1	Three-Phase Rotating Machines (Student Manual)	579407 (86364-00)
1	Three-Phase Rotating Machines (Instructor Guide)	579409 (86364-10)
1	Single-Phase Power Transformer (Student Manual)	579437 (86377-00)
1	Single-Phase Power Transformer (Instructor Guide)	579439 (86377-10)
1	Three-Phase Transformer Banks (Student Manual)	579448 (86379-00)
1	Three-Phase Transformer Banks (Instructor Guide)	579451 (86379-10)
1	Tabletop Workstation	579484 (8134-20)
1	Permanent Magnet DC Motor	8114247 (8213-10)
1	Four-Pole Squirrel Cage Motor	586267 (8221-20)
1	Three-Phase Synchronous Motor/Generator	579502 (8241-20)
1	Resistive Load	763359 (8311-00)
1	Inductive Load	763362 (8321-00)
1	Capacitive Load	763366 (8331-00)
1	Three-Phase Transformer Bank	579559 (8348-40)
1	Transformer	763371 (8353-00)
1	Synchronizing Module / Three-Phase Contactor	8204391 (8621-B0)
1	Lead-Acid Battery Pack	579591 (8802-10)
1	Three-Phase Power Supply	579612 (8823-00)
1	Timing Belt	579637 (8942-00)
1	Connection Lead Set	579638 (8951-L0)
1	Four-Quadrant Dynamometer / Power Supply with Manual and Computer-Based Control	579648 (8960-C0)
1	Data Acquisition and Control Interface	579692 (9063-G0)
1	AC 24 V Wall Mount Power Supply	579696 (30004-20)

List of Manuals

Description	Manual number
Power Factor Correction (Workbook)	579334 (20116-00)
Power Factor Correction (Workbook (Instructor))	579335 (20116-10)

Description	Manual number
DC Power Circuits (Workbook)	579339 (86350-00)
DC Power Circuits (Workbook (Instructor))	579341 (86350-10)
Single-Phase AC Power Circuits (Workbook)	579366 (86358-00)
Single-Phase AC Power Circuits (Workbook (Instructor))	579368 (86358-10)
Three-Phase AC Power Circuits (Workbook)	579374 (86360-00)
Three-Phase AC Power Circuits (Workbook (Instructor))	579378 (86360-10)
Three-Phase Rotating Machines (Workbook)	579407 (86364-00)
Three-Phase Rotating Machines (Workbook (Instructor))	579409 (86364-10)
Single-Phase Power Transformers (Workbook)	579437 (86377-00)
Single-Phase Power Transformers (Workbook (Instructor))	579439 (86377-10)
Three-Phase Transformer Banks (Workbook)	579448 (86379-00)
Three-Phase Transformer Banks (Workbook (Instructor))	579451 (86379-10)
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)
Permanent Magnet DC Machine (Workbook (Instructor))	8113732 (81137-32)
Permanent Magnet DC Machine (Workbook)	8113734 (81137-34)

Table of Contents of the Manual(s)

Power Factor Correction (Workbook) (579334 (20116-00))

- 1 Power Factor Correction

DC Power Circuits (Workbook) (579339 (86350-00))

- 1 Voltage, Current, and Ohm's Law
- 2 Equivalent Resistance
- 3 Power in DC Circuits
- 4 Series and Parallel Circuits

Single-Phase AC Power Circuits (Workbook) (579366 (86358-00))

- 1-1 The Sine Wave
- 1-2 Phase Angle and Phase Shift
- 1-3 Instantaneous Power and Average Power
- 2-1 Inductive Reactance
- 2-2 Capacitive reactance
- 2-3 Impedance
- 3-1 Active and Reactive Power
- 3-2 Apparent Power and the Power Triangle
- 4-1 Solving Simple AC Circuits Using Circuit Impedance Calculation
- 4-2 Solving AC Circuits Using the Power Triangle Method

Three-Phase AC Power Circuits (Workbook) (579374 (86360-00))

- 1 Three-Phase Circuits
- 2 Three-Phase Power Measurement
- 3 Phase Sequence

Three-Phase Rotating Machines (Workbook) (579407 (86364-00))

- 1-1 Prime Mover and Brake Operation
- 2-1 The Three-Phase Squirrel-Cage Induction Motor
- 2-2 Eddy-Current Brake and Asynchronous Generator
- 3-1 The Three-Phase Synchronous Motor
- 3-2 Synchronous Motor Pull-Out Torque
- 4-1 Three-Phase Synchronous Generator No-Load Operation
- 4-2 Voltage Regulation Characteristics
- 4-3 Generator Synchronization

Single-Phase Power Transformers (Workbook) (579437 (86377-00))

- 1 Voltage and Current Ratios
- 2 Transformer Winding Polarity and Interconnection
- 3 Transformer Losses, Efficiency, and Regulation
- 4 Transformer Rating
- 5 Effect of Frequency on Transformer Rating
- 6 The Autotransformer

Three-Phase Transformer Banks (Workbook) (579448 (86379-00))

- 1 Three-Phase Transformer Configurations

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

- 1 General Safety Recommendations
- 2 System Power Requirements
- 3 Quick Start Installation Guide
- 4 Equipment Installation
- 5 Modules Handling, Installation, and Removal
- 6 Equipment Maintenance
- A Connection of the Power Supply to the AC Power Network
- B Description, Specifications, and Operation of the EMS Modules

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Permanent Magnet DC Machine (Workbook (Instructor)) (8113732 (81137-32))

- 0 Introduction to Permanent Magnet DC Machines

- 1 Prime Mover and Brake Operation
- 2 Permanent Magnet DC Machine Operating as a Generator
- 3 Permanent Magnet DC Machine Operating as a Motor

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Digital Multimeter	579782 (8946-20) [31]

Software

Qty	Description	Model number
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 1 User Online, 1 year	586971 (8972-00) [32]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 5 Users Online, 1 year	586974 (8972-A0) [33]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 10 Users Online, 1 year	586977 (8972-B0) [34]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 15 Users Online, 1 year	586980 (8972-C0) [35]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 20 Users Online, 1 year	586983 (8972-D0) [36]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 25 Users Online, 1 year	586986 (8972-E0) [37]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 30 Users Online, 1 year	586989 (8972-F0) [38]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 35 Users Online, 1 year	586992 (8972-G0) [39]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 40 Users Online, 1 year	586995 (8972-H0) [40]
1	SCADA for LVDAC-EMS	8094377 (8973-00) [41]
1	Software Development Kit (SDK)	581459 (9069-90) [42]

System Specifications

Parameter	Value
System Requirements	
Maximum Current	10 A
Typical Current	1.5 A per student group

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[31] The data acquisition already includes this function and many more, but the DC Circuits manual references using multimeters.

[32] Simulation software that covers these topics as well as transmission lines.

[33] Simulation software that covers these topics as well as transmission lines.

[34] Simulation software that covers these topics as well as transmission lines.

[35] Simulation software that covers these topics as well as transmission lines.

[36] Simulation software that covers these topics as well as transmission lines.

[37] Simulation software that covers these topics as well as transmission lines.

[38] Simulation software that covers these topics as well as transmission lines.

[39] Simulation software that covers these topics as well as transmission lines.

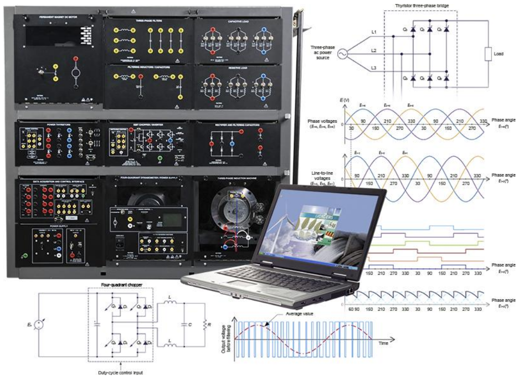
[40] Simulation software that covers these topics as well as transmission lines.

[41] Software allowing the monitoring of up to 5 Stations through OPC.

[42] Additional firmware for the Data Acquisition.

Parameter	Value
AC Power Network Installation	3 phases (120/208 V – 60 Hz), star (wye) configuration including neutral and ground wires, protected by a 20 A circuit breaker
AC Power Network Connector	NEMA L21-20
Computer Requirements	A currently available personal computer with USB 2.0 ports, running under one of the following operating systems: Windows® 7 or Windows® 8.
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment
Dimensions (H x W x D)	900 x 930 x 530 mm (35.4 x 36.6 x 20.9 in)
Net Weight	205 kg (451 lb)
EMS Modules	
Full-Size Dimensions (H x W x D)	308 x 287 x 440 mm (12.1 x 11.3 x 17.3 in)
Half-Size Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)

Power Electronics Training System
579314 (8010-A0)



The Power Electronics Training System combines a modular design approach with computer-based data acquisition and control to provide unrivaled training in power electronics to students already having a sound knowledge of basic electric power technology. The system features the Four-Quadrant Dynamometer/Power Supply and the Data Acquisition and Control Interface, two state-of-the-art USB peripherals that greatly enhance the learning experience of students.

Training begins with the following four courses:

- DC Power Electronics

- Single-Phase AC Power Electronics

- Three-Phase AC Power Electronics

- Thyristor Power Electronics

These courses introduce the student to the most common power electronic components (power diode, thyristor, and power transistor) as well as to many power electronic devices used in numerous applications today (power diode single-phase and three-phase rectifiers, choppers, single-phase and three-phase inverters, thyristor single-phase and three-phase bridges, solid-state relays or SSRs, and thyristor ac power controllers). Training continues with the following three courses which deal with common industrial applications using power electronics:

- DC Motor Drives

- Three-Phase Motor Drives

- Three-Phase Induction Motor Starters

The following two courses from the Electric Power Technology Training Program, can be optionally added to the Power Electronics Training System to enhance student training in power electronic applications:

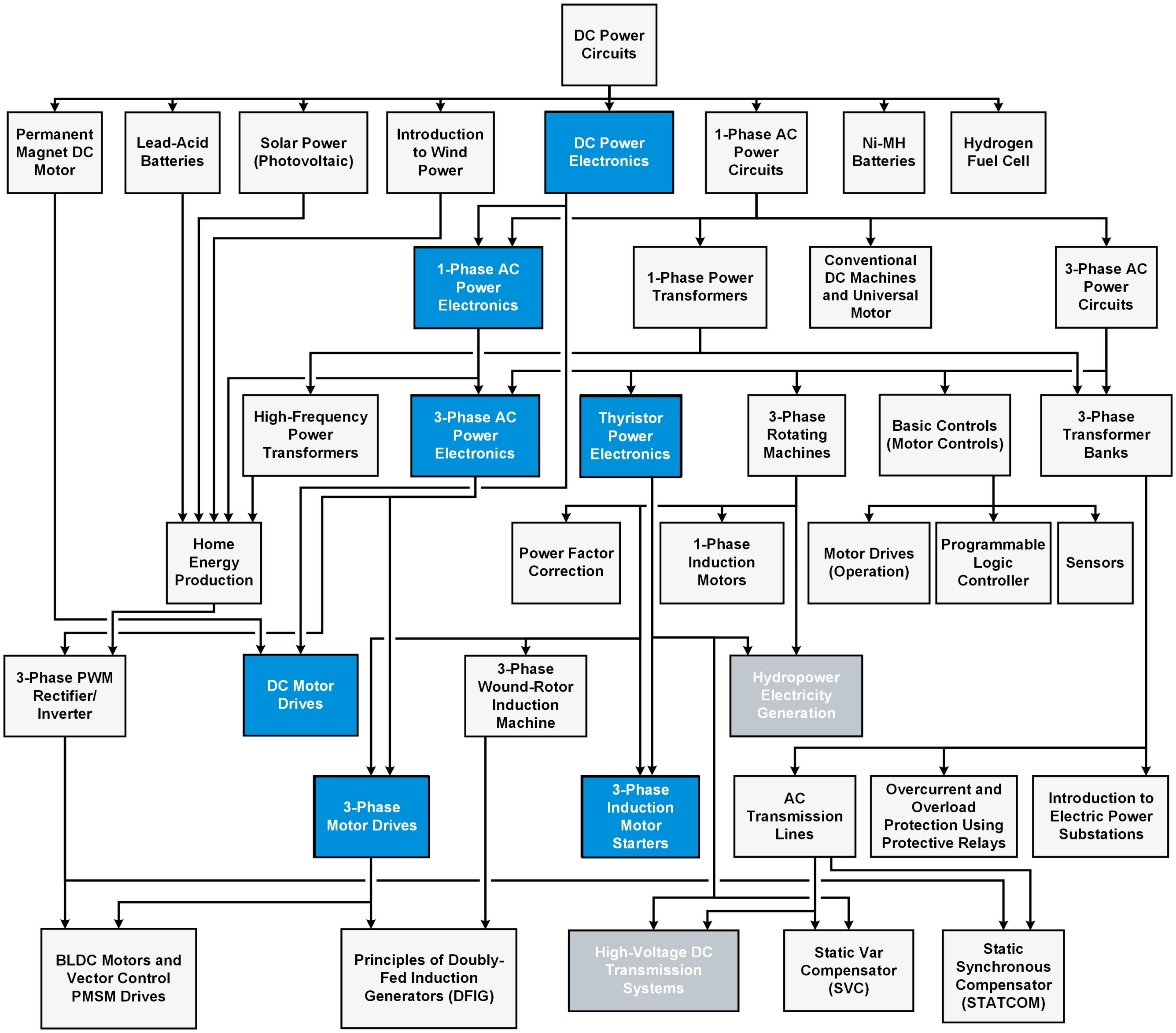
- Hydropower Electricity Generation

- High-Voltage DC Transmission Systems

These two courses familiarize the student with the use of hydropower to produce electrical power using synchronous generators, as well as with the transmission of large amounts of electrical power using high-voltage, direct-current (HVDC) lines, two advanced applications using thyristor power electronics.

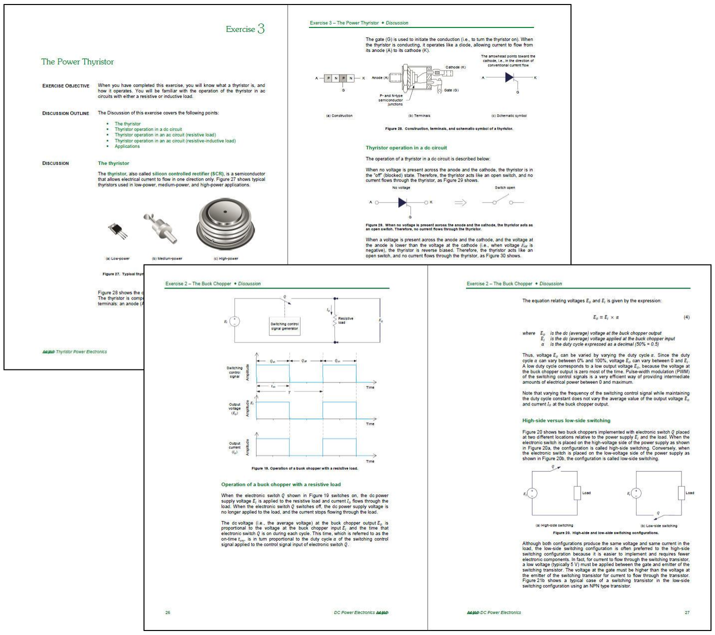
The Power Electronics Training System is part of the Electric Power Technology Training Systems, Series 8010. Each training system in Series 8010 is based on the Electric Power Technology Training Program and provides a turn-key solution dealing with some aspects of the wide field of electrical energy. The exhaustive courseware provided with each training system covers all the theory required to perform the laboratory exercises, while review questions and unit tests allow students to test the knowledge they have gained.

The Electric Power Technology Training Program is highly modular in both courseware and hardware. Because of this, courses and equipment from the program are available as required, either individually or in the context of a specific training system. The program covers several different subjects in the field of electrical energy, such as rotating machines, electrical power transmission, power electronics, home energy production from renewable resources (wind and sunlight), large-scale electricity production from hydropower and wind power, smart-grid technologies (SVC, STATCOM, HVDC transmission, etc.), storage of electrical energy in batteries, and drive systems for small electric vehicles and cars.


DC Power Circuits
Permanent Magnet DC Motor
Lead-Acid Batteries
Solar Power (Photovoltaic)
Introduction to Wind Power
DC Power Electronics
1-Phase AC Power Circuits
Ni-MH Batteries
Hydrogen Fuel Cell
1-Phase AC Power Electronics
1-Phase Power Transformers
Conventional DC Machines and Universal Motor
3-Phase AC Power Circuits
High-Frequency Power Transformers
3-Phase AC Power Electronics
Thyristor Power Electronics
3-Phase Rotating Machines
Basic Controls (Motor Controls)
3-Phase Transformer Banks
Home Energy Production
Power Factor Correction
1-Phase Induction Motors
Motor Drives (Operation)
Programmable Logic Controller
Sensors
3-Phase PWM Rectifier/ Inverter
DC Motor Drives
3-Phase Wound-Rotor Induction Machine
Hydropower Electricity Generation
3-Phase Motor Drives
3-Phase Induction Motor Starters
AC Transmission Lines
Overcurrent and Overload Protection Using Protective Relays
Introduction to Electric Power Substations
BLDC Motors and Vector Control PMSM Drives
Principles of Doubly-Fed Induction Generators (DFIG)
High-Voltage DC Transmission Systems
Static Var Compensator (SVC)
Static Synchronous Compensator (STATCOM)

The above chart shows all courses in the Electric Power Technology Training Program. Blue boxes highlight courses included in the training system covered in this datasheet, while dark grey boxes, if any, highlight courses that can be optionally added to this training system.

Courseware


Exercise 3

The Power Thyristor

EXERCISE OBJECTIVE When you have completed this exercise, you will know what a thyristor is, and how it operates. You will be familiar with the operation of the thyristor in ac circuits with either a resistive or inductive load.

DISCUSSION OUTLINE The Discussion of this exercise covers the following points:

- The thyristor
- Thyristor operation in a dc circuit
- Thyristor operation in an ac circuit (resistive load)
- Thyristor operation in an ac circuit (resistive-inductive load)
- Applications

DISCUSSION **The thyristor**

The **thyristor**, also called **silicon controlled rectifier (SCR)**, is a semiconductor that allows electrical current to flow in one direction only. Figure 27 shows typical thyristors used in low-power, medium-power, and high-power applications.

(a) Low-power (b) Medium-power (c) High-power

Figure 27. Typical thyr

Figure 28 shows the c
The thyristor is comp
terminals: an anode (A

Thyristor Power Electronics

Exercise 3 – The Power Thyristor ◆ *Discussion*

The gate (G) is used to initiate the conduction (i.e., to turn the thyristor on). When the thyristor is conducting, it operates like a diode, allowing current to flow from its anode (A) to its cathode (K).

A
P
N
P
N
K
G
Anode (A)
Cathode (K)
Gate (G)
P- and N-type semiconductor junctions
The arrowhead points toward the cathode, i.e., in the direction of conventional current flow
A
K
G

(a) Construction (b) Terminals (c) Schematic symbol

Figure 28. Construction, terminals, and schematic symbol of a thyristor.

Thyristor operation in a dc circuit

The operation of a thyristor in a dc circuit is described below:

When no voltage is present across the anode and the cathode, the thyristor is in the "off" (blocked) state. Therefore, the thyristor acts like an open switch, and no current flows through the thyristor, as Figure 29 shows.

Figure 29. When no voltage is present across the anode and the cathode, the thyristor acts as an open switch. Therefore, no current flows through the thyristor.

When a voltage is present across the anode and the cathode, and the voltage at the anode is lower than the voltage at the cathode (i.e., when voltage E_{AK} is negative), the thyristor is reverse biased. Therefore, the thyristor acts like an open switch, and no current flows through the thyristor, as Figure 30 shows.

Exercise 2 – The Buck Chopper ◆ *Discussion*

Figure 19. Operation of a buck chopper with a resistive load.

Operation of a buck chopper with a resistive load

When the electronic switch Q shown in Figure 19 switches on, the dc power supply voltage E_I is applied to the resistive load and current I_O flows through the load. When the electronic switch Q switches off, the dc power supply voltage is no longer applied to the load, and the current stops flowing through the load.

The dc voltage (i.e., the average voltage) at the buck chopper output E_O is proportional to the voltage at the buck chopper input E_I and the time that electronic switch Q is on during each cycle. This time, which is referred to as the on-time t_{on}, is in turn proportional to the duty cycle α of the switching control signal applied to the control signal input of electronic switch Q.

26 DC Power Electronics

Exercise 2 – The Buck Chopper ◆ *Discussion*

The equation relating voltages E_O and E_I is given by the expression:

$$E_O = E_I \times \alpha \qquad (4)$$

where E_O *is the dc (average) voltage at the buck chopper output*
E_I *is the dc (average) voltage applied at the buck chopper input*
α *is the duty cycle expressed as a decimal (50% = 0.5)*

Thus, voltage E_O can be varied by varying the duty cycle α. Since the duty cycle α can vary between 0% and 100%, voltage E_O can vary between 0 and E_I. A low duty cycle corresponds to a low output voltage E_O, because the voltage at the buck chopper output is zero most of the time. Pulse-width modulation (PWM) of the switching control signals is a very efficient way of providing intermediate amounts of electrical power between 0 and maximum.

Note that varying the frequency of the switching control signal while maintaining the duty cycle constant does not vary the average value of the output voltage E_O and current I_O at the buck chopper output.

High-side versus low-side switching

Figure 20 shows two buck choppers implemented with electronic switch Q placed at two different locations relative to the power supply E_I and the load. When the electronic switch is placed on the high-voltage side of the power supply as shown in Figure 20a, the configuration is called high-side switching. Conversely, when the electronic switch is placed on the low-voltage side of the power supply as shown in Figure 20b, the configuration is called low-side switching.

(a) High-side switching (b) Low-side switching

Figure 20. High-side and low-side switching configurations.

Although both configurations produce the same voltage and same current in the load, the low-side switching configuration is often preferred to the high-side switching configuration because it is easier to implement and requires fewer electronic components. In fact, for current to flow through the switching transistor, a low voltage (typically 5 V) must be applied between the gate and emitter of the switching transistor. The voltage at the gate must be higher than the voltage at the emitter of the switching transistor for current to flow through the transistor. Figure 21b shows a typical case of a switching transistor in the low-side switching configuration using an NPN type transistor.

DC Power Electronics 27

Each course in the training system includes a full-color student manual providing all the theoretical matter required, guided lab-exercise procedures to be performed with the training equipment, and review questions that test the knowledge gained by the student. Whenever possible, each course is built to bring the student to actual applications as soon as possible. A full-color instructor guide providing all lab results and answers to questions is also included with each course.

Modular Design Approach

The modular approach for designing the training program and lab equipment enables instructors to start building their electrical-energy laboratory with a basic package of courses and equipment and add new courses and equipment over time without needless duplication of equipment.

All lab equipment consists of modules that can be inserted into a workstation. Module dimensions vary between two standard EMS sizes: full-size and half-size. Symbols and diagrams representing the electrical components in each module are clearly silk-screened on the front panel. Standard, color-coded safety banana jacks are used to provide access to the various components in each module.

Features & Benefits

- The training system teaches the principles of dc and ac power electronics. To this end, students follow a complete curriculum that includes these topics:
    - Courses that cover the operation of various power electronics devices, both dc and ac, as well as single-phase and three-phase.
    - Courses that cover a variety of common power electronics applications, such as dc motor drives, three-phase motor drives, and three-phase induction motor starters.
    - Optional courses that cover advanced applications of power electronics, such as hydropower electricity generation, and HVDC transmission systems.

- All control of power electronics devices is computerized via the LVDAC-EMS software, allowing for user-friendly operation, high configurability, and ease of monitoring.
- Video presentations of several power electronics control functions used in the training system are available on Youtube.
- The course curriculum of the Electric Power Technology Training Program is highly flexible and allows a multitude of different customized training solutions.
- The courseware includes student manuals and instructor guides with all the theory required to perform the hands-on experiments.
- All workstations, modules, and components are sturdy and protected against electrical damage to ensure a prolonged service life in a demanding environment such as a training laboratory.
- The modular design approach of the training equipment allows a large variety of courses to be performed using a small number of modules, without unnecessary duplication of equipment.
- All electrical components can be interconnected without electric shock hazard since all live parts of the connection leads are concealed and insulated.
- All electrical symbols representing the components used in a laboratory exercise are clearly silk-screened on the front panel of the modules.
- The training system includes two highly versatile USB peripherals:
    - Four-Quadrant Dynamometer/Power Supply, Model 8960-2. This module is used as a dc power source and a battery charger/discharger with a large variety of configurable parameters. It can also be used as an overnight battery float charger.
    - Data Acquisition and Control Interface, Model 9063. This module gives access to a large variety of computer-based measuring instruments and is used to control the various dc power electronics devices. All functions are implemented via the LVDAC-EMS software.
- The training system also includes three highly versatile power electronics modules controlled using the Data Acquisition and Control Interface:
    - IGBT Chopper/Inverter, Model 8837-B. This module is used to implement various types of choppers and inverters.
    - Power Thyristors, Model 8841. This module is used to implement various thyristor-based devices (e.g., bridges, ac power controllres, solid-state relays)
    - Rectifier and Filtering Capacitors, Model 8842-A. This module is used to implement various types of power diode rectifiers.
- Software upgrades for LVDAC-EMS and firmware upgrades for the Four-Quadrant Dynamometer/Power Supply and Data Acquisition and Control Interface are available for download free of charge on the Festo Didactic website.

List of Equipment

Qty	Description	Model number
1	DC Motor Drives (Instructor Guide)	8113740 (81137-40)
1	DC Motor Drives (Student Manual)	8113742 (81137-42)
1	DC Power Electronics (Student Manual)	579358 (86356-00)
1	DC Power Electronics (Instructor Guide)	579360 (86356-10)
1	Single-Phase AC Power Electronics (Student Manual)	579370 (86359-00)
1	Single-Phase AC Power Electronics (Instructor Guide)	579372 (86359-10)
1	Three-Phase AC Power Electronics (Student Manual)	579393 (86362-00)
1	Three-Phase AC Power Electronics (Instructor Guide)	579395 (86362-10)
1	Thyristor Power Electronics (Student Manual)	579402 (86363-00)
1	Thyristor Power Electronics (Instructor Guide)	579403 (86363-10)

Qty	Description	Model number
1	Three-Phase Motor Drives (Student Manual)	579426 (86368-00)
1	Three-Phase Motor Drives (Instructor Guide)	579427 (86368-10)
1	Three-Phase Motor Starters (Student Manual)	579462 (88197-00)
1	Three-Phase Motor Starters (Instructor Guide)	579463 (88197-10)
1	Tabletop Workstation	579484 (8134-20)
1	Permanent Magnet DC Motor	8114247 (8213-10)
1	Four-Pole Squirrel Cage Motor	586267 (8221-20)
1	Resistive Load	763359 (8311-00)
1	Filtering Inductors/Capacitors	579523 (8325-A0)
1	Three-Phase Filter	579529 (8326-00)
1	Capacitive Load	763366 (8331-00)
1	Three-Phase Transformer Bank	579559 (8348-40)
1	Synchronizing Module / Three-Phase Contactor	8204391 (8621-B0)
1	Lead-Acid Battery Pack	579591 (8802-10)
1	Three-Phase Power Supply	579612 (8823-00)
1	IGBT Chopper/Inverter	579623 (8837-B0)
1	Power Thyristors	763376 (8841-20)
1	Rectifier and Filtering Capacitors	579630 (8842-A0)
1	Timing Belt	579637 (8942-00)
1	Connection Lead Set	579638 (8951-L0)
1	Four-Quadrant Dynamometer/Power Supply	579662 (8960-E0)
1	Data Acquisition and Control Interface	579686 (9063-D0)
1	AC 24 V Wall Mount Power Supply	579696 (30004-20)

List of Manuals

Description	Manual number
DC Power Electronics (Workbook)	579358 (86356-00)
DC Power Electronics (Workbook (Instructor))	579360 (86356-10)
Single-Phase AC Power Electronics (Workbook)	579370 (86359-00)
Single-Phase AC Power Electronics (Workbook (Instructor))	579372 (86359-10)
Three-Phase AC Power Electronics (Workbook)	579393 (86362-00)
Three-Phase AC Power Electronics (Workbook (Instructor))	579395 (86362-10)
Thyristor Power Electronics (Workbook)	579402 (86363-00)
Thyristor Power Electronics (Workbook (Instructor))	579403 (86363-10)
Three-Phase Motor Drives (Workbook)	579426 (86368-00)
Three-Phase Motor Drives (Workbook (Instructor))	579427 (86368-10)
Three-Phase Induction Motor Starters (Workbook)	579462 (88197-00)
Three-Phase Induction Motor Starters (Workbook (Instructor))	579463 (88197-10)
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)
DC Motor Drives (Workbook (Instructor))	8113740 (81137-40)
DC Motor Drives (Workbook)	8113742 (81137-42)

Table of Contents of the Manual(s)

DC Power Electronics (Workbook) (579358 (86356-00))

- 1 The Diode and Switching Transistor

- 2 The Buck Chopper
- 3 Introduction to High-Speed Power Switching
- 4 Ripple in Choppers
- 5 The Lead-Acid Battery Charger
- 6 The Boost Chopper
- 7 The Buck/Boost Chopper
- 8 The Four-Quadrant Chopper

Single-Phase AC Power Electronics (Workbook) (579370 (86359-00))

- 1 Power Diode Single-Phase Rectifiers
- 2 The Single-Phase PWM Inverter

Three-Phase AC Power Electronics (Workbook) (579393 (86362-00))

- 1 Power Diode Three-Phase Rectifiers
- 2 The Single-Phase PWM Inverter with Dual-Polarity DC Bus
- 3 The Three-Phase PWM Inverter

Thyristor Power Electronics (Workbook) (579402 (86363-00))

- 1 Power Diode Single-Phase Rectifiers
- 2 Power Diode Three-Phase Rectifiers
- 3 The Power Thyristor
- 4 The Solid State Relay
- 5 Single-Phase AC Power Control
- 6 Three-Phase AC Power Control
- 7 Thyristor Three-Phase Rectifier/Inverter

Three-Phase Motor Drives (Workbook) (579426 (86368-00))

- 1 Three-Phase, Variable-Frequency Induction-Motor Drive
- 2 Three-Phase, Variable-Frequency Induction-Motor Drive with Constant V/f ratio

Three-Phase Induction Motor Starters (Workbook) (579462 (88197-00))

- 1 DOL Starters and Soft Starters
- 2 Advanced Features of Soft Starters

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

- 1 General Safety Recommendations
- 2 System Power Requirements
- 3 Quick Start Installation Guide
- 4 Equipment Installation
- 5 Modules Handling, Installation, and Removal
- 6 Equipment Maintenance
- A Connection of the Power Supply to the AC Power Network
- B Description, Specifications, and Operation of the EMS Modules

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Digital Multimeter	579782 (8946-20) [43]

Software

Qty	Description	Model number
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 1 User Online, 1 year	586971 (8972-00) [44]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 5 Users Online, 1 year	586974 (8972-A0) [45]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 10 Users Online, 1 year	586977 (8972-B0) [46]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 15 Users Online, 1 year	586980 (8972-C0) [47]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 20 Users Online, 1 year	586983 (8972-D0) [48]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 25 Users Online, 1 year	586986 (8972-E0) [49]

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[43] The data acquisition already includes this function and many more, but the DC Circuits manual references using multimeters.

[44] Simulation software that covers DC, single-phase and 3 phase circuits as well as motors and generators and transmission lines. Doesn't cover power electronics.

[45] Simulation software that covers DC, single-phase and 3 phase circuits as well as motors and generators and transmission lines. Doesn't cover power electronics.

[46] Simulation software that covers DC, single-phase and 3 phase circuits as well as motors and generators and transmission lines. Doesn't cover power electronics.

[47] Simulation software that covers DC, single-phase and 3 phase circuits as well as motors and generators and transmission lines. Doesn't cover power electronics.

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[49] Simulation software that covers DC, single-phase and 3 phase circuits as well as motors and generators and transmission lines. Doesn't cover power electronics.

Qty	Description	Model number
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 30 Users Online, 1 year	586989 (8972-F0) [50]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 35 Users Online, 1 year	586992 (8972-G0) [51]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 40 Users Online, 1 year	586995 (8972-H0) [52]
1	SCADA for LVDAC-EMS	8094377 (8973-00) [53]
1	Software Development Kit (SDK)	581459 (9069-90) [54]

System Specifications

Parameter	Value
Sytem Requirements	
Maximum Current	10 A
Typical Current	1.5 A per student group
AC Power Network Installation	3 phases (120/208 V – 60 Hz), star (wye) configuration including neutral and ground wires, protected by a 20 A circuit breaker
AC Power Network Connector	NEMA L21-20
Computer Requirements	A currently available personal computer with USB 2.0 ports, running under one of the following operating systems: Windows® 7 or Windows® 8.
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment
Dimensions (H x W x D)	900 x 930 x 530 mm (35.4 x 36.6 x 20.9 in)
Net Weight	191 kg (420 lb)
EMS Modules	
Full-Size Dimensions (H x W x D)	308 x 287 x 440 mm (12.1 x 11.3 x 17.3 in)
Half-Size Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)

AC Power Transmission Training System
579320 (8010-B0)

The AC Power Transmission Training System combines a modular design approach with computer-based data acquisition and control to provide unrivaled training in ac power transmission systems to students having a basic knowledge in electric power technology (dc power circuits, single-phase ac power circuits, and single-phase power transformers). The system features the Data Acquisition and Control Interface, Model 9063, a state-of-the-art USB peripheral that greatly enhance the learning experience of students.

Training begins with the following two courses:

- Three-Phase AC Power Circuits

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[50] Simulation software that covers DC, single-phase and 3 phase circuits as well as motors and generators and transmission lines. Doesn't cover power electronics.

[51] Simulation software that covers DC, single-phase and 3 phase circuits as well as motors and generators and transmission lines. Doesn't cover power electronics.

[52] Simulation software that covers DC, single-phase and 3 phase circuits as well as motors and generators and transmission lines. Doesn't cover power electronics.

[53] Software allowing the monitoring of up to 5 Stations through OPC.

[54] Additional firmware for the Data Acquisition.

- Three-Phase Transformer Banks

These courses introduce students to the fundamentals of three-phase ac power circuits (wye and delta configurations, three-phase ac power measurement, phase sequence), as well as to the operating characteristics of three-phase transformer banks, which are an essential component in ac power transmission systems. Training continues with the main course of the AC Power Transmission Training System:

- AC Transmission Lines

This course is the core of the training system and introduces students to the characteristics and behavior of high-voltage ac transmission lines, as well as to the voltage compensation of these lines using switched shunt compensation (SSC). It covers a multitude of topics related to high-voltage transmission lines, such as voltage regulation characteristics, characteristic impedance, natural load, corrected PI equivalent circuit, power voltage curve, line length, and active power transmission.

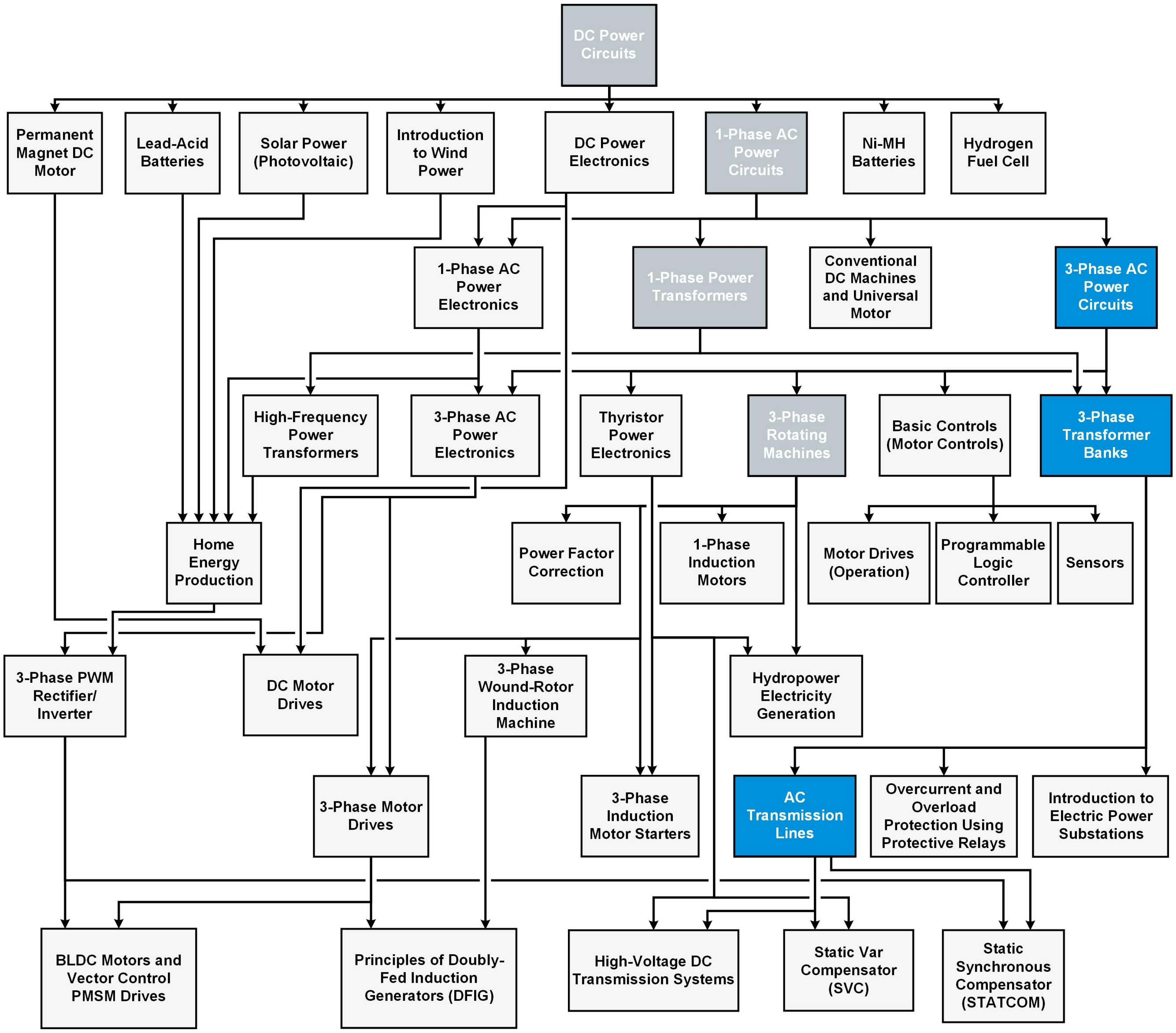
The following four courses from the Electric Power Technology Training Program can be optionally added to the AC Power Transmission Training System to provide students with the basic knowledge of electric power technology required to study ac power transmission systems:

- DC Power Circuits
- Single-Phase AC Power Circuits
- Single-Phase Power Transformers
- Three-Phase Rotating Machines

These four courses familiarize the student with the fundamentals of dc power circuits and single-phase ac power circuits, as well as with the operating characteristics of single-phase power transformers and three-phase rotating machines (notably the three-phase synchronous generator).

The AC Power Transmission Training System is part of the Electric Power Technology Training Systems, Series 8010. Each training system in Series 8010 is based on the Electric Power Technology Training Program and provides a turn-key solution dealing with some aspects of the wide field of electrical energy. The exhaustive courseware provided with each training system covers all the theory required to perform the laboratory exercises, while review questions and unit tests allow students to test the knowledge they have gained.

The Electric Power Technology Training Program is highly modular in both courseware and hardware. Because of this, courses and equipment from the program are available as required, either individually or in the context of a specific training system. The program covers several different subjects in the field of electrical energy, such as rotating machines, electrical power transmission, power electronics, home energy production from renewable resources (wind and sunlight), large-scale electricity production from hydropower and wind power, smart-grid technologies (SVC, STATCOM, HVDC transmission, etc.), storage of electrical energy in batteries, and drive systems for small electric vehicles and cars.


DC Power Circuits
Permanent Magnet DC Motor
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Hydrogen Fuel Cell
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Motor Drives (Operation)
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Sensors
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DC Motor Drives
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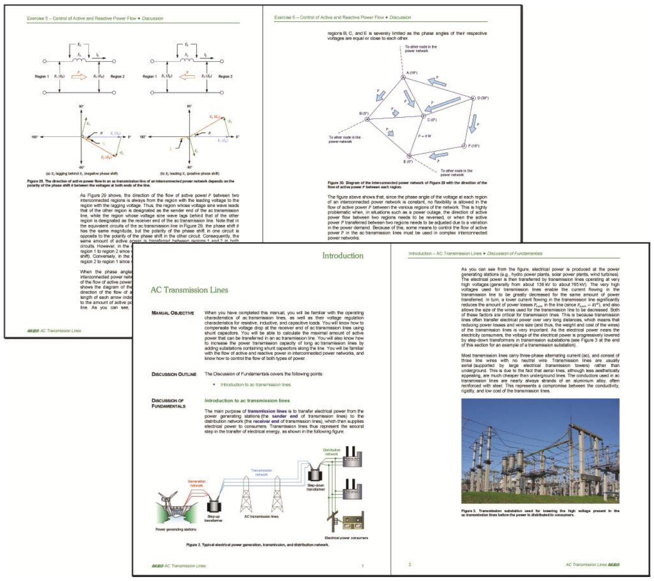
The above chart shows all courses in the Electric Power Technology Training Program. Blue boxes highlight courses included in the training system covered in this datasheet, while dark grey boxes, if any, highlight courses that can be optionally added to this training system.

Courseware



Each course in the training system includes a full-color student manual providing all the theoretical matter required, guided lab-exercise procedures to be performed with the training equipment, and review questions that test the knowledge gained by the student. Whenever possible, each course is built to bring the student to actual applications as soon as possible. A full-color instructor guide providing all lab results and answers to questions is also included with each course.

Modular Design Approach

The modular approach for designing the training program and lab equipment enables instructors to start building their electrical-energy laboratory with a basic package of courses and equipment and add new courses and equipment over time without needless duplication of equipment.

All lab equipment consists of modules that can be inserted into a workstation. Module dimensions vary between two standard EMS sizes: full-size and half-size. Symbols and diagrams representing the electrical components in each module are clearly silk-screened on the front panel. Standard, color-coded safety banana jacks are used to provide access to the various components in each module.

Features & Benefits

- The training system teaches the principles of ac power transmission directly in the laboratory. To this end, students follow a complete curriculum that includes these topics:
    - An introduction to three-phase ac power circuits and three-phase transformer banks, necessary concepts in the study of ac power transmission.
    - A complete course that covers extensively the principles, characteristics, and operation of ac transmission lines.
    - Optional courses that provide the basic knowledge of electric power technology required to study ac power transmission.
- The course curriculum of the Electric Power Technology Training Program is highly flexible and allows a multitude of different customized training solutions.
- The courseware includes student manuals and instructor guides with all the theory required to perform the hands-on experiments.
- All workstations, modules, and components are sturdy and protected against electrical damage to ensure a prolonged service life in a demanding environment such as a training laboratory.
- The modular design approach of the training equipment allows a large variety of courses to be performed using a small number of modules, without unnecessary duplication of equipment.
- All electrical components can be interconnected without electric shock hazard since all live parts of the connection leads are concealed and insulated.
- All electrical symbols representing the components used in a laboratory exercise are clearly silk-screened on the front panel of the modules.
- The training system includes a highly versatile USB peripheral:
    - Data Acquisition and Control Interface, Model 9063. This module gives access to a large variety of computer-based measuring instruments via the LVDAC-EMS software.
- Software upgrades for LVDAC-EMS and firmware upgrades for the Data Acquisition and Control Interface are available for download free of charge on the Festo Didactic website.

List of Equipment

Qty	Description	Model number
1	AC Transmission Line (Student Manual)	580204 (20521-00)
1	AC Transmission Line (Instructor Guide)	580205 (20521-10)
1	Three-Phase AC Power Circuits (Student Manual)	579374 (86360-00)
1	Three-Phase AC Power Circuits (Instructor Guide)	579378 (86360-10)
1	Three-Phase Transformer Banks (Student Manual)	579448 (86379-00)
1	Three-Phase Transformer Banks (Instructor Guide)	579451 (86379-10)
1	Tabletop Workstation	579484 (8134-20)
1	Resistive Load	763359 (8311-00)
2	Inductive Load	763362 (8321-00)
1	Three-Phase Transmission Line	579535 (8329-00)
3	Capacitive Load	763366 (8331-00)
1	Three-Phase Transformer Bank	579559 (8348-40)
1	Three-Phase Regulating Autotransformer	763369 (8349-00)
1	Three-Phase Power Supply	579612 (8823-00)
1	Connection Lead Set	579638 (8951-L0)
1	Connection Lead Set	579639 (8951-N0)
1	Data Acquisition and Control Interface	579680 (9063-B0)
1	AC 24 V Wall Mount Power Supply	579696 (30004-20)

List of Manuals

Description	Manual number
Three-Phase AC Power Circuits (Workbook)	579374 (86360-00)
Three-Phase AC Power Circuits (Workbook (Instructor))	579378 (86360-10)
Three-Phase Transformer Banks (Workbook)	579448 (86379-00)
Three-Phase Transformer Banks (Workbook (Instructor))	579451 (86379-10)
AC Transmission Lines (Workbook)	580204 (20521-00)
AC Transmission Lines (Workbook (Instructor))	580205 (20521-10)
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)

Table of Contents of the Manual(s)

Three-Phase AC Power Circuits (Workbook) (579374 (86360-00))

- 1 Three-Phase Circuits
- 2 Three-Phase Power Measurement

- 3 Phase Sequence

Three-Phase Transformer Banks (Workbook) (579448 (86379-00))

- 1 Three-Phase Transformer Configurations

AC Transmission Lines (Workbook) (580204 (20521-00))

- 1 Voltage Regulation Characteristics
- 2 Characteristics of a High-Voltage AC Transmission Line
- 3 Voltage Compensation of a High-Voltage AC Transmission Line Using Switched Shunt Compensation
- 4 Effect of Length on the Characteristics and Voltage Compensation of a High-Voltage AC Transmission Line
- 5 Voltage Compensation of a Long, High-Voltage AC Transmission Line Using Distributed, Switched Shunt Compensation
- 6 Control of the Active Power Flowing Through Voltage-Compensated AC Transmission Lines

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

- 1 General Safety Recommendations
- 2 System Power Requirements
- 3 Quick Start Installation Guide
- 4 Equipment Installation
- 5 Modules Handling, Installation, and Removal
- 6 Equipment Maintenance
- A Connection of the Power Supply to the AC Power Network
- B Description, Specifications, and Operation of the EMS Modules

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Digital Multimeter	579782 (8946-20) [55]

Software

Qty	Description	Model number
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 1 User Online, 1 year	586971 (8972-00) [56]

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[55] The data acquisition already includes this function and many more, but the DC Circuits manual references using multimeters.

[56] Simulation software that covers these topics and more.

Qty	Description	Model number
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 5 Users Online, 1 year	586974 (8972-A0) [57]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 10 Users Online, 1 year	586977 (8972-B0) [58]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 15 Users Online, 1 year	586980 (8972-C0) [59]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 20 Users Online, 1 year	586983 (8972-D0) [60]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 25 Users Online, 1 year	586986 (8972-E0) [61]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 30 Users Online, 1 year	586989 (8972-F0) [62]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 35 Users Online, 1 year	586992 (8972-G0) [63]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 40 Users Online, 1 year	586995 (8972-H0) [64]
1	SCADA for LVDAC-EMS	8094377 (8973-00) [65]
1	Software Development Kit (SDK)	581459 (9069-90) [66]

System Specifications

Parameter	Value
Sytem Requirements	
Maximum Current	10 A
Typical Current	1.5 A per student group
AC Power Network Installation	3 phases (120/208 V – 60 Hz), star (wye) configuration including neutral and ground wires, protected by a 20 A circuit breaker
AC Power Network Connector	NEMA L21-20
Computer Requirements	A currently available personal computer with USB 2.0 ports, running under one of the following operating systems: Windows® 7 or Windows® 8.
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment
Dimensions (H x W x D)	900 x 930 x 530 mm (35.4 x 36.6 x 20.9 in)
Net Weight	TBE
EMS Modules	
Full-Size Dimensions (H x W x D)	308 x 287 x 440 mm (12.1 x 11.3 x 17.3 in)
Half-Size Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)

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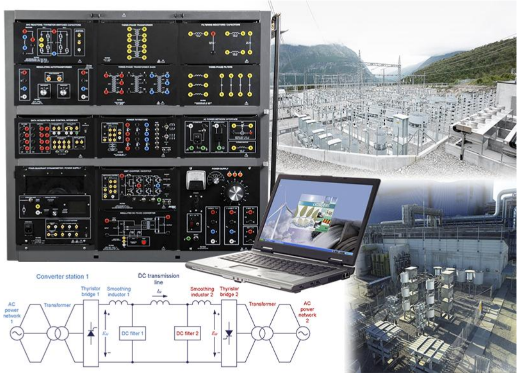
[57] Simulation software that covers these topics and more.
[58] Simulation software that covers these topics and more.
[59] Simulation software that covers these topics and more.
[60] Simulation software that covers these topics and more.
[61] Simulation software that covers these topics and more.
[62] Simulation software that covers these topics and more.
[63] Simulation software that covers these topics and more.
[64] Simulation software that covers these topics and more.
[65] Software allowing the monitoring of up to 5 Stations through OPC.
[66] Additional firmware for the Data Acquisition.

Smart Grid Technologies Training System
579325 (8010-C0)



The Smart Grid Technologies Training System combines a modular design approach with computer-based data acquisition and control to provide unrivaled training in smart grid technologies. The system features the Four-Quadrant Dynamometer/Power Supply, Model 8960, and the Data Acquisition and Control Interface, Model 9063, two state-of-the-art USB peripherals that greatly enhance the learning experience of students.

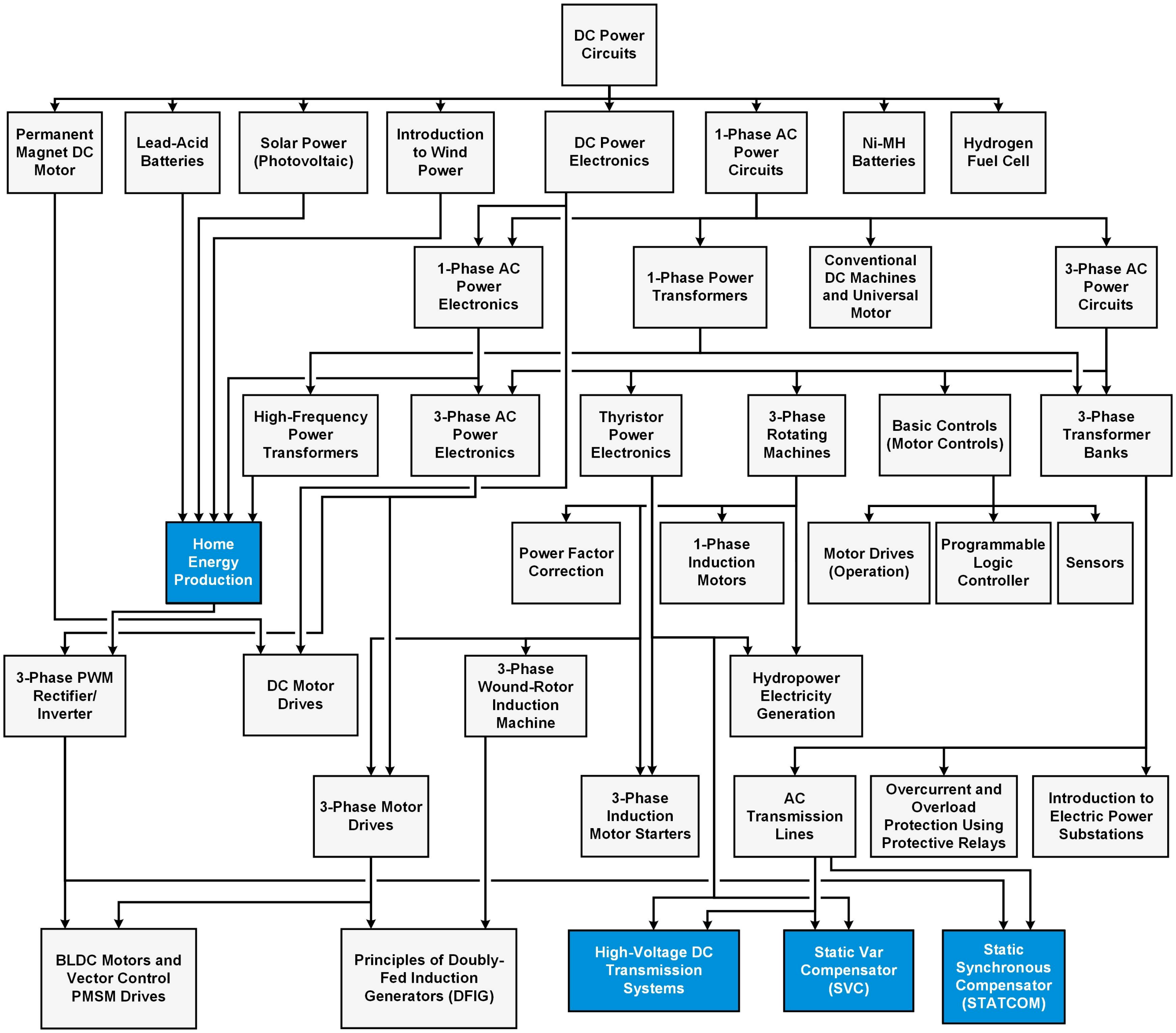
Training begins with the Home Energy Production course. This course familiarizes students with the fundamentals of home energy production from renewable resources such as wind and sunlight. It covers both stand-alone home energy production and grid-tied home energy production. The course also explains and demonstrates how home energy production is an important contributor to the implementation of a smart grid. Students then continue with the following three courses dealing with smart grid technologies:

- Static Var Compensator (SVC)
- Static Synchronous Compensator (STATCOM)
- High-Voltage DC (HVDC) Transmission Systems

These courses introduce students to the fundamentals of SVCs, STATCOMs, and HVDC transmission systems. Students learn that SVCs and STATCOMs, which are examples of flexible ac transmission systems (FACTS), can be used in conjunction with HVDC transmission systems to greatly enhance the controllability and power transfer capability of a power network and are thus essential tools to the implementation of a smart grid. These courses also allow students to experiment with actual SVCs, STATCOMs, and HVDC transmission systems implemented with power electronics modules.

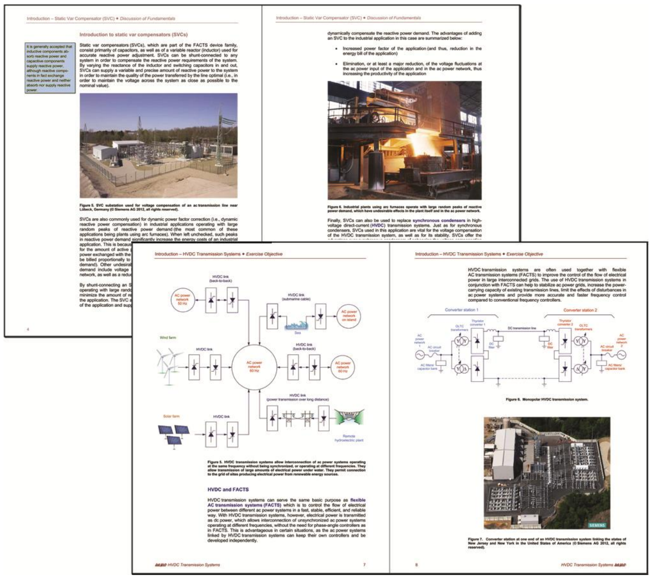
The Smart Grid Technologies Training System is part of the Electric Power Technology Training Systems, Series 8010. Each training system in Series 8010 is based on the Electric Power Technology Training Program and provides a turn-key solution dealing with some aspects of the wide field of electrical energy. The exhaustive courseware provided with each training system covers all the theory required to perform the laboratory exercises, while review questions and unit tests allow students to test the knowledge they have gained.

The Electric Power Technology Training Program is highly modular in both courseware and hardware. Because of this, courses and equipment from the program are available as required, either individually or in the context of a specific training system. The program covers several different subjects in the field of electrical energy, such as rotating machines, electrical power transmission, power electronics, home energy production from renewable resources (wind and sunlight), large-scale electricity production from hydropower and wind power, smart-grid technologies (SVC, STATCOM, HVDC transmission, etc.), storage of electrical energy in batteries, and drive systems for small electric vehicles and cars.


DC Power Circuits
Permanent Magnet DC Motor
Lead-Acid Batteries
Solar Power (Photovoltaic)
Introduction to Wind Power
DC Power Electronics
1-Phase AC Power Circuits
Ni-MH Batteries
Hydrogen Fuel Cell
1-Phase AC Power Electronics
1-Phase Power Transformers
Conventional DC Machines and Universal Motor
3-Phase AC Power Circuits
High-Frequency Power Transformers
3-Phase AC Power Electronics
Thyristor Power Electronics
3-Phase Rotating Machines
Basic Controls (Motor Controls)
3-Phase Transformer Banks
Home Energy Production
Power Factor Correction
1-Phase Induction Motors
Motor Drives (Operation)
Programmable Logic Controller
Sensors
3-Phase PWM Rectifier/ Inverter
DC Motor Drives
3-Phase Wound-Rotor Induction Machine
Hydropower Electricity Generation
3-Phase Motor Drives
3-Phase Induction Motor Starters
AC Transmission Lines
Overcurrent and Overload Protection Using Protective Relays
Introduction to Electric Power Substations
BLDC Motors and Vector Control PMSM Drives
Principles of Doubly-Fed Induction Generators (DFIG)
High-Voltage DC Transmission Systems
Static Var Compensator (SVC)
Static Synchronous Compensator (STATCOM)

The above chart shows all courses in the Electric Power Technology Training Program. Blue boxes highlight courses included in the training system covered in this datasheet, while dark grey boxes, if any, highlight courses that can be optionally added to this training system.

Courseware



Each course in the training system includes a full-color student manual providing all the theoretical matter required, guided lab-exercise procedures to be performed with the training equipment, and review questions that test the knowledge gained by the student. Whenever possible, each course is built to bring the student to actual applications as soon as possible. A full-color instructor guide providing all lab results and answers to questions is also included with each course.

Modular Design Approach

The modular approach for designing the training program and lab equipment enables instructors to start building their electrical-energy laboratory with a basic package of courses and equipment and add new courses and equipment over time without needless duplication of equipment.

All lab equipment consists of modules that can be inserted into a workstation. Module dimensions vary between two standard EMS sizes: full-size and half-size. Symbols and diagrams representing the electrical components in each module are clearly silk-screened on the front panel. Standard, color-coded safety banana jacks are used to provide access to the various components in each module.

Features & Benefits

- The training system teaches the principles behind certain key technologies allowing the implementation of a smart grid. These technologies include home energy production, SVCs, STATCOMs, and HVDC transmission systems.
- Realistic control functions implemented using the Data Acquisition and Control Interface via the LVDAC-EMS software allow the implementation of complex devices such as an SVC and a STATCOM directly in the laboratory.
- The course curriculum of the Electric Power Technology Training Program is highly flexible and allows a multitude of different customized training solutions.
- The courseware includes student manuals and instructor guides with all the theory required to perform the hands-on experiments.
- All workstations, modules, and components are sturdy and protected against electrical damage to ensure a prolonged service life in a demanding environment such as a training laboratory.
- The modular design approach of the training equipment allows a large variety of courses to be performed using a small number of modules, without unnecessary duplication of equipment.
- All electrical components can be interconnected without electric shock hazard since all live parts of the connection leads are concealed and insulated.
- All electrical symbols representing the components used in a laboratory exercise are clearly silk-screened on the front panel of the modules.
- The training system includes two highly versatile USB peripherals:
    - Four-Quadrant Dynamometer/Power Supply, Model 8960-2. This module is used as a solar panel emulator with a large variety of configurable parameters.
    - Data Acquisition and Control Interface, Model 9063. This module gives access to a large variety of computer-based measuring instruments and is used to control the various power electronics devices necessary for home energy production, as well as SVC, STATCOM, and HVDC implantation. All functions are implemented via the LVDAC-EMS software.

- The training system also includes four highly versatile power electronics modules controlled using the Data Acquisition and Control Interface:
    - SVC Reactors/Thyristor Switched Capacitors, Model 8334. This module is used to implement the TCR and TSCs for SVC operation.
    - Insulated DC-to-DC Converter, Model 8835. This module is used to implement a solar/wind power inverter with HF transformer topology.
    - + IGBT Chopper/Inverter, Model 8837-B. This module is used to implement the solar/wind power inverter for home energy production and the three-phase PWM rectifier/inverter for STATCOM operation.
    - Power Thyristors, Model 8841. This module is used to implement the TCR and TSCs for SVC operation and the thyristor converters for HVDC operation.
- Software upgrades for LVDAC-EMS and firmware upgrades for the Four-Quadrant Dynamometer/Power Supply and Data Acquisition and Control Interface are available for download free of charge on the Festo Didactic website.

List of Equipment

Qty	Description	Model number
1	Home Energy Production (Student Manual)	579385 (86361-00)
1	Home Energy Production (Instructor Guide)	579387 (86361-10)
1	Static Var Compensators (SVC) (Student Manual)	579431 (86370-00)
1	Static Var Compensators (SVC) (Instructor Guide)	579432 (86370-10)
1	Static Synchronous Compensator (STATCOM) (Student Manual)	579433 (86371-00)
1	Static Synchronous Compensator (STATCOM) (Instructor Guide)	579434 (86371-10)
1	High-Voltage DC Transmission Systems (Student Manual)	579460 (86380-00)
1	High-Voltage DC Transmission Systems (Instructor Guide)	579461 (86380-10)
1	Tabletop Workstation	579484 (8134-20)
1	Resistive Load	763359 (8311-00)
1	Inductive Load	763362 (8321-00)
1	Filtering Inductors/Capacitors	579523 (8325-A0)
1	Three-Phase Filter	579529 (8326-00)
1	Line Inductors	763364 (8326-A0)
2	Three-Phase Transmission Line	579535 (8329-00)
1	Capacitive Load	763366 (8331-00)
1	SVC Reactors / Thyristor-Switched Capacitors	763368 (8334-00)
2	Three-Phase Transformer Bank	579559 (8348-40)
2	Three-Phase Regulating Autotransformer	763369 (8349-00)
1	Transformer	763371 (8353-00)
1	Three-Phase Transformer	763373 (8354-00)
1	AC Power Network Interface	579581 (8622-00)
1	Lead-Acid Battery Pack	579591 (8802-10)
1	Variable Three-Phase Power Supply	579603 (8821-20)
1	Insulated DC-to-DC Converter	579618 (8835-00)
1	IGBT Chopper/Inverter	579623 (8837-B0)
2	Power Thyristors	763376 (8841-20)

Qty	Description	Model number
1	Connection Lead Set	579638 (8951-L0)
1	Connection Lead Set	579639 (8951-N0)
1	Four-Quadrant Dynamometer/Power Supply	579674 (8960-G0)
1	Data Acquisition and Control Interface	579677 (9063-00)
1	Data Acquisition and Control Interface	579694 (9063-H0)

List of Manuals

Description	Manual number
Home Energy Production (Workbook)	579385 (86361-00)
Home Energy Production (Workbook (Instructor))	579387 (86361-10)
Static Var Compensator (SVC) (Workbook)	579431 (86370-00)
Static Var Compensator (SVC) (Workbook (Instructor))	579432 (86370-10)
Static Synchronous Compensator (STATCOM) (Workbook)	579433 (86371-00)
Static Synchronous Compensator (STATCOM) (Workbook (Instructor))	579434 (86371-10)
HVDC Transmission Systems (Workbook)	579460 (86380-00)
HVDC Transmission Systems (Workbook (Instructor))	579461 (86380-10)
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)

Table of Contents of the Manual(s)

Home Energy Production (Workbook) (579385 (86361-00))

- 1 Stand-Alone Home Energy Production
- 2 Single-Phase Grid-Tied Inverter (PWM Rectifier/Inverter)
- 3 Grid-Tied Home Energy Production Using a Solar or Wind Power Inverter without DC-to-DC Converter
- 4 Grid-Tied Home Energy Production Using a Solar or Wind Power Inverter with DC-to-DC Converter
- 5 Large-Scale Energy Storage: A Step in the Implementation of the Smart Grid

Static Var Compensator (SVC) (Workbook) (579431 (86370-00))

- 1 Main Components of a Static Var Compensator (SVC)
- 2 Voltage Compensation of AC Transmission Lines Using an SVC
- 3 Dynamic Power Factor Correction Using an SVC

Static Synchronous Compensator (STATCOM) (Workbook) (579433 (86371-00))

- 1 Voltage Compensation of AC Transmission Lines Using a STATCOM
- 2 Dynamic Power Factor Correction Using a STATCOM

HVDC Transmission Systems (Workbook) (579460 (86380-00))

- 1 Voltage Regulation and Displacement Power Factor (DPF) in Thyristor Three-Phase Bridges
- 2 Basic Operation of HVDC Transmission Systems
- 3 DC Current Regulation and Power Flow Control in HVDC Transmission Systems
- 4 Commutation Failure at the Inverter Bridge
- 5 Harmonic Reduction using Thyristor 12-Pulse Converters

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

- 1 General Safety Recommendations
- 2 System Power Requirements
- 3 Quick Start Installation Guide

- 4 Equipment Installation
- 5 Modules Handling, Installation, and Removal
- 6 Equipment Maintenance
- A Connection of the Power Supply to the AC Power Network
- B Description, Specifications, and Operation of the EMS Modules

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Digital Multimeter	579782 (8946-20) [67]

Software

Qty	Description	Model number
1	SCADA for LVDAC-EMS	8094377 (8973-00) [68]
1	Software Development Kit (SDK)	581459 (9069-90) [69]

System Specifications

Parameter	Value
Sytem Requirements	
Maximum Current	15 A
Typical Current	1.5 A per student group
AC Power Network Installation	3 phases (120/208 V – 60 Hz), star (wye) configuration including neutral and ground wires, protected by a 20 A circuit breaker
AC Power Network Connector	NEMA L21-20
Computer Requirements	
Computer Requirements	A currently available personal computer with USB 2.0 ports, running under one of the following operating systems: Windows® 7 or Windows® 8.
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment
Dimensions (H x W x D)	900 x 930 x 530 mm (35.4 x 36.6 x 20.9 in)
Net Weight	TBE
EMS Modules	
Full-Size Dimensions (H x W x D)	308 x 287 x 440 mm (12.1 x 11.3 x 17.3 in)
Half-Size Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)

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[67] The data acquisition already includes this function and many more, but the DC Circuits manual references using multimeters.

[68] Software allowing the monitoring of up to 5 Stations through OPC.

[69] Additional firmware for the Data Acquisition.

DFIG Principles Training System
579328 (8010-D0)

Synchronized ac current
Doubly-fed induction generator
P_M
To ac power network
AC/DC converter
DC current
AC/DC converter
Variable voltage and frequency ac current
Synchronized ac current
$n_{\phi,stator} = n_{Rotor} - n_{\phi,rotor}$
Mechanical power P_M
AC currents (f_{Stator})
Rotor
Stator
Variable-frequency ac currents (f_{Rotor})

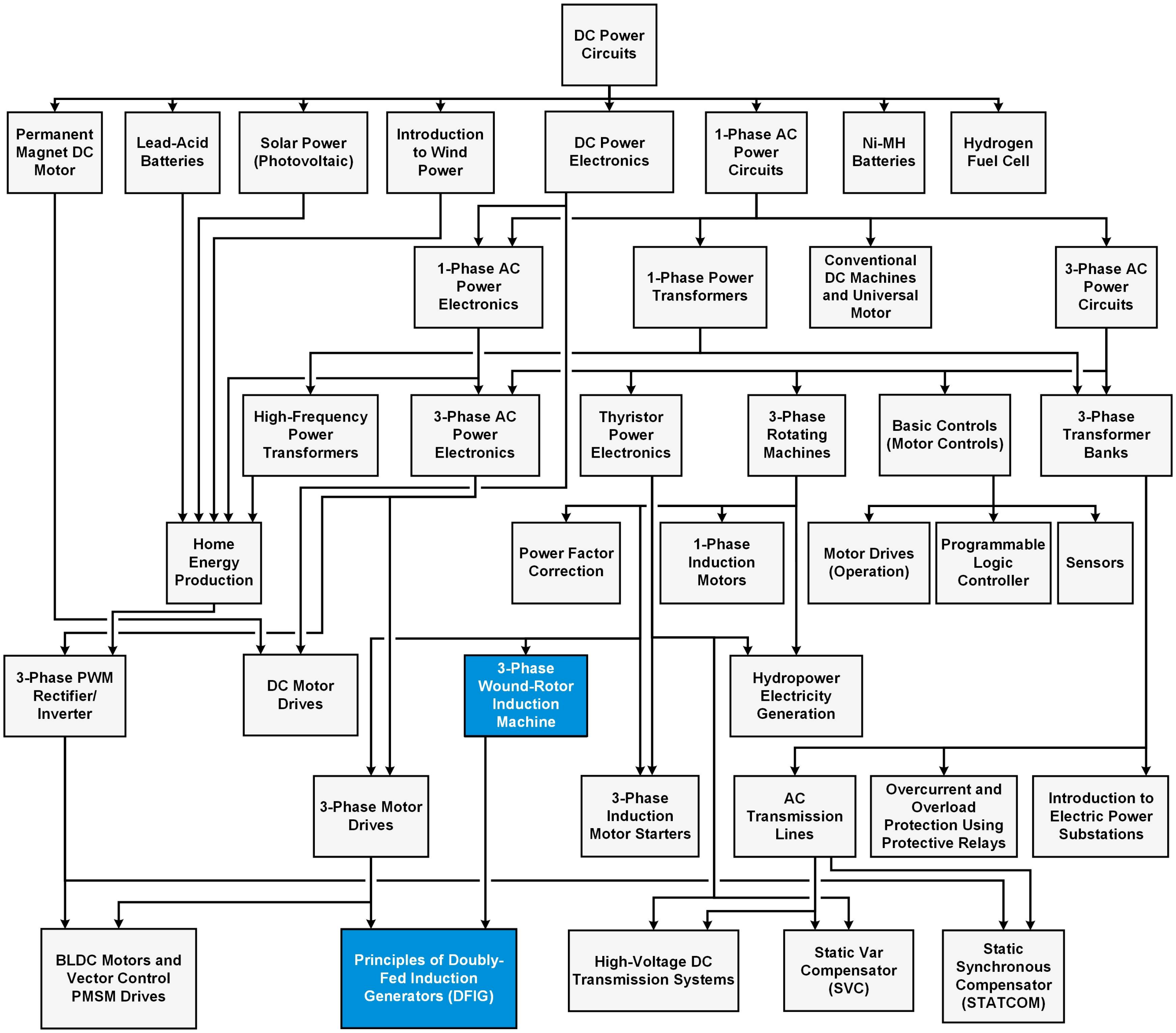
The DFIG Principles Training System combines a modular design approach with computer-based data acquisition and control to provide unrivaled training in the basic principles of the doubly-fed induction generator (DFIG) to students that already have a sound knowledge of three-phase ac power circuits, rotating machines, and motor drives. The system features the Four-Quadrant Dynamometer/Power Supply, Model 8960, and the Data Acquisition and Control Interface, Model 9063, two state-of-the-art USB peripherals that greatly enhance the learning experience of students.

Training begins with the Three-Phase Wound-Rotor Induction Machine course. This course familiarizes students with the fundamentals of the three-phase wound-rotor induction machine, which can be used as a doubly-fed induction motor as well as a doubly-fed induction generator. The course covers the operation of the machine both with a short-circuited rotor and with rotor resistance.

Students then continue with the Principles of Doubly-Fed Induction Generators (DFIG) course. This course covers in detail the main components as well as the operation of doubly-fed induction generators. It explains how and why DFIGs are commonly used in wind turbines designed for large-scale production of electricity. The course also allows students to experiment with an actual doubly-fed induction generator implemented with power electronics modules and a three-phase wound-rotor induction machine.

The DFIG Principles Training System is part of the Electric Power Technology Training Systems, Series 8010. Each training system in Series 8010 is based on the Electric Power Technology Training Program and provides a turn-key solution dealing with some aspects of the wide field of electrical energy. The exhaustive courseware provided with each training system covers all the theory required to perform the laboratory exercises, while review questions and unit tests allow students to test the knowledge they have gained.

The Electric Power Technology Training Program is highly modular in both courseware and hardware. Because of this, courses and equipment from the program are available as required, either individually or in the context of a specific training system. The program covers several different subjects in the field of electrical energy, such as rotating machines, electrical power transmission, power electronics, home energy production from renewable resources (wind and sunlight), large-scale electricity production from hydropower and wind power, smart-grid technologies (SVC, STATCOM, HVDC transmission, etc.), storage of electrical energy in batteries, and drive systems for small electric vehicles and cars.


DC Power Circuits
Permanent Magnet DC Motor
Lead-Acid Batteries
Solar Power (Photovoltaic)
Introduction to Wind Power
DC Power Electronics
1-Phase AC Power Circuits
Ni-MH Batteries
Hydrogen Fuel Cell
1-Phase AC Power Electronics
1-Phase Power Transformers
Conventional DC Machines and Universal Motor
3-Phase AC Power Circuits
High-Frequency Power Transformers
3-Phase AC Power Electronics
Thyristor Power Electronics
3-Phase Rotating Machines
Basic Controls (Motor Controls)
3-Phase Transformer Banks
Home Energy Production
Power Factor Correction
1-Phase Induction Motors
Motor Drives (Operation)
Programmable Logic Controller
Sensors
3-Phase PWM Rectifier/ Inverter
DC Motor Drives
3-Phase Wound-Rotor Induction Machine
Hydropower Electricity Generation
3-Phase Motor Drives
3-Phase Induction Motor Starters
AC Transmission Lines
Overcurrent and Overload Protection Using Protective Relays
Introduction to Electric Power Substations
BLDC Motors and Vector Control PMSM Drives
Principles of Doubly-Fed Induction Generators (DFIG)
High-Voltage DC Transmission Systems
Static Var Compensator (SVC)
Static Synchronous Compensator (STATCOM)

The above chart shows all courses in the Electric Power Technology Training Program. Blue boxes highlight courses included in the training system covered in this datasheet, while dark grey boxes, if any, highlight courses that can be optionally added to this training system.

Courseware

Each course in the training system includes a full-color student manual providing all the theoretical matter required, guided lab-exercise procedures to be performed with the training equipment, and review questions that test the knowledge gained by the student. Whenever possible, each course is built to bring the student to actual applications as soon as possible. A full-color instructor guide providing all lab results and answers to questions is also included with each course.

Modular Design Approach

The modular approach for designing the training program and lab equipment enables instructors to start building their electrical-energy laboratory with a basic package of courses and equipment and add new courses and equipment over time without needless duplication of equipment.

All lab equipment consists of modules that can be inserted into a workstation. Module dimensions vary between two standard EMS sizes: full-size and half-size. Symbols and diagrams representing the electrical components in each module are clearly silk-screened on the front panel. Standard, color-coded safety banana jacks are used to provide access to the various components in each module.

Features & Benefits

- The training system teaches the principles of doubly-fed induction generators (DFIGs), including the operation of three-phase wound-rotor induction machines, which are used to implement DFIGs.
- The course curriculum of the Electric Power Technology Training Program is highly flexible and allows a multitude of different customized training solutions.
- The courseware includes student manuals and instructor guides with all the theory required to perform the hands-on experiments.
- All workstations, modules, and components are sturdy and protected against electrical damage to ensure a prolonged service life in a demanding environment such as a training laboratory.
- The modular design approach of the training equipment allows a large variety of courses to be performed using a small number of modules, without unnecessary duplication of equipment.
- All electrical components can be interconnected without electric shock hazard since all live parts of the connection leads are concealed and insulated.
- All electrical symbols representing the components used in a laboratory exercise are clearly silk-screened on the front panel of the modules.
- The training system includes two highly versatile USB peripherals:
  - Four-Quadrant Dynamometer/Power Supply, Model 8960-2. This module can be mechanically coupled to all rotating machines to operate as a prime mover or brake.
  - Data Acquisition and Control Interface, Model 9063. This module gives access to a large variety of computer-based measuring instruments and is used to control the various dc power electronics devices necessary to DFIG operation. All functions are implemented via the LVDAC-EMS software.
- The training system also includes two highly versatile power electronics modules controlled using the Data Acquisition and Control Interface:
  - IGBT Chopper/Inverter, Model 8837-B. This module is used to implement the three-phase PWM inverter for DFIG operation.

- Rectifier and Filtering Capacitors, Model 8842-A. This module is used to implement the three-phase rectifier for DFIG operation.

List of Equipment

Qty	Description	Model number
1	Three-Phase Wound Rotor Induction Machine (Student Manual)	579421 (86367-00)
1	Three-Phase Wound Rotor Induction Machine (Instructor Guide)	579422 (86367-10)
1	Principles of Doubly-Fed Induction Generators (DFIG) (Student Manual)	579435 (86376-00)
1	Principles of Doubly-Fed Induction Generators (DFIG) (Instructor Guide)	579436 (86376-10)
1	Tabletop Workstation	579484 (8134-20)
1	Three-Phase Wound-Rotor Induction Machine (DFIG)	579497 (8231-B0)
1	Resistive Load	763359 (8311-00)
1	Three-Phase Transformer Bank	579559 (8348-40)
1	Three-Phase Power Supply	579612 (8823-00)
1	IGBT Chopper/Inverter	579623 (8837-B0)
1	Rectifier and Filtering Capacitors	579630 (8842-A0)
1	Timing Belt	579637 (8942-00)
1	Connection Lead Set	579638 (8951-L0)
1	Four-Quadrant Dynamometer / Power Supply with Manual and Computer-Based Control	579648 (8960-C0)
1	Data Acquisition and Control Interface	579683 (9063-C0)
1	AC 24 V Wall Mount Power Supply	579696 (30004-20)

List of Manuals

Description	Manual number
Three-Phase Wound-Rotor Induction Machines (Workbook)	579421 (86367-00)
Three-Phase Wound-Rotor Induction Machines (Workbook (Instructor))	579422 (86367-10)
Principles of Doubly-Fed Induction Generators (DFIG) (Workbook)	579435 (86376-00)
Principles of Doubly-Fed Induction Generators (DFIG) (Workbook (Instructor))	579436 (86376-10)
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)

Table of Contents of the Manual(s)

Three-Phase Wound-Rotor Induction Machines (Workbook) (579421 (86367-00))

- 1 Three-Phase Wound-Rotor Induction Machine with a Short-Circuited Rotor
- 2 Three-Phase Wound-Rotor Induction Machine with Rotor Resistance

Principles of Doubly-Fed Induction Generators (DFIG) (Workbook) (579435 (86376-00))

- 1 Three-Phase Wound-Rotor Induction Machine Used as a Synchronous Machine
- 2 Doubly-Fed Induction Motors
- 3 Doubly-Fed Induction Generators

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

- 1 General Safety Recommendations
- 2 System Power Requirements
- 3 Quick Start Installation Guide
- 4 Equipment Installation
- 5 Modules Handling, Installation, and Removal
- 6 Equipment Maintenance

- A Connection of the Power Supply to the AC Power Network
- B Description, Specifications, and Operation of the EMS Modules

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Digital Multimeter	579782 (8946-20) [70]

Software

Qty	Description	Model number
1	SCADA for LVDAC-EMS	8094377 (8973-00) [71]
1	Software Development Kit (SDK)	581459 (9069-90) [72]

System Specifications

Parameter	Value
Sytem Requirements	
Maximum Current	10 A
Typical Current	1.5 A per student group
AC Power Network Installation	3 phases (120/208 V – 60 Hz), star (wye) configuration including neutral and ground wires, protected by a 20 A circuit breaker
AC Power Network Connector	NEMA L21-20
Computer Requirements	A currently available personal computer with USB 2.0 ports, running under one of the following operating systems: Windows® 7 or Windows® 8.
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment
Dimensions (H x W x D)	900 x 930 x 530 mm (35.4 x 36.6 x 20.9 in)
Net Weight	TBE
EMS Modules	
Full-Size Dimensions (H x W x D)	308 x 287 x 440 mm (12.1 x 11.3 x 17.3 in)
Half-Size Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)

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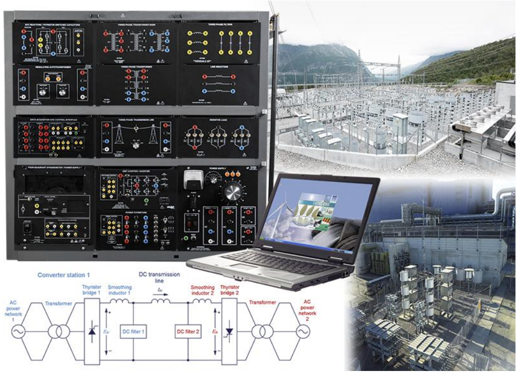
[70] The data acquisition already includes this function and many more, but the DC Circuits manual references using multimeters.

[71] Software allowing the monitoring of up to 5 Stations through OPC.

[72] Additional firmware for the Data Acquisition.

Power Transmission Smart Grid Technologies Training System
579331 (8010-E0)



The Power Transmission Smart Grid Technologies Training System combines a modular design approach with computer-based data acquisition and control to provide unrivaled training in smart grid technologies related to power transmission. The system features the Four-Quadrant Dynamometer/Power Supply and the Data Acquisition and Control Interface, two state-of-the-art USB peripherals that greatly enhance the learning experience of students.

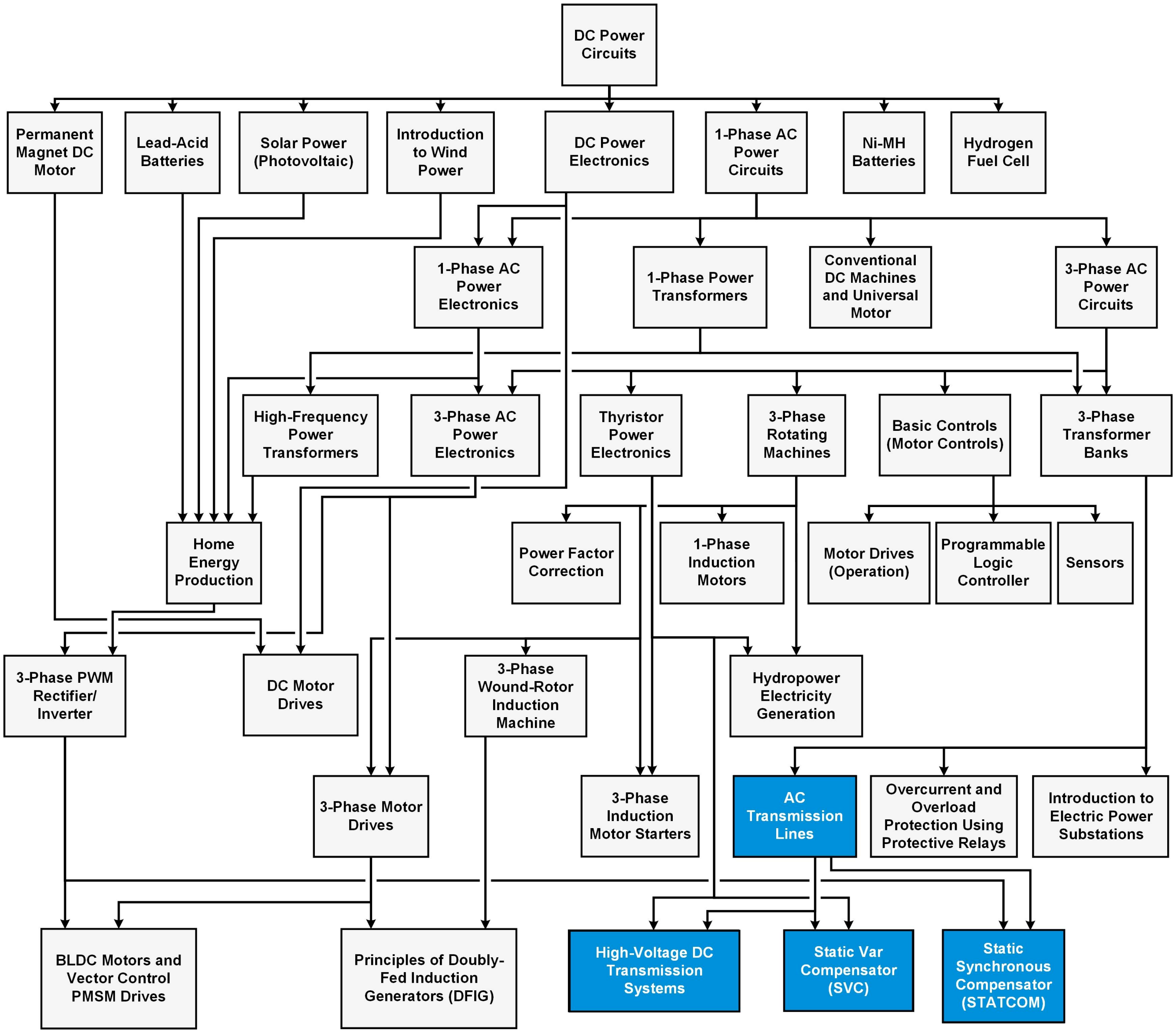
Training begins with the AC Transmission Line course. This course introduces students to the characteristics and behavior of high-voltage ac transmission lines, as well as to the voltage compensation of these lines using switched shunt compensation (SSC). It covers a multitude of topics related to high-voltage transmission lines, such as voltage regulation characteristics, characteristic impedance, natural load, corrected PI equivalent circuit, power voltage curve, line length, and active power transmission. Students then continue with the following three courses dealing with smart grid technologies related to power transmission:

- Static Var Compensator (SVC)
- Static Synchronous Compensator (STATCOM)
- High-Voltage DC (HVDC) Transmission Systems

These courses introduce students to the fundamentals of SVCs, STATCOMs, and HVDC transmission systems. Students learn that SVCs and STATCOMs, which are examples of flexible ac transmission systems (FACTS), can be used in conjunction with HVDC transmission systems to greatly enhance the controllability and power transfer capability of a power network and are thus essential tools to the implementation of a smart grid. These courses also allow students to experiment with actual SVCs, STATCOMs, and HVDC transmission systems implemented using power electronics modules.

The Power Transmission Smart Grid Technologies Training System is part of the Electric Power Technology Training Systems, Series 8010. Each training system in Series 8010 is based on the Electric Power Technology Training Program and provides a turn-key solution dealing with some aspects of the wide field of electrical energy. The exhaustive courseware provided with each training system covers all the theory required to perform the laboratory exercises, while review questions and unit tests allow students to test the knowledge they have gained.

The Electric Power Technology Training Program is highly modular in both courseware and hardware. Because of this, courses and equipment from the program are available as required, either individually or in the context of a specific training system. The program covers several different subjects in the field of electrical energy, such as rotating machines, electrical power transmission, power electronics, home energy production from renewable resources (wind and sunlight), large-scale electricity production from hydropower and wind power, smart-grid technologies (SVC, STATCOM, HVDC transmission, etc.), storage of electrical energy in batteries, and drive systems for small electric vehicles and cars.


DC Power Circuits
Permanent Magnet DC Motor
Lead-Acid Batteries
Solar Power (Photovoltaic)
Introduction to Wind Power
DC Power Electronics
1-Phase AC Power Circuits
Ni-MH Batteries
Hydrogen Fuel Cell
1-Phase AC Power Electronics
1-Phase Power Transformers
Conventional DC Machines and Universal Motor
3-Phase AC Power Circuits
High-Frequency Power Transformers
3-Phase AC Power Electronics
Thyristor Power Electronics
3-Phase Rotating Machines
Basic Controls (Motor Controls)
3-Phase Transformer Banks
Home Energy Production
Power Factor Correction
1-Phase Induction Motors
Motor Drives (Operation)
Programmable Logic Controller
Sensors
3-Phase PWM Rectifier/ Inverter
DC Motor Drives
3-Phase Wound-Rotor Induction Machine
Hydropower Electricity Generation
3-Phase Motor Drives
3-Phase Induction Motor Starters
AC Transmission Lines
Overcurrent and Overload Protection Using Protective Relays
Introduction to Electric Power Substations
BLDC Motors and Vector Control PMSM Drives
Principles of Doubly-Fed Induction Generators (DFIG)
High-Voltage DC Transmission Systems
Static Var Compensator (SVC)
Static Synchronous Compensator (STATCOM)

The above chart shows all courses in the Electric Power Technology Training Program. Blue boxes highlight courses included in the training system covered in this datasheet, while dark grey boxes, if any, highlight courses that can be optionally added to this training system.

Courseware

Each course in the training system includes a full-color student manual providing all the theoretical matter required, guided lab-exercise procedures to be performed with the training equipment, and review questions that test the knowledge gained by the student. Whenever possible, each course is built to bring the student to actual applications as soon as possible. A full-color instructor guide providing all lab results and answers to questions is also included with each course.

Modular Design Approach

The modular approach for designing the training program and lab equipment enables instructors to start building their electrical-energy laboratory with a basic package of courses and equipment and add new courses and equipment over time without needless duplication of equipment.

All lab equipment consists of modules that can be inserted into a workstation. Module dimensions vary between two standard EMS sizes: full-size and half-size. Symbols and diagrams representing the electrical components in each module are clearly silk-screened on the front panel. Standard, color-coded safety banana jacks are used to provide access to the various components in each module.

Features & Benefits

- The training system teaches the principles behind certain key technologies allowing the implementation of a smart grid, within the context of power transmission. These technologies include home energy production, SVCs, STATCOMs, and HVDC transmission systems.
- Realistic control functions implemented using the Data Acquisition and Control Interface via the LVDAC-EMS software allow the implementation of complex devices such as an SVC and a STATCOM directly in the laboratory.
- The course curriculum of the Electric Power Technology Training Program is highly flexible and allows a multitude of different customized training solutions.
- The courseware includes student manuals and instructor guides with all the theory required to perform the hands-on experiments.
- All workstations, modules, and components are sturdy and protected against electrical damage to ensure a prolonged service life in a demanding environment such as a training laboratory.
- The modular design approach of the training equipment allows a large variety of courses to be performed using a small number of modules, without unnecessary duplication of equipment.
- All electrical components can be interconnected without electric shock hazard since all live parts of the connection leads are concealed and insulated.
- All electrical symbols representing the components used in a laboratory exercise are clearly silk-screened on the front panel of the modules.
- The training system includes two highly versatile USB peripherals:
    - Four-Quadrant Dynamometer/Power Supply, Model 8960-2. This module is used as a solar panel emulator with a large variety of configurable parameters.
    - Data Acquisition and Control Interface, Model 9063. This module gives access to a large variety of computer-based measuring instruments and is used to control the various power electronics devices necessary for home energy production, as well as SVC, STATCOM, and HVDC implantation. All functions are implemented via the LVDAC-EMS software.

- The training system also includes four highly versatile power electronics modules controlled using the Data Acquisition and Control Interface:
  - SVC Reactors/Thyristor Switched Capacitors, Model 8334. This module is used to implement the TCR and TSCs for SVC operation.
  - Insulated DC-to-DC Converter, Model 8835. This module is used to implement a solar/wind power inverter with HF transformer topology.
  - + IGBT Chopper/Inverter, Model 8837-B. This module is used to implement the solar/wind power inverter for home energy production and the three-phase PWM rectifier/inverter for STATCOM operation.
  - Power Thyristors, Model 8841. This module is used to implement the TCR and TSCs for SVC operation and the thyristor converters for HVDC operation.
- Software upgrades for LVDAC-EMS and firmware upgrades for the Four-Quadrant Dynamometer/Power Supply and Data Acquisition and Control Interface are available for download free of charge on the Festo Didactic website.

List of Equipment

Qty	Description	Model number
1	AC Transmission Line (Student Manual)	580204 (20521-00)
1	AC Transmission Line (Instructor Guide)	580205 (20521-10)
1	Static Var Compensators (SVC) (Student Manual)	579431 (86370-00)
1	Static Var Compensators (SVC) (Instructor Guide)	579432 (86370-10)
1	Static Synchronous Compensator (STATCOM) (Student Manual)	579433 (86371-00)
1	Static Synchronous Compensator (STATCOM) (Instructor Guide)	579434 (86371-10)
1	High-Voltage DC Transmission Systems (Student Manual)	579460 (86380-00)
1	High-Voltage DC Transmission Systems (Instructor Guide)	579461 (86380-10)
1	Tabletop Workstation	579484 (8134-20)
1	Resistive Load	763359 (8311-00)
2	Inductive Load	763362 (8321-00)
1	Three-Phase Filter	579529 (8326-00)
1	Line Inductors	763364 (8326-A0)
2	Three-Phase Transmission Line	579535 (8329-00)
3	Capacitive Load	763366 (8331-00)
1	SVC Reactors / Thyristor-Switched Capacitors	763368 (8334-00)
2	Three-Phase Transformer Bank	579559 (8348-40)
2	Three-Phase Regulating Autotransformer	763369 (8349-00)
1	Three-Phase Transformer	763373 (8354-00)

Qty	Description	Model number
1	Variable Three-Phase Power Supply	579603 (8821-20)
1	IGBT Chopper/Inverter	579623 (8837-B0)
2	Power Thyristors	763376 (8841-20)
1	Connection Lead Set	579638 (8951-L0)
1	Connection Lead Set	579639 (8951-N0)
1	Four-Quadrant Dynamometer / Power Supply with Manual and Computer-Based Control	579648 (8960-C0)
1	Data Acquisition and Control Interface	579677 (9063-00)
1	Data Acquisition and Control Interface	579695 (9063-J0)

List of Manuals

Description	Manual number
Static Var Compensator (SVC) (Workbook)	579431 (86370-00)
Static Var Compensator (SVC) (Workbook (Instructor))	579432 (86370-10)
Static Synchronous Compensator (STATCOM) (Workbook)	579433 (86371-00)
Static Synchronous Compensator (STATCOM) (Workbook (Instructor))	579434 (86371-10)
HVDC Transmission Systems (Workbook)	579460 (86380-00)
HVDC Transmission Systems (Workbook (Instructor))	579461 (86380-10)
AC Transmission Lines (Workbook)	580204 (20521-00)
AC Transmission Lines (Workbook (Instructor))	580205 (20521-10)
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)

Table of Contents of the Manual(s)

Static Var Compensator (SVC) (Workbook) (579431 (86370-00))

- 1 Main Components of a Static Var Compensator (SVC)
- 2 Voltage Compensation of AC Transmission Lines Using an SVC
- 3 Dynamic Power Factor Correction Using an SVC

Static Synchronous Compensator (STATCOM) (Workbook) (579433 (86371-00))

- 1 Voltage Compensation of AC Transmission Lines Using a STATCOM
- 2 Dynamic Power Factor Correction Using a STATCOM

HVDC Transmission Systems (Workbook) (579460 (86380-00))

- 1 Voltage Regulation and Displacement Power Factor (DPF) in Thyristor Three-Phase Bridges
- 2 Basic Operation of HVDC Transmission Systems
- 3 DC Current Regulation and Power Flow Control in HVDC Transmission Systems
- 4 Commutation Failure at the Inverter Bridge
- 5 Harmonic Reduction using Thyristor 12-Pulse Converters

AC Transmission Lines (Workbook) (580204 (20521-00))

- 1 Voltage Regulation Characteristics
- 2 Characteristics of a High-Voltage AC Transmission Line
- 3 Voltage Compensation of a High-Voltage AC Transmission Line Using Switched Shunt Compensation
- 4 Effect of Length on the Characteristics and Voltage Compensation of a High-Voltage AC Transmission Line
- 5 Voltage Compensation of a Long, High-Voltage AC Transmission Line Using Distributed, Switched Shunt Compensation

- 6 Control of the Active Power Flowing Through Voltage-Compensated AC Transmission Lines

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

- 1 General Safety Recommendations
- 2 System Power Requirements
- 3 Quick Start Installation Guide
- 4 Equipment Installation
- 5 Modules Handling, Installation, and Removal
- 6 Equipment Maintenance
- A Connection of the Power Supply to the AC Power Network
- B Description, Specifications, and Operation of the EMS Modules

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Software

Qty	Description	Model number
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 1 User Online, 1 year ____	586971 (8972-00) [73]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 5 Users Online, 1 year ___	586974 (8972-A0) [74]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 10 Users Online, 1 year __	586977 (8972-B0) [75]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 15 Users Online, 1 year __	586980 (8972-C0) [76]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 20 Users Online, 1 year __	586983 (8972-D0) [77]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 25 Users Online, 1 year __	586986 (8972-E0) [78]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 30 Users Online, 1 year ___	586989 (8972-F0) [79]
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 35 Users Online, 1 year __	586992 (8972-G0) [80]

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[73] Simulation software that covers transmission lines and more. Doesn't cover SCV and STATCOM.

[74] Simulation software that covers transmission lines and more. Doesn't cover SCV and STATCOM.

[75] Simulation software that covers transmission lines and more. Doesn't cover SCV and STATCOM.

[76] Simulation software that covers transmission lines and more. Doesn't cover SCV and STATCOM.

[77] Simulation software that covers transmission lines and more. Doesn't cover SCV and STATCOM.

[78] Simulation software that covers transmission lines and more. Doesn't cover SCV and STATCOM.

[79] Simulation software that covers transmission lines and more. Doesn't cover SCV and STATCOM.

[80] Simulation software that covers transmission lines and more. Doesn't cover SCV and STATCOM.

Qty	Description	Model number
1	Electromechanical Systems Simulation Software (LVSIM®-EMS) - 40 Users Online, 1 year	586995 (8972-H0) [81]
1	SCADA for LVDAC-EMS	8094377 (8973-00) [82]
1	Acquisition functions	581452 (9069-10) [83]
1	Software Development Kit (SDK)	581459 (9069-90) [84]

System Specifications

Parameter	Value
Sytem Requirements	
Maximum Current	15 A
Typical Current	1.5 A per student group
AC Power Network Installation	3 phases (120/208 V – 60 Hz), star (wye) configuration including neutral and ground wires, protected by a 20 A circuit breaker
AC Power Network Connector	NEMA L21-20
Computer Requirements	A currently available personal computer with USB 2.0 ports, running under one of the following operating systems: Windows® 7 or Windows® 8.
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment
Dimensions (H x W x D)	900 x 930 x 530 mm (35.4 x 36.6 x 20.9 in)
Net Weight	TBE
EMS Modules	
Full-Size Dimensions (H x W x D)	308 x 287 x 440 mm (12.1 x 11.3 x 17.3 in)
Half-Size Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)

Smart Grid Training System
8117310 (8010-F0)

The Smart Grid Training System introduces students to the concept of upgrading and operating an electric power substation in today's smart grid.

The course starts with a brief presentation of the electric power grid. It then explains what the smart grid is, as concretely as possible. This is no easy task, because the definition of the smart grid differs slightly from one country to another. The course continues by presenting several different ways of improving the infrastructure of the grid to make it smart. To demonstrate this in a concrete way, the course shows how an aging distribution substation can be upgraded to improve its reliability, maintainability, flexibility of operation, and power efficiency, i.e., to make it ready for operation in the smart grid and to help meet objectives of the smart grid. The course terminates by showing that proper control of the operations in electric power substations is as important as upgrading the infrastructure of substations to achieve objectives of the smart grid.

The Smart Grid Training System is part of the Electric Power Technology Training Systems, Series 8010. Each training system in Series 8010 is based on the Electric Power

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[81] Simulation software that covers transmission lines and more. Doesn't cover SCV and STATCOM.

[82] Software allowing the monitoring of up to 5 Stations through OPC.

[83] For the 2nd data acquisition unit.

[84] Additional firmware for the Data Acquisition.

Technology Training Program and provides a turnkey solution dealing with some aspects of the wide field of electrical energy. The exhaustive courseware provided with each training system covers all the theory required to perform the laboratory exercises, while review questions and unit tests allow students to test the knowledge they have gained. The Electric Power Technology Training Program is highly modular in both courseware and hardware. Because of this, courses and equipment from the program are available as required, either individually or in the context of a specific training system. The program covers several different subjects in the field of electrical energy, such as rotating machines, electrical power transmission, power electronics, home energy production from renewable resources (wind and sunlight), large-scale electricity production from hydropower and wind power, smart-grid technologies (SVC, STATCOM, HVDC transmission, etc.), storage of electrical energy in batteries, and drive systems for small electric vehicles and cars.

Courseware

Each course in the training system includes a full-color student manual providing all the theoretical matter required, guided lab-exercise procedures to be performed with the training equipment, and review questions that test the knowledge gained by the student. Whenever possible, each course is built to bring the student to actual applications as soon as possible. A full-color instructor guide providing all lab results and answers to questions is also included with each course.

Modular Design Approach

The modular approach for designing the training program and lab equipment enables instructors to start building their electrical-energy laboratory with a basic package of courses and equipment and add new courses and equipment over time without needless duplication of equipment.

All lab equipment consists of modules that can be inserted into a workstation. Module dimensions vary between two standard EMS sizes: full-size and half-size. Symbols and diagrams representing the electrical components in each module are clearly silk-screened on the front panel. Standard, color-coded safety banana jacks are used to provide access to the various components in each module.

Features & Benefits

- The course curriculum of the Electric Power Technology Training Program is highly flexible and allows a multitude of different customized training solutions.
- Flexible learning system to which several other Smart Grid topics can be added such as Electric Power Substations, Numerical Protective Relaying, Transmission Lines, SVC, STATCOM, HVDC, ...
- The courseware includes student manuals and instructor guides with all the theory required to perform the hands-on experiments.

- All workstations, modules, and components are sturdy and protected against electrical damage to ensure a prolonged service life in a demanding environment such as a training laboratory.
- The modular design approach of the training equipment allows a large variety of courses to be performed using a small number of modules, without unnecessary duplication of equipment.
- All electrical components can be interconnected without electric shock hazard since all live parts of the connection leads are concealed and insulated.

List of Equipment

Qty	Description	Model number
1		8107696
1		8107698
1	Circuit Breakers and Disconnecting Switches 1	588952 (3783-00)
1	Circuit Breakers and Disconnecting Switches 2	588953 (3783-A0)
1	Fault Module	588972 (3790-A0)
1	Three-Module Workstation	579483 (8131-00)
1	Tabletop Workstation	579484 (8134-20)
1	Four-Pole Squirrel Cage Motor	586267 (8221-20)
2	Resistive Load	763359 (8311-00)
1	Capacitive Load	763366 (8331-00)
2	Three-Phase Transformer Bank	579559 (8348-40)
1	Three-Phase Power Supply	579612 (8823-00)
1	Ethernet Switch	8198102 (8824-10)
1	Timing Belt	579637 (8942-00)
1	Connection Lead Set	8112387 (8951-S0)
1	Four-Quadrant Dynamometer / Power Supply with Manual and Computer-Based Control	579648 (8960-C0)
1	Data Acquisition and Control Interface	579677 (9063-00)
1	Data Acquisition and Control Interface	579680 (9063-B0)
2	Software Development Kit (SDK)	581459 (9069-90)
1	AC 24 V Wall Mount Power Supply	579696 (30004-20)
1	PLC Software (Step 7 Professional / WinCC) - 1 User	587904 (5939-00)

List of Manuals

Description	Manual number
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)
Smart Grid (Workbook (Instructor))	8107696
Smart Grid (Workbook)	8107698

Table of Contents of the Manual(s)

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

- 1 General Safety Recommendations
- 2 System Power Requirements
- 3 Quick Start Installation Guide
- 4 Equipment Installation
- 5 Modules Handling, Installation, and Removal
- 6 Equipment Maintenance
- A Connection of the Power Supply to the AC Power Network

- B Description, Specifications, and Operation of the EMS Modules

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Smart Grid (Workbook) (8107698)

- 0 The Smart Grid
- 1 Reducing Power Losses in Electric Power Substations
- 2 Upgrading a Substation for Operation in the Smart Grid
- 3 Operating a Substation in the Smart Grid

Software

Qty	Description	Model number
1	SCADA for LVDAC-EMS	8094377 (8973-00) [85]
1	Step 7 professional and WinCC Advanced, 6 users (perpetual) + 20 Students (1 year), Educational	8164650 (81646-50) [86]
1	Step 7 professional and WinCC Advanced, 20 Students (1 year), Educational	8164652 (81646-52) [87]

System Specifications

Parameter	Value
System Requirements	
Maximum Current	15 A
Typical Current	1.5 A per student group
AC Power Network Installation	3 phases (120/208 V – 60 Hz), star (wye) configuration including neutral and ground wires, protected by a 20 A circuit breaker
AC Power Network Connector	NEMA L21-20
Computer Requirements	A currently available personal computer with USB 2.0 ports, running under one of the following operating systems: Windows® 7, Windows® 8 or Windows® 10.
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment
Dimensions (H x W x D)	1275 x 930 x 530 mm (50.2 x 36.6 x 20.9 in)
Net Weight	TBE

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[85] Software allowing the monitoring of up to 5 Stations through OPC.

[86] The system includes 1 user license.

[87] The system includes 1 user license.

Electric Power Generation Training System
8108668 (8010-G0)

The Electric Power Generation Training System examines the production of electricity from two different sources:

- hydro power using a synchronous generator, a proven technology long used worldwide by power utilities

- diesel generators using a synchronous generator, a common mean of electric power generation and also an essential component of micro grids

The system includes a specific course on each power source using the same hardware equipment.

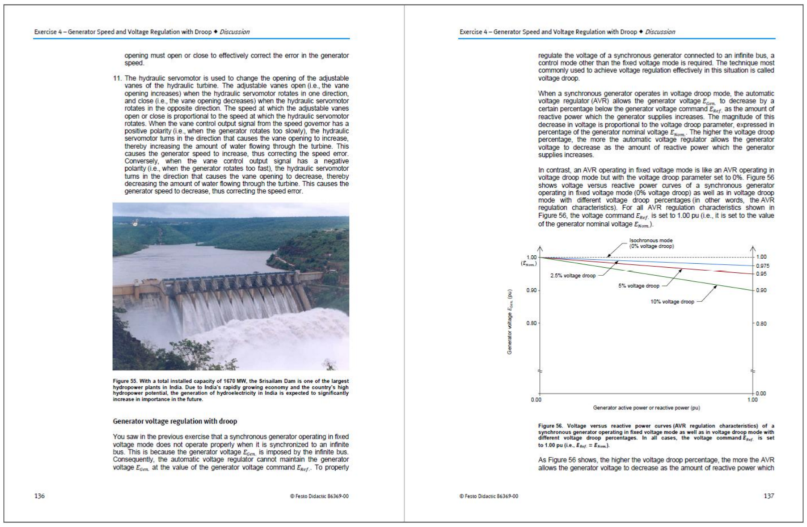
In the course Hydropower Electricity Generation, the training system first introduces the student to the configuration of a typical hydropower plant. The student then learns how to adjust the voltage and frequency of the synchronous generator in a hydropower plant, as well as how to synchronize the generator using a synchro-check relay. The training system concludes with a study of the automatic speed (frequency) and voltage regulation systems used in a hydropower plant. The training system also includes an optional exercise dealing with the operation of hydropower generators connected in parallel as well as with load sharing.

In the course Diesel Electricity Generation, students are introduced to the different components of a typical diesel electric generator. They learn how to synchronize the diesel engine-driven synchronous generator to other generators of the microgrid, such as those using solar and wind energy, as well as to the main power grid. They also learn how to regulate the speed (frequency) and voltage of the synchronous generator. Finally, the theory presented in the course is verified by performing various circuit measurements and observations.

The Electric Power Generation Training System is part of the Electric Power Technology Training Systems, Series 8010. Each training system in Series 8010 is based on the Electric Power Technology Training Program and provides a turn-key solution dealing with some aspects of the wide field of electrical energy. The exhaustive courseware provided with each training system covers all the theory required to perform the laboratory exercises, while review questions and unit tests allow students to test the knowledge they have gained.

The Electric Power Technology Training Program is highly modular in both courseware and hardware. Because of this, courses and equipment from the program are available as required, either individually or in the context of a specific training system. The program covers several different subjects in the field of electrical energy, such as rotating machines, electrical power transmission, power electronics, home energy production from renewable resources (wind and sunlight), large-scale electricity production from hydropower and wind power, smart-grid technologies (SVC, STATCOM, HVDC transmission, etc.), storage of electrical energy in batteries, and drive systems for small electric vehicles and cars.

Courseware



Exercise 4 – Generator Speed and Voltage Regulation with Droop ◆ *Discussion*

opening must open or close to effectively correct the error in the generator speed.

11. The hydraulic servomotor is used to change the opening of the adjustable vanes of the hydraulic turbine. The adjustable vanes open (i.e., the vane opening increases) when the hydraulic servomotor rotates in one direction, and close (i.e., the vane opening decreases) when the hydraulic servomotor rotates in the opposite direction. The speed at which the adjustable vanes open or close is proportional to the speed at which the hydraulic servomotor rotates. When the vane control output signal from the speed governor has a positive polarity (i.e., when the generator rotates too slowly), the hydraulic servomotor turns in the direction that causes the vane opening to increase, thereby increasing the amount of water flowing through the turbine. This causes the generator speed to increase, thus correcting the speed error. Conversely, when the vane control output signal has a negative polarity (i.e., when the generator rotates too fast), the hydraulic servomotor turns in the direction that causes the vane opening to decrease, thereby decreasing the amount of water flowing through the turbine. This causes the generator speed to decrease, thus correcting the speed error.

Figure 55. With a total installed capacity of 1670 MW, the Srisailam Dam is one of the largest hydropower plants in India. Due to India's rapidly growing economy and the country's high hydropower potential, the generation of hydroelectricity in India is expected to significantly increase in importance in the future.

Generator voltage regulation with droop

You saw in the previous exercise that a synchronous generator operating in fixed voltage mode does not operate properly when it is synchronized to an infinite bus. This is because the generator voltage $E_{Gen.}$ is imposed by the infinite bus. Consequently, the automatic voltage regulator cannot maintain the generator voltage $E_{Gen.}$ at the value of the generator voltage command $E_{Ref.}$. To properly

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Exercise 4 – Generator Speed and Voltage Regulation with Droop ◆ *Discussion*

regulate the voltage of a synchronous generator connected to an infinite bus, a control mode other than the fixed voltage mode is required. The technique most commonly used to achieve voltage regulation effectively in this situation is called voltage droop.

When a synchronous generator operates in voltage droop mode, the automatic voltage regulator (AVR) allows the generator voltage $E_{Gen.}$ to decrease by a certain percentage below the generator voltage command $E_{Ref.}$ as the amount of reactive power which the generator supplies increases. The magnitude of this decrease in voltage is proportional to the voltage droop parameter, expressed in percentage of the generator nominal voltage $E_{Nom.}$. The higher the voltage droop percentage, the more the automatic voltage regulator allows the generator voltage to decrease as the amount of reactive power which the generator supplies increases.

In contrast, an AVR operating in fixed voltage mode is like an AVR operating in voltage droop mode but with the voltage droop parameter set to 0%. Figure 56 shows voltage versus reactive power curves of a synchronous generator operating in fixed voltage mode (0% voltage droop) as well as in voltage droop mode with different voltage droop percentages (in other words, the AVR regulation characteristics). For all AVR regulation characteristics shown in Figure 56, the voltage command $E_{Ref.}$ is set to 1.00 pu (i.e., it is set to the value of the generator nominal voltage $E_{Nom.}$).

Figure 56. Voltage versus reactive power curves (AVR regulation characteristics) of a synchronous generator operating in fixed voltage mode as well as in voltage droop mode with different voltage droop percentages. In all cases, the voltage command $E_{Ref.}$ is set to 1.00 pu (i.e., $E_{Ref.} = E_{Nom.}$).

As Figure 56 shows, the higher the voltage droop percentage, the more the AVR allows the generator voltage to decrease as the amount of reactive power which

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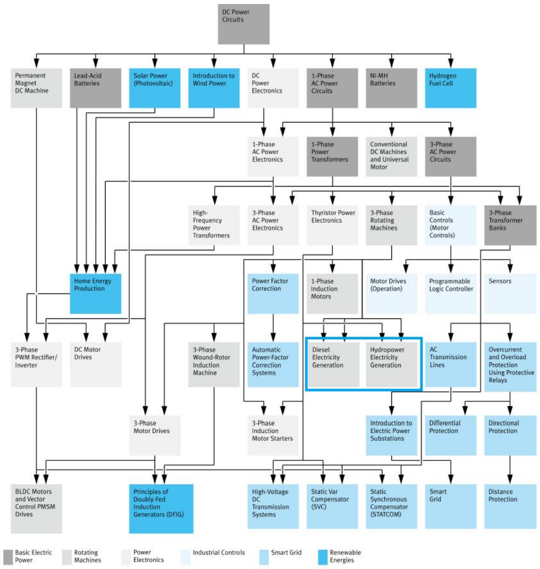
Each course in the training system includes a full-color student manual providing all the theoretical matter required, guided lab-exercise procedures to be performed with the training equipment, and review questions that test the knowledge gained by the student. Whenever possible, each course is built to bring the student to actual applications as soon as possible. A full-color instructor guide providing all lab results and answers to questions is also included with each course.

Modular Design Approach

The modular approach for designing the training program and lab equipment enables instructors to start building their electrical-energy laboratory with a basic package of courses and equipment and add new courses and equipment over time without needless duplication of equipment.

All lab equipment consists of modules that can be inserted into a workstation. Module dimensions vary between two standard EMS sizes: full-size and half-size. Symbols and diagrams representing the electrical components in each module are clearly silk-screened on the front panel. Standard, color-coded safety banana jacks are used to provide access to the various components in each module.

8010-G Flowchart


DC Power Circuits
Permanent Magnet DC Machine
Lead-Acid Batteries
Solar Power (Photovoltaic)
Introduction to Wind Power
DC Power Electronics
1-Phase AC Power Circuits
Ni-MH Batteries
Hydrogen Fuel Cell
1-Phase AC Power Electronics
1-Phase Power Transformers
Conventional DC Machines and Universal Motor
3-Phase AC Power Circuits
High-Frequency Power Transformers
3-Phase AC Power Electronics
Thyristor Power Electronics
3-Phase Rotating Machines
Basic Controls (Motor Controls)
3-Phase Transformer Banks
Home Energy Production
Power Factor Correction
1-Phase Induction Motors
Motor Drives (Operation)
Programmable Logic Controller
Sensors
3-Phase PWM Rectifier/ Inverter
DC Motor Drives
3-Phase Wound-Rotor Induction Machine
Automatic Power-Factor Correction Systems
Diesel Electricity Generation
Hydropower Electricity Generation
AC Transmission Lines
Overcurrent and Overload Protection Using Protective Relays
3-Phase Motor Drives
3-Phase Induction Motor Starters
Introduction to Electric Power Substations
Differential Protection
Directional Protection
BLDC Motors and Vector Control PMSM Drives
Principles of Doubly-Fed Induction Generators (DFIG)
High-Voltage DC Transmission Systems
Static Var Compensator (SVC)
Static Synchronous Compensator (STATCOM)
Smart Grid
Distance Protection
Basic Electric Power
Rotating Machines
Power Electronics
Industrial Controls
Smart Grid
Renewable Energies

The above chart shows all courses in the Electric Power Technology Training Program. The courses included in the training system are highlighted with a blue rectangle. While the other courses in the program can be added optionally to this training system.

Features & Benefits

- Realistic control functions implemented using the Data Acquisition and Control Interface and Four-Quadrant Dynamometer via the LVDAC-EMS software allow for a perfect emulation of hydropower plant setup and diesel generators.
- The course curriculum of the Electric Power Technology Training Program is highly flexible and allows a multitude of different customized training solutions.
- The courseware includes student manuals and instructor guides with all the theory required to perform the hands-on experiments.
- All workstations, modules, and components are sturdy and protected against electrical damage to ensure a prolonged service life in a demanding environment such as a training laboratory.
- The modular design approach of the training equipment allows a large variety of courses to be performed using a small number of modules, without unnecessary duplication of equipment.
- All electrical components can be interconnected without electric shock hazard since all live parts of the connection leads are concealed and insulated.
- All electrical symbols representing the components used in a laboratory exercise are clearly silk-screened on the front panel of the modules.
- The training system includes two highly versatile USB peripherals:
    - Four-Quadrant Dynamometer/Power Supply, Model 8960-2. This module is used as a solar panel emulator with a large variety of configurable parameters.
    - Data Acquisition and Control Interface, Model 9063. This module gives access to a large variety of computer-based measuring instruments and is used to control the power thyristors bridge that regulates the generator voltage with the AVR. All functions are implemented via the LVDAC-EMS software.
- Software upgrades for LVDAC-EMS and firmware upgrades for the Four-Quadrant Dynamometer/Power Supply and Data Acquisition and Control Interface are available for download free of charge on the Festo Didactic website.

List of Equipment

Qty	Description	Model number
1	Hydropower Electricity Generation (Student Manual)	579742 (86369-00)
1	Hydropower Electricity Generation (Instructor Guide)	579743 (86369-10)
1	Tabletop Workstation	579484 (8134-20)
1	Three-Phase Synchronous Motor/Generator	579502 (8241-20)
1	Resistive Load	763359 (8311-00)
1	Inductive Load	763362 (8321-00)
1	Synchronizing Module / Three-Phase Contactor	8204391 (8621-B0)
1	Three-Phase Power Supply	579612 (8823-00)
1	Power Thyristors	763376 (8841-20)
1	Timing Belt	579637 (8942-00)
1	Connection Lead Set	579638 (8951-L0)
1	Connection Lead Set	579639 (8951-N0)
1	Four-Quadrant Dynamometer / Power Supply with Manual and Computer-Based Control	579648 (8960-C0)
1	Turbine/Engine Emulator Function Set	579783 (8968-30)
1	Data Acquisition and Control Interface	579680 (9063-B0)
1	Synchronous Generator Control Function Set	579788 (9069-A0)
1	AC 24 V Wall Mount Power Supply	579696 (30004-20)

List of Manuals

Description	Manual number
Hydropower Electricity Generation (Workbook)	579742 (86369-00)
Hydropower Electricity Generation (Workbook (Instructor))	579743 (86369-10)
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)

Table of Contents of the Manual(s)

Hydropower Electricity Generation (Workbook) (579742 (86369-00))

- 1 Generator Frequency and Voltage Control Principles
- 2 Generator Synchronization Using a Synchro-Check Relay
- 3 Generator Operation with Speed and Voltage Regulation
- 4 Generator Speed and Voltage Regulation with Droop
- 5 Generator Parallel Operation and Load Sharing (Optional)

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

- 1 General Safety Recommendations
- 2 System Power Requirements
- 3 Quick Start Installation Guide
- 4 Equipment Installation
- 5 Modules Handling, Installation, and Removal
- 6 Equipment Maintenance
- A Connection of the Power Supply to the AC Power Network
- B Description, Specifications, and Operation of the EMS Modules

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Software

Qty	Description	Model number
1	SCADA for LVDAC-EMS	8094377 (8973-00) [88]
1	Software Development Kit (SDK)	581459 (9069-90) [89]

System Specifications

Parameter	Value
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment
Dimensions (H x W x D)	890 x 935 x 465 mm (35.0 x 36.8 x 18.3 in)
Net Weight	X kg (X lb)

BLDC Motors and Vector Control PMSM Drives Training System
8108674 (8010-J0)

The BLDC Motor and Vector Control PMSM Drives Training System introduces the student to the permanent magnet synchronous machine (PMSM). This type of machine is used in a wide range of modern applications such as computers, household appliances, and electric vehicles. The training system covers the operation and characteristics of two types of motor that use PMSM technology: the brushless dc (BLDC) motor and the PMSM drive. It also deals with the most common types of modulation used to implement BLDC motors (six-step 120° modulation and six-step PWM) and PMSM drives (vector control).

The BLDC Motor and Vector Control PMSM Drives Training System is part of the Electric Power Technology Training Systems, Series 8010. Each training system in Series 8010 is based on the Electric Power Technology Training Program and provides a turn-key solution dealing with some aspects of the wide field of electrical energy. The exhaustive courseware provided with each training system covers all the theory required to perform the laboratory exercises, while review questions and unit tests allow students to test the knowledge they have gained.

The Electric Power Technology Training Program is highly modular in both courseware and hardware. Because of this, courses and equipment from the program are available as required, either individually or in the context of a specific training system. The program covers several different subjects in the field of electrical energy, such as rotating machines, electrical power transmission, power electronics, home energy production from renewable resources (wind and sunlight), large-scale electricity production from hydropower and wind power, smart-grid technologies (SVC, STATCOM, HVDC transmission, etc.), storage of electrical energy in batteries, and drive systems for small electric vehicles and cars.

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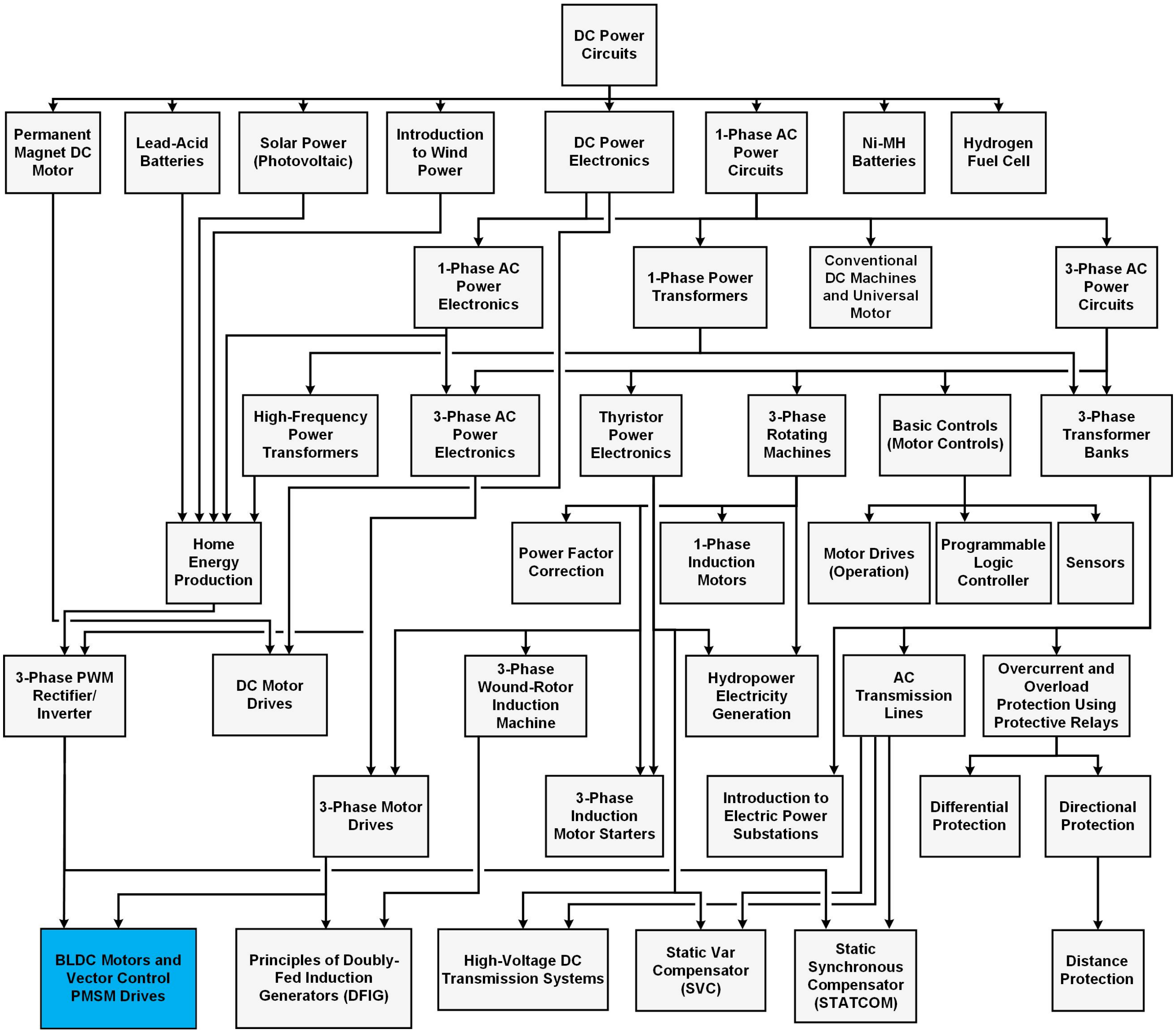
[88] Software allowing the monitoring of up to 5 Stations through OPC.

[89] Additional firmware for the Data Acquisition.


DC Power Circuits
Permanent Magnet DC Motor
Lead-Acid Batteries
Solar Power (Photovoltaic)
Introduction to Wind Power
DC Power Electronics
1-Phase AC Power Circuits
Ni-MH Batteries
Hydrogen Fuel Cell
1-Phase AC Power Electronics
1-Phase Power Transformers
Conventional DC Machines and Universal Motor
3-Phase AC Power Circuits
High-Frequency Power Transformers
3-Phase AC Power Electronics
Thyristor Power Electronics
3-Phase Rotating Machines
Basic Controls (Motor Controls)
3-Phase Transformer Banks
Home Energy Production
Power Factor Correction
1-Phase Induction Motors
Motor Drives (Operation)
Programmable Logic Controller
Sensors
3-Phase PWM Rectifier/ Inverter
DC Motor Drives
3-Phase Wound-Rotor Induction Machine
Hydropower Electricity Generation
AC Transmission Lines
Overcurrent and Overload Protection Using Protective Relays
3-Phase Motor Drives
3-Phase Induction Motor Starters
Introduction to Electric Power Substations
Differential Protection
Directional Protection
BLDC Motors and Vector Control PMSM Drives
Principles of Doubly-Fed Induction Generators (DFIG)
High-Voltage DC Transmission Systems
Static Var Compensator (SVC)
Static Synchronous Compensator (STATCOM)
Distance Protection

The above chart shows all courses in the Electric Power Technology Training Program. Blue boxes highlight courses included in the training system covered in this datasheet, while dark grey boxes, if any, highlight courses that can be optionally added to this training system.

Courseware

Each course in the training system includes a full-color student manual providing all the theoretical matter required, guided lab-exercise procedures to be performed with the training equipment, and review questions that test the knowledge gained by the student. Whenever possible, each course is built to bring the student to actual applications as soon as possible. A full-color instructor guide providing all lab results and answers to questions is also included with each course.

Modular Design Approach

The modular approach for designing the training program and lab equipment enables instructors to start building their electrical-energy laboratory with a basic package of courses and equipment and add new courses and equipment over time without needless duplication of equipment.

All lab equipment consists of modules that can be inserted into a workstation. Module dimensions vary between two standard EMS sizes: full-size and half-size. Symbols and diagrams representing the electrical components in each module are clearly silk-screened on the front panel. Standard, color-coded safety banana jacks are used to provide access to the various components in each module.

Features & Benefits

- Self-learning curriculum complete with the necessary theory and hands-on experiments
- All control of power electronics devices is computerized via LVDAC-EMS software, allowing for quick setup and easy monitoring
- Totally safe and sturdy working environment with a complete and automatic grounding of all components
- Top-of-the-line data acquisition measuring tools designed to enhance the learning approach and reduce setup time
- Versatile power electronics modules (IGBT) easily reconfigurable in multiple different controllers

List of Equipment

Qty	Description	Model number
1		585206 (86373-00)
1		585207 (86373-10)
1	Tabletop Workstation	579484 (8134-20)
1	Permanent Magnet Synchronous Machine	8190269 (8245-10)
1	Resistive Load	763359 (8311-00)
3	Lead-Acid Battery Pack	579591 (8802-10)
1	IGBT Chopper/Inverter	579623 (8837-B0)
1	Timing Belt	579637 (8942-00)
1	Connection Lead Set	579638 (8951-L0)
1	Connection Lead Set	586897 (8951-P0)
1	Four-Quadrant Dynamometer / Power Supply with Manual and Computer-Based Control	579648 (8960-C0)
1	Data Acquisition and Control Interface	579680 (9063-B0)
1	BLDC Motor/PMSM Control Function Set	581457 (9069-60)
1	AC 24 V Wall Mount Power Supply	579696 (30004-20)

List of Manuals

Description	Manual number
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)
BLDC Motors and Vector Control PMSM Drives (Workbook)	585206 (86373-00)
BLDC Motors and Vector Control PMSM Drives (Workbook (Instructor))	585207 (86373-10)
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)

Table of Contents of the Manual(s)

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

- 1 General Safety Recommendations
- 2 System Power Requirements
- 3 Quick Start Installation Guide
- 4 Equipment Installation
- 5 Modules Handling, Installation, and Removal
- 6 Equipment Maintenance
- A Connection of the Power Supply to the AC Power Network
- B Description, Specifications, and Operation of the EMS Modules

BLDC Motors and Vector Control PMSM Drives (Workbook) (585206 (86373-00))

- 1 PMSM Control Using a Three-Phase, Six-Step 120° Modulation Inverter
- 2 The BLDC Motor
- 3 The Vector Control PMSM Drive

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Software

Qty	Description	Model number
1	SCADA for LVDAC-EMS	8094377 (8973-00) [90]
1	Software Development Kit (SDK)	581459 (9069-90) [91]

System Specifications

Parameter	Value
System Requirements	
Maximum Current	15 A
Typical Current	1.5 A per student group
AC Power Network Installation	3 phases (120/208 V - 60 Hz), star (wye) configuration including neutral and ground protected by a 20 A circuit breaker
AC Power Network Connector	NEMA L21-20
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment
Dimensions (H x W x D)	890 x 935 x 465 mm (35.0 x 36.8 x 18.3 in)
Net Weight	X kg (X lb)

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[90] Software allowing the monitoring of up to 5 Stations through OPC.

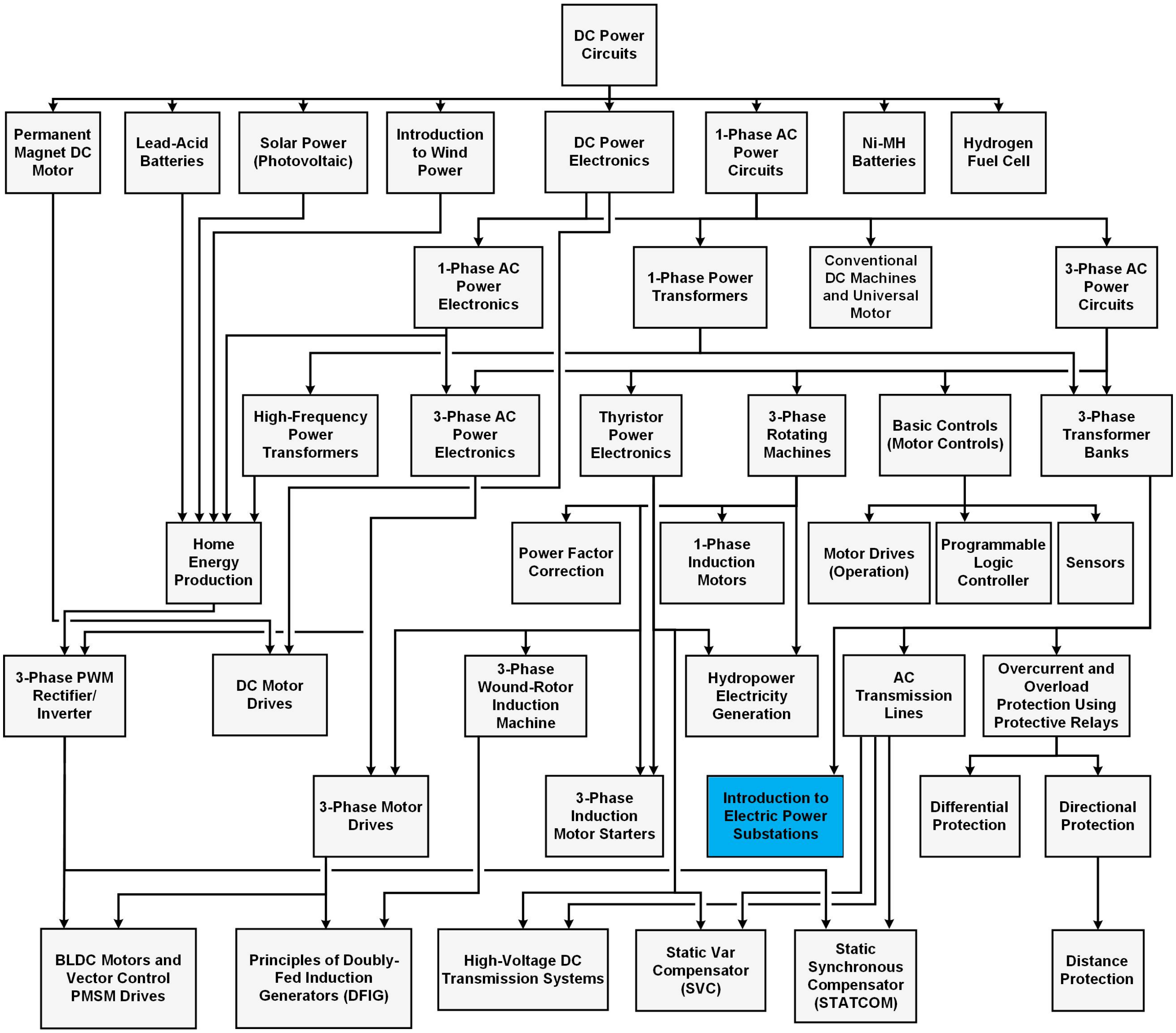
[91] Additional firmware for the Data Acquisition.

Electric Power Substations Training System
8108677 (8010-K0)

The Electric Power Substations Training System introduces students to the operation of electric power substations. It begins by covering the main components of substations: buses, circuit breakers, and disconnecting switches. The training system then fully describes and presents both advantages and disadvantages of two switching schemes commonly implemented in substations: the single-bus scheme and the double-bus, single-breaker scheme.

The Electric Power Substations Training System is part of the Electric Power Technology Training Systems, Series 8010. Each training system in Series 8010 is based on the Electric Power Technology Training Program and provides a turn-key solution dealing with some aspects of the wide field of electrical energy. The exhaustive courseware provided with each training system covers all the theory required to perform the laboratory exercises, while review questions and unit tests allow students to test the knowledge they have gained.

The Electric Power Technology Training Program is highly modular in both courseware and hardware. Because of this, courses and equipment from the program are available as required, either individually or in the context of a specific training system. The program covers several different subjects in the field of electrical energy, such as rotating machines, electrical power transmission, power electronics, home energy production from renewable resources (wind and sunlight), large-scale electricity production from hydropower and wind power, smart-grid technologies (SVC, STATCOM, HVDC transmission, etc.), storage of electrical energy in batteries, and drive systems for small electric vehicles and cars.


DC Power Circuits
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Thyristor Power Electronics
3-Phase Rotating Machines
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Power Factor Correction
1-Phase Induction Motors
Motor Drives (Operation)
Programmable Logic Controller
Sensors
3-Phase PWM Rectifier/ Inverter
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High-Voltage DC Transmission Systems
Static Var Compensator (SVC)
Static Synchronous Compensator (STATCOM)
Distance Protection

The above chart shows all courses in the Electric Power Technology Training Program. Blue boxes highlight courses included in the training system covered in this datasheet, while dark grey boxes, if any, highlight courses that can be optionally added to this training system.

Courseware

Each course in the training system includes a full-color student manual providing all the theoretical matter required, guided lab-exercise procedures to be performed with the training equipment, and review questions that test the knowledge gained by the student. Whenever possible, each course is built to bring the student to actual applications as soon as possible. A full-color instructor guide providing all lab results and answers to questions is also included with each course.

Modular Design Approach

The modular approach for designing the training program and lab equipment enables instructors to start building their electrical-energy laboratory with a basic package of courses and equipment and add new courses and equipment over time without needless duplication of equipment.

All lab equipment consists of modules that can be inserted into a workstation. Module dimensions vary between two standard EMS sizes: full-size and half-size. Symbols and diagrams representing the electrical components in each module are clearly silk-screened on the front panel. Standard, color-coded safety banana jacks are used to provide access to the various components in each module.

Features & Benefits

- The course curriculum of the Electric Power Technology Training Program is highly flexible and allows a multitude of different customized training solutions.
- The courseware includes student manuals and instructor guides with all the theory required to perform the hands-on experiments.
- All workstations, modules, and components are sturdy and protected against electrical damage to ensure a prolonged service life in a demanding environment such as a training laboratory.
- The modular design approach of the training equipment allows a large variety of courses to be performed using a small number of modules, without unnecessary duplication of equipment.
- All electrical components can be interconnected without electric shock hazard since all live parts of the connection leads are concealed and insulated.
- All electrical symbols representing the components used in a laboratory exercise are clearly silk-screened on the front panel of the modules.
- Top of the line data acquisition and control interface designed for learning purposes.

List of Equipment

Qty	Description	Model number
1		589173 (20528-00)
1		589174 (20528-10)
1	Circuit Breakers and Disconnecting Switches 1	588952 (3783-00)
1	Circuit Breakers and Disconnecting Switches 2	588953 (3783-A0)
1	Fault Module	588972 (3790-A0)
1	Tabletop Workstation	579484 (8134-20)
1	Resistive Load	763359 (8311-00)
1	Line Inductors	763364 (8326-A0)
1	Three-Phase Power Supply	579612 (8823-00)
1	Ethernet Switch	8198102 (8824-10)

Qty	Description	Model number
1	Connection Lead Set	586891 (8951-A0)
1	Data Acquisition and Control Interface	579680 (9063-B0)
1	Software Development Kit (SDK)	581459 (9069-90)
1	AC 24 V Wall Mount Power Supply	579696 (30004-20)
1	PLC Software (Step 7 Professional / WinCC) - 1 User	587904 (5939-00)

List of Manuals

Description	Manual number
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)
Introduction to Electric Power Substations (Workbook)	589173 (20528-00)
Introduction to Electric Power Substations (Workbook (Instructor))	589174 (20528-10)

Table of Contents of the Manual(s)

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

- 1 General Safety Recommendations
- 2 System Power Requirements
- 3 Quick Start Installation Guide
- 4 Equipment Installation
- 5 Modules Handling, Installation, and Removal
- 6 Equipment Maintenance
- A Connection of the Power Supply to the AC Power Network
- B Description, Specifications, and Operation of the EMS Modules

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Introduction to Electric Power Substations (Workbook) (589173 (20528-00))

- 1 High-Voltage Disconnecting Switches and Circuit Breakers
- 2 Single Bus Scheme
- 3 Double Bus, Single Breaker Scheme

Software

Qty	Description	Model number
1	SCADA for LVDAC-EMS	8094377 (8973-00) [92]
1	Step 7 professional and WinCC Advanced, 6 users (perpetual) + 20 Students (1 year), Educational	8164650 (81646-50) [93]

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[92] Software allowing the monitoring of up to 5 Stations through OPC.

[93] The system includes 1 user license.

Qty	Description	Model number
1	Step 7 professional and WinCC Advanced, 20 Students (1 year), Educational	8164652 (81646-52) [94]

System Specifications

Parameter	Value
System Requirements	
Maximum Current	15 A
Typical Current	1.5 A per student group
AC Power Network Installation	3 phases (120/208 V - 60 Hz), star (wye) configuration including neutral and ground protected by a 20 A circuit breaker
AC Power Network Connector	NEMA L21-20
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment
Dimensions (H x W x D)	890 x 935 x 465 mm (35.0 x 36.8 x 18.3 in)
Net Weight	X kg (X lb)

Numerical Protective Relays Training System
8108680 (8010-L0)

SIEMENS
SIPROTEC 7SA82
FESTO
Numerical Distance Relay

SIEMENS
SIPROTEC 7SD82
FESTO
Numerical Differential Protective Relay

Protective relaying provides detection of abnormal operating conditions in electrical systems and is needed in order to act quickly to protect circuits, equipment, and the general public. The theoretical background, as well as practical application, of these protective devices and their protection functions are an important part of the education of power systems for electrical engineers.

Power-utility-grade equipment, Siemens' newest generation the SIPROTEC 5 series, is used in this innovative teaching approach. Example scenarios are created in the accompanying professional programming tool, DIGSI 5, which allows users to create different setups and simulate possible faults using the built-in relay testing unit. The response of the relay is then analyzed with the relay display and the fault record. This customizable solution allows perfect alignment for individual teaching needs.

The available range of relays and manuals provide coverage of these general topics:

- Overcurrent/Overload Protection
- Directional Protection
- Differential Protection
- Distance Protection

Features & Benefits

- Self-contained devices with internal testing capabilities not requiring external devices to create faults
- Power-utility grade equipment with Siemens' newest generation of the SIPROTEC 5 Series
- Professionnal programming tool DIGSI 5 to create and test different scenarios
- Complete curriculum with all the necessary theory and manipulations to cover these comprehensive topics
- Possibility to cover all dedicated workbooks on numerical relay protection with only two units

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[94] The system includes 1 user license.

List of Equipment

Qty	Description	Model number
1		589887 (52173-00)
1		589888 (52173-10)
1		589889 (52174-00)
1		589890 (52174-10)
1		590085 (52175-00)
1		590086 (52175-10)
1		593880 (52176-00)
1		593881 (52176-10)
1	Numerical Distance Relay	589062 (3813-00)
1	Numerical Differential Protective Relay	589891 (3819-00)

List of Manuals

Description	Manual number
Overcurrent and Overload Protection Using Protective Relays (Workbook)	589887 (52173-00)
Overcurrent and Overload Protection Using Protective Relays (Workbook (Instructor))	589888 (52173-10)
Directional Protection (Workbook)	589889 (52174-00)
Directional Protection (Workbook (Instructor))	589890 (52174-10)
Differential Protection (Workbook)	590085 (52175-00)
Differential Protection (Workbook (Instructor))	590086 (52175-10)
Numerical Protective Relays (User Guide)	590108 (52766-E0)
Distance Protection (Workbook)	593880 (52176-00)
Distance Protection (Workbook (Instructor))	593881 (52176-10)
Numerische Schutzrelais (User Guide)	593908 (52766-EG)
Relais de protection numériques (User Guide)	593909 (52766-E1)
Relés numéricos de protección (User Guide)	593910 (52766-E2)

Table of Contents of the Manual(s)

Overcurrent and Overload Protection Using Protective Relays (Workbook) (589887 (52173-00))

- 1 Overcurrent Protection
- 2 Overcurrent and Overload Protection of AC Machines and Power Transformers
- 3 Overcurrent Protection of Radial Feeders

Directional Protection (Workbook) (589889 (52174-00))

- 1 Directional Overcurrent Protection
- 2 Directional Comparison Protection
- 3 Directional Power Protection

Differential Protection (Workbook) (590085 (52175-00))

- 1 Fundamentals of Differential Protection
- 2 Percentage Restrained Differential Protection

Distance Protection (Workbook) (593880 (52176-00))

- 1 Distance Relay Impedance Characteristic
- 2 Conventional Time-Stepped Distance Protection
- 3 Distance Protection Using Communication-Assisted Tripping Schemes

Additional Equipment Required to Perform the Exercises (Purchased separately)

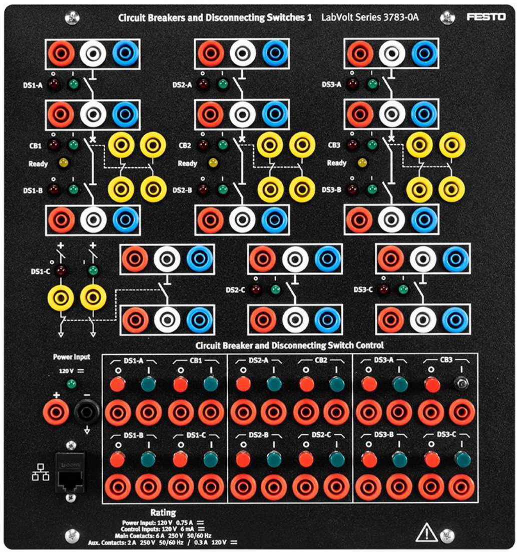
Qty	Description	Model number
1	License for DIGSI 5 Premium Software	779959 (52286-00) [95]

System Specifications

Parameter	Value
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment
Dimensions (H x W x D)	890 x 935 x 465 mm (35.0 x 36.8 x 18.3 in)
Net Weight	X kg (X lb)

Equipment Description

Circuit Breakers and Disconnecting Switches 1
588952 (3783-00)


Circuit Breakers and Disconnecting Switches 1
LabVolt Series 3783-0A
FESTO
DS1-A
DS2-A
DS3-A
CB1
CB2
CB3
Ready
DS1-B
DS2-B
DS3-B
DS1-C
DS2-C
DS3-C
Circuit Breaker and Disconnecting Switch Control
Power Input
120 V
Rating
Power Input: 120 V 0.75 A
Control Inputs: 120 V 6 mA
Main Contacts: 6 A 250 V 50/60 Hz
Aux. Contacts: 2 A 250 V 50/60 Hz / 0.3 A 120 V

The Circuit Breakers and Disconnecting Switches 1, Model 3783-0 can be operated independently using dedicated I/O (open/close) switches or open/close control inputs on the front panel. An Ethernet port on the module front panel allows all circuit breakers and disconnecting switches to be controlled independently using a SCADA system. Green (close) and red (open) pilot lights on the front panel indicate the state of each circuit breaker and disconnecting switch. Open/close auxiliary contact sets are provided for each of the 3 circuit breakers. Open/close auxiliary contact sets are provided for one of the disconnecting switch. Module operation requires 120 V dc power which is applied to the module via two safety banana jacks on the front panel. Electric power substations with the following switching schemes, i.e., the bus (busbar) arrangements, can be implemented using two Circuit Breakers and Disconnecting Switches modules (Models 3783-0 and 3783-A):

- Single Bus
- Double Bus, Single Breaker
- Main Bus with Transfer Bus
- Ring Bus
- Breaker-and-a-Half
- Double Bus, Double Breaker

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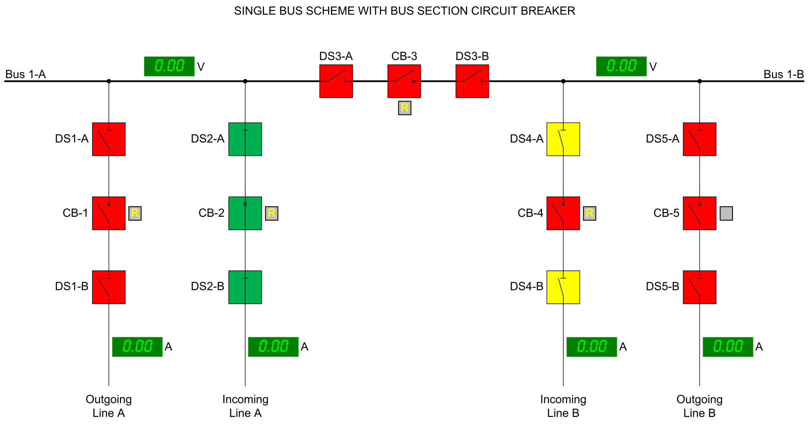
[95] Required for non-educational customers only. For educational customer, the software is provided for free with a 10 users license.

SCADA Application

Included with the module is the SCADA application that allows control and supervision of an electric power substation implemented using modules Circuit Breakers and Disconnecting Switches 1 and 2, Models 3783-0 and 3783-A, respectively. This application must be installed on the host computer used to control the substation.

The SCADA application displays the simplified diagram of the substation, integrating the main system controls with the meters showing the values of the meaningful system parameters. This allows students to quickly understand what is going on in the substation.


SINGLE BUS SCHEME WITH BUS SECTION CIRCUIT BREAKER
Bus 1-A
0.00 V
DS3-A
CB-3
DS3-B
0.00 V
Bus 1-B
DS1-A
DS2-A
DS4-A
DS5-A
CB-1
CB-2
CB-4
CB-5
DS1-B
DS2-B
DS4-B
DS5-B
0.00 A
0.00 A
0.00 A
0.00 A
Outgoing Line A
Incoming Line A
Incoming Line B
Outgoing Line B

Example of a substation viewed in the SCADA application.

Specifications

Parameter	Value
Contactor Ratings	
Power Input	120 V dc – 100 mA
Control Inputs	120 V dc – 6 mA
Main Contacts	250 V ac – 6 A
Auxilliary Contacts	250 V ac – 2 A / 120 V dc – 0.3 A
Communication Port	
Socket	RJ45
Physical Characteristics	
Dimensions (H x W x D)	308 x 287 x 490 mm (12.1 x 11.3 x 19.3 in)
Net Weight	TBE

Circuit Breakers and Disconnecting Switches 2
588953 (3783-A0)

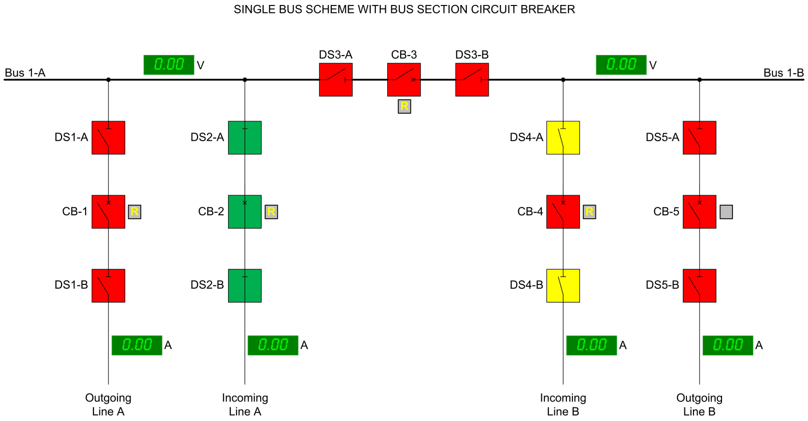
The Circuit Breakers and Disconnecting Switches 2, Model 3783-A, consists of 3 three-phase circuit breakers and 9 three-phase disconnecting switches, enclosed in a full-size EMS module, that can be used to implement electric power substations with different switching schemes. Each circuit breaker and each disconnecting switch can be operated independently using dedicated I/O (open/close) switches or open/close control inputs on the front panel. An Ethernet port on the module front panel allows all circuit breakers and disconnecting switches to be controlled independently using a SCADA system. Green (close) and red (open) pilot lights on the front panel indicate the state of each circuit breaker and disconnecting switch. Open/close auxiliary contact sets are provided for each of the 3 circuit breakers. Open/close auxiliary contact sets are provided for one of the disconnecting switch. Module operation requires 120 V dc power which is applied to the module via two safety banana jacks on the front panel. Electric power substations with the following switching schemes, i.e., the bus (busbar) arrangements, can be implemented using two Circuit Breakers and Disconnecting Switches modules (Models 3783-0 and 3783-A):

- Single Bus
- Double Bus, Single Breaker
- Main Bus with Transfer Bus
- Ring Bus
- Breaker-and-a-Half
- Double Bus, Double Breaker

SCADA Application

Included with the module is the SCADA application that allows control and supervision of an electric power substation implemented using modules Circuit Breakers and Disconnecting Switches 1 and 2, Models 3783-0 and 3783-A, respectively. This application must be installed on the host computer used to control the substation.

The SCADA application displays the simplified diagram of the substation, integrating the main system controls with the meters showing the values of the meaningful system parameters. This allows students to quickly understand what is going on in the substation.

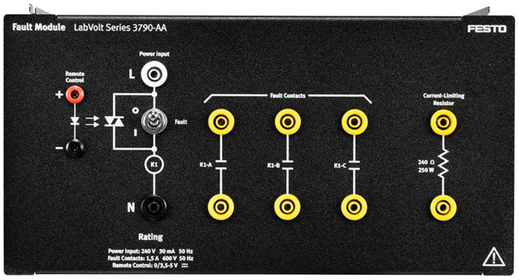

SINGLE BUS SCHEME WITH BUS SECTION CIRCUIT BREAKER
Bus 1-A
0.00 V
DS3-A
CB-3
DS3-B
0.00 V
Bus 1-B
DS1-A
DS2-A
DS4-A
DS5-A
CB-1
CB-2
CB-4
CB-5
DS1-B
DS2-B
DS4-B
DS5-B
0.00 A
0.00 A
0.00 A
0.00 A
Outgoing Line A
Incoming Line A
Incoming Line B
Outgoing Line B

Example of a substation viewed in the SCADA application.

Specifications

Parameter	Value
Contactor Ratings	
Power Input	120 V dc – 100 mA
Control Inputs	120 V dc – 6 mA
Main Contacts	250 V ac – 6 A
Auxilliary Contacts	250 V ac – 2 A / 120 V dc – 0.3 A
Communication Port	
Socket	RJ45
Physical Characteristics	
Dimensions (H x W x D)	308 x 287 x 490 mm (12.1 x 11.3 x 19.3 in)
Net Weight	TBE

Fault Module
588972 (3790-A0)


Fault Module LabVolt Series 3790-AA
FESTO
Power Input
Remote Control
L
N
Fault
Fault Contacts
Current-Limiting Resistor
K1-A
K1-B
K1-C
Rating

The Fault Module consists of a three-phase normally open contactor enclosed in a half-size EMS module. Each phase of the contactor can be used to insert different types of faults in an electric power circuit, such as ground faults and phase-to-phase faults. Control of the contactor is achieved using either a toggle switch or TTL control signals through a low-voltage control input. Both the toggle switch and control inputs are located on the module front panel. The Fault Module also includes a resistor used to limit the intensity of the current flowing in any inserted fault. Access to each phase of the contactor as well as to the resistor is achieved through safety banana jacks on the module front panel.

Specifications

Parameter	Value
Contactor Rating	
Power Input	120 V – 40 mA – 60 Hz
Contacts	400 V – 3 A ac
Remote Control	0/3.5-5 V dc
Resistor Ratings	
Resistor	60 Ω - 250 W
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 410 mm (6.1 x 11.3 x 16.1 in)
Net Weight	TBE

Numerical Distance Relay
589062 (3813-00)

FESTO
NUMERICAL DISTANCE RELAY
Ethernet
SIEMENS
Run
Error
SIPROTEC 7SA82
Power Input 100...240V 35VA 50/60Hz
Reset
Ctrl
CLOSE
TRIP
Fn

The Numerical Distance Relay is a power-utility grade, numerical protective relay (Siemens SIPROTEC 5 series) mounted in a table-top enclosure. The relay can perform the protection functions listed below.

Phase distance (21) protection
Ground distance (21N) protection
Directional phase overcurrent (67) protection
Directional ground overcurrent (67N) protection
Directional power (32) protection
Instantaneous phase overcurrent (50) protection
Instantaneous ground overcurrent (50N) protection
Phase overcurrent (51) protection
Ground overcurrent (51N) protection
Machine or transformer thermal (49) protection

The Numerical Distance Relay can also perform several other standard protection functions (ANSI 27, 37, 38, 46, 59, 68, 74, 81, 86, and 87N).

The front panel of the relay features a display that can provide information about the relay protection functions, indicate numerous currently measured values such as the line voltages, line currents, phase power, three-phase power, and power factor, and show information about trip events that have been recorded. A keypad, also on the front panel of the relay, allows users to select the information displayed. The front panel of the relay also features a set of 16 LEDs that allows quick monitoring of the status of various relay functions.

Relay programming (e.g., protection function selection, function settings) is achieved via the Siemens DIGSI 5 software. This software is designed to be run from a personal computer with a Microsoft® Windows™ operating system. Communication between the computer and the relay is through a USB port or an Ethernet port. Relay function settings can also be performed using the keypad and display located on the front panel of the relay. Once programmed, the Numerical Distance Relay can be tested using a built-in relay testing unit to ensure it is programmed to operate as expected. This eliminates the need for users to purchase a costly external relay tester to perform relay testing. The built-in relay testing unit is operated using the DIGSI 5 software.

Access to the voltage and current inputs of the Numerical Distance Relay is through a removable panel located at the back of the relay enclosure. Access to the relay Ethernet port, binary inputs, and binary outputs (e.g., trip contacts) is also through this removable panel. The Numerical Distance Relay is powered via an ac power inlet mounted on the front of the relay enclosure. A variant of the Numerical Distance Relay with safety jacks and connectors mounted on the front panel to provide access to all relay inputs, outputs, and ports is also available. See the Numerical Distance Relay, Model 3813-A.

Courseware

Different courses are available to perform exercises using the Numerical Distance Relay. Each course consists of a student manual providing comprehensive theory presentations, guided, easy-to-understand lab procedures, and review questions. Each course also comprises an instructor guide that includes both the content of the student manuals as well as the results and answers to questions.

The following table indicates which courses are available for each numerical protective relay.

	Available courses (each including a student manual and an instructor guide)			
Numerical protection relay	**Overcurrent and Overload Protection Using Protective Relays Manual 52173**	**Directional Protection Manual 52174**	**Differential Protection Manual 52175**	**Distance Protection Manual 52176**
3812	X	X		
3813	X	X		X
3819	X		X	

List of Manuals

Description	Manual number
Numerical Protective Relays (User Guide)	590108 (52766-E0)
Numerische Schutzrelais (User Guide)	593908 (52766-EG)
Relais de protection numériques (User Guide)	593909 (52766-E1)
Relés numéricos de protección (User Guide)	593910 (52766-E2)

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	License for DIGSI 5 Premium Software	779959 (52286-00) [96]

Optional Manual(s)

Qty	Description	Model number
1	Overcurrent and Overload Protection Using Protective Relays (Workbook)	589887 (52173-00)
1	Overcurrent and Overload Protection Using Protective Relays (Workbook (Instructor))	589888 (52173-10)
1	Directional Protection (Workbook)	589889 (52174-00)
1	Directional Protection (Workbook (Instructor))	589890 (52174-10)
1	Distance Protection (Workbook)	593880 (52176-00)
1	Distance Protection (Workbook (Instructor))	593881 (52176-10)

Specifications

Parameter	Value
Relay Type	Siemens 7SA82
Power Requirements	
Voltage	100-240 V
Apparent Power	35 VA

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[96] This license is intended only for the non-educational customers. For educational customer, the software is provided for free with a 10 users license. No need to add this additional part number in the order.

Parameter	Value
Frequency	50/60 Hz
Input	IEC C14 input on the front panel
Protection	6 A circuit breaker
Computer Interface	
Connection	RJ45 EtherNet port on the front panel
Software	DIGSI 5 Software included, free license for educational institutions obtainable from Siemens via application
Physical Characteristics	
Intended Location	On a work surface able to support the weight of the equipment, or on a Festo-approved A4 workstation or equivalent
Dimensions (H x W x D)	295 x 260 x 240 mm (11.61 x 10.24 x 9.45 in)
Net Weight	7.08 kg (15.6 lb)

Numerical Differential Protective Relay
589891 (3819-00)

FESTO
SIEMENS
SIPROTEC

The Numerical Differential Protective Relay is a power-utility grade, numerical protective relay (Siemens SIPROTEC 5 series) mounted in a table-top enclosure. The relay can perform the protection functions listed below.

Transformer differential (87T) protection
Instantaneous phase overcurrent (50) protection
Instantaneous ground overcurrent (50N) protection
Phase overcurrent (51) protection
Ground overcurrent (51N) protection
Machine or transformer thermal (49) protection

The Numerical Differential Protective Relay can also perform several other standard protection functions (ANSI 37, 38, 46, 74, 86, 87N, and 87M).

The front panel of the relay features a display that can provide information about the relay protection functions, indicate currently measured values of the transformer winding currents, and show information about trip events that have been recorded. A keypad, also on the front panel of the relay, allows users to select the information displayed. The front panel of the relay also features a set of 16 LEDs that allows quick monitoring of the status of various relay functions.

Relay programming (e.g., protection function selection, function settings) is achieved via the Siemens DIGSI 5 software. This software is designed to be run from a personal computer with a Microsoft® Windows™ operating system. Communication between the computer and the relay is through a USB port or an Ethernet port. Relay function settings can also be performed using the keypad and display located on the front panel of the relay. Once programmed, the Numerical Differential Protective Relay can be tested using a built-in relay testing unit to ensure it is programmed to operate as expected. This eliminates the need for users to purchase a costly external relay tester to perform relay testing. The built-in relay testing unit is operated using the DIGSI 5 software.

Access to the current inputs of the Numerical Differential Protective Relay is through a removable panel located at the back of the relay enclosure. Access to the relay Ethernet port, binary inputs, and binary outputs (e.g., trip contacts) is also through this removable panel. The Numerical Differential Protective Relay is powered via an ac power inlet mounted on the front of the relay enclosure. A variant of the Numerical Differential Protective Relay with safety jacks and connectors mounted on the front panel to provide access to all relay inputs, outputs, and ports is also available. See the Numerical Differential Protective Relay, Model 3819-A.

Courseware

Different courses are available to perform exercises using the Numerical Differential Protective Relay. Each course consists of a student manual providing comprehensive theory presentations, guided, easy-to-understand lab procedures, and review questions. Each course also comprises an instructor guide that includes both the content of the student manuals as well as the results and answers to questions.

The following table indicates which courses are available for each numerical protective relay.

	Available courses (each including a student manual and an instructor guide)			
Numerical protection relay	**Overcurrent and Overload Protection Using Protective Relays Manual 52173**	**Directional Protection Manual 52174**	**Differential Protection Manual 52175**	**Distance Protection Manual 52176**
3812	X	X		
3813	X	X		X
3819	X		X	

List of Manuals

Description	Manual number
Numerical Protective Relays (User Guide)	590108 (52766-E0)
Numerische Schutzrelais (User Guide)	593908 (52766-EG)
Relais de protection numériques (User Guide)	593909 (52766-E1)
Relés numéricos de protección (User Guide)	593910 (52766-E2)

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	License for DIGSI 5 Premium Software	779959 (52286-00) [97]

Optional Manual(s)

Qty	Description	Model number
1	Overcurrent and Overload Protection Using Protective Relays (Workbook)	589887 (52173-00)
1	Overcurrent and Overload Protection Using Protective Relays (Workbook (Instructor))	589888 (52173-10)
1	Differential Protection (Workbook)	590085 (52175-00)
1	Differential Protection (Workbook (Instructor))	590086 (52175-10)

Specifications

Parameter	Value
Relay Type	Siemens 7UT82
Power Requirements	
Voltage	100-240 V
Apparent Power	35 VA
Frequency	50/60 Hz
Input	IEC C14 input on the front panel
Protection	6 A circuit breaker

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[97] This license is intended only for the non-educational customers. For educational customer, the software is provided for free with a 10 users license. No need to add this additional part number in the order.

Parameter	Value
Computer Interface	
Connection	RJ45 EtherNet port on the front panel
Software	DIGSI 5 Software included, free license for educational institutions obtainable from Siemens via application
Physical Characteristics	
Intended Location	On a work surface able to support the weight of the equipment, or on a Festo-approved A4 workstation or equivalent
Dimensions (H x W x D)	295 x 260 x 240 mm (11.61 x 10.24 x 9.45 in)
Net Weight	7.08 kg (15.6 lb)

PLC Software (Step 7 Professional / WinCC) - 1 User
587904 (5939-00)

The PLC Software (Step 7 Professional) is a programming software that is required for programming Siemens programmable logic controllers.

Specifications

Parameter	Value
Software	Step 7 Professional
Features	Designed for SIMATIC® controllers, Step 7 allows programming in LAD, FBD, and STL languages. It also includes tools for graphic and high-level language programming.
Computer Requirements	A currently available personal computer Pentium type with RS-232 serial port, running under one of the Microsoft® operating systems, Windows® 2000, Windows® XP, Windows® Vista or Windows® 7, is required.

Three-Module Workstation
579483 (8131-00)

The Three-Module Workstation is a fully assembled workstation that serves the same purpose as the Mobile Workstation, Model 8110, but without any storage cabinet or pull-out work surface. This workstation is intended for use on a bench (not supplied) and is fitted with wooden feet to protect the bench top.

The Three-Module Workstation consists of a single row of three full-height compartments that can accommodate up to three full-size EMS modules or six half-size EMS modules.

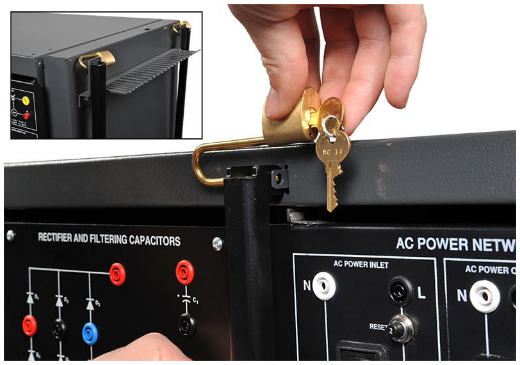
Module Installation

The EMS modules are guided into position along stainless steel guide rails. Separators between each bay of the workstation ensure perfect alignment of the EMS modules and allow their easy insertion in the workstation. A holding mechanism ensures that each EMS module stays in place once it is installed in a compartment of the workstation. A front-mounted push lever allows all EMS modules on the workstation to be released for easy removal.

FILTERING INDUCTORS / CAPACITORS
LINE INDUCTORS
WIND TURBINE GENERATOR / CONTROLLER
PERMANENT MAGNET SYNCHRONOUS GENERATOR
CONTROLLER
AC POWER NETWORK INTERFACE
RATING

Safety Padlock Bars

Two safety padlock bars on the front of the workstation prevent students from removing EMS modules during laboratory exercises. The bars can be removed and locked to the side of the workstation when the safety lock is not necessary.


RECTIFIER AND FILTERING CAPACITORS
AC POWER NETW
AC POWER INLET
AC POWER O
N
L
N
RESET

Additional Information

Three holes in the rear panel of the workstation allow connection to a power supply, as well as the connection of 2 kW machines to their interconnection modules. Assembly of the workstation before painting ensures that each EMS module in the workstation is correctly grounded.

Manual

Description	Manual number
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)

Table of Contents of the Manual(s)

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

- 1 General Safety Recommendations
- 2 System Power Requirements
- 3 Quick Start Installation Guide
- 4 Equipment Installation
- 5 Modules Handling, Installation, and Removal
- 6 Equipment Maintenance
- A Connection of the Power Supply to the AC Power Network
- B Description, Specifications, and Operation of the EMS Modules

Specifications

Parameter	Value
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment
Dimensions (H x W x D)	375 x 930 x 530 mm (14.8 x 36.6 x 20.9 in)
Net Weight	TBE

Tabletop Workstation
579484 (8134-20)

The Workstation is a fully assembled workstation that serves the same purpose as the Mobile Workstation but has no storage cabinet or pull-out work surface. This workstation is intended for use on a bench (not supplied) and is fitted with rubber feet to protect the bench top. Alternatively, this workstation can be mounted on either a Mobile Storage Cabinet, to make a Mobile Workstation, or on a Mobile Base, to make a mobile workstation without storage cabinet. In that case, it is possible to mount and lock a second Workstation, on top of the first Workstation to double the space available for EMS modules.

The Workstation consists of three rows of compartments designed to house EMS modules. Two of these rows have full-height compartments while the other row has half-height compartments. Each row of full-height compartments can accommodate up to three full-size EMS modules or six half-size EMS modules whereas the row of half-height compartments can accommodate up to three half-size EMS modules.

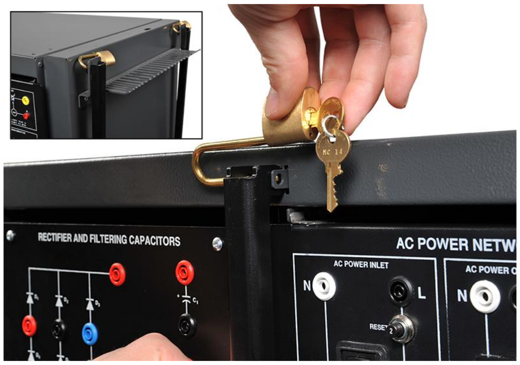
Module Installation

The EMS modules are guided into position along stainless steel guide rails. Separators between each bay of the workstation ensure perfect alignment of the EMS modules and allow their easy insertion in the workstation. A holding mechanism ensures that each EMS module stays in place once it is installed in a compartment of the workstation. Front-mounted push levers allow all EMS modules on a single row to be released for easy removal.

RATING
LINE INDUCTORS
FILTERING INDUCTORS / CAPACITORS
AC POWER NETWORK INTERFACE
WIND TURBINE GENERATOR / CONTROLLER
PERMANENT MAGNET SYNCHRONOUS GENERATOR
CONTROLLER

Safety Padlock Bars

Two safety padlock bars on the front of the workstation prevent students from removing EMS modules during laboratory exercises. The bars can be removed and locked to the side of the workstation when the safety lock is not necessary.


RECTIFIER AND FILTERING CAPACITORS
AC POWER NETW
AC POWER INLET
N
L
RESET
AC POWER O
N

Additional Information

Six holes in the rear panel of the workstation allow connection to a power supply, as well as the connection of 2 kW machines to their interconnection modules. Assembly of the workstation before painting ensures that each EMS module in the workstation is correctly grounded.

Manual

Description	Manual number
Electric Power Technology Training Equipment (User Guide)	584778 (38486-E0)

Table of Contents of the Manual(s)

Electric Power Technology Training Equipment (User Guide) (584778 (38486-E0))

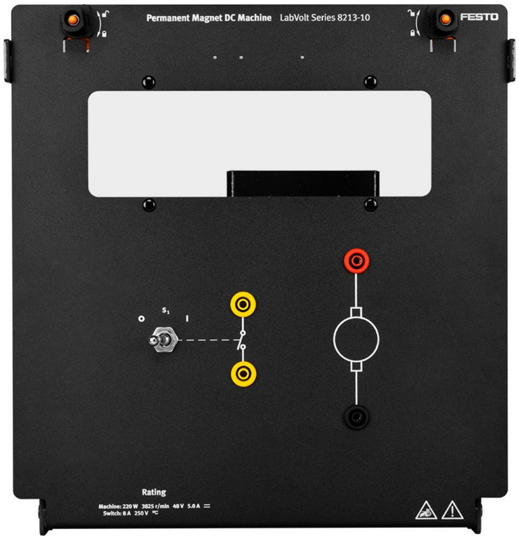
- 1 General Safety Recommendations
- 2 System Power Requirements
- 3 Quick Start Installation Guide
- 4 Equipment Installation
- 5 Modules Handling, Installation, and Removal
- 6 Equipment Maintenance

- A Connection of the Power Supply to the AC Power Network
- B Description, Specifications, and Operation of the EMS Modules

Specifications

Parameter	Value
Physical Characteristics	
Intended Location	On a table able to support the weight of the workstation and installed equipment
Dimensions (H x W x D)	890 x 935 x 465 mm (35.0 x 36.8 x 18.3 in)
Net Weight	31.8 kg (70 lb)

Permanent Magnet DC Motor
8114247 (8213-10)


Permanent Magnet DC Machine LabVolt Series 8213-10
FESTO
S1
O
I
Rating
Machine: 220 W 3825 r/min 48 V 5.0 A
Switch: 8 A 250 V

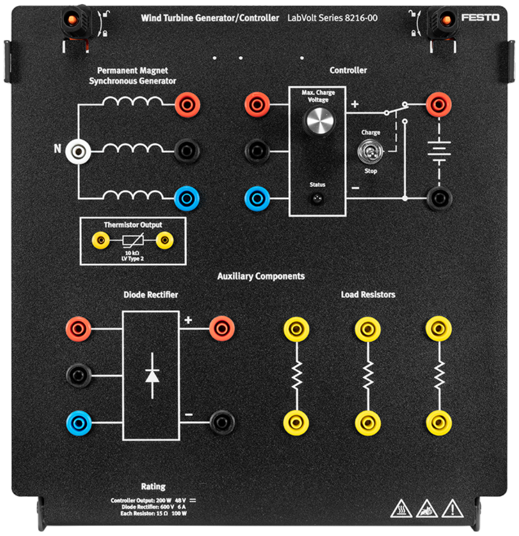
The Permanent Magnet DC Motor is a high-speed, brushed dc motor mounted in a full-size EMS module. The magnetic field required for motor operation is produced by powerful permanent magnets mounted on the motor stator. Connections to the motor are made through color-coded safety banana jacks located on the front panel on the module. Power to the motor must be fed by an external dc power source. A toggle switch mounted on the front panel can be used to switch dc power to the motor on and off when the motor is connected to a battery pack. When driven by a prime mover, the Permanent Magnet DC Motor operates as a dc generator.

The front panel of the Permanent Magnet DC Motor module can be opened to install a Timing Belt on the pulley of the motor shaft. This permits mechanical coupling of this motor to the Four-Quadrant Dynamometer/Power Supply. The diameter of the Permanent Magnet DC Motor pulley is smaller (12 teeth) than that of the pulleys of the Four-Quadrant Dynamometer/Power Supply (24 teeth). This difference of pulley ratio (12 to 24) permits adapting the speed (0 4000 r/min) of the Permanent Magnet DC Motor to the speed of the Four-Quadrant Dynamometer/Power Supply (between 0 2000 r/min).

Specifications

Parameter	Value
Rating	
Power	220 W
Voltage	48 V
Current	5.5 A
Speed	3600 rpm
Maximum voltage	60 V
Maximum speed	4712 rpm
Pulley	
Number of teeth	12
Physical Characteristics	
Dimensions (H x W x D)	308 x 291 x 440 mm (2.1 x 11.5 x 17.3 in)
Net Weight	7.6 kg (16.8 lb)

Wind Turbine Generator/Controller
579487 (8216-00)


Wind Turbine Generator/Controller LabVolt Series 8216-00
FESTO
Permanent Magnet Synchronous Generator
N
Controller
Max. Charge Voltage
Charge
Stop
Status
+
–
Thermistor Output
10 kΩ
LV Type 2
Auxiliary Components
Diode Rectifier
Load Resistors
Rating
Controller Output: 200 W 48 V ═
Diode Rectifier: 600 V 6 A
Each Resistor: 15 Ω 100 W

The Wind Turbine Generator/Controller mainly consists of the generator and controller of an actual small-scale wind turbine, mounted in a full-size EMS module. The module also includes auxiliary components (a three-phase diode rectifier and a set of three power resistors) that can be used to apply a variable electric load to the generator. Color-coded, 4 mm safety banana jacks mounted on the front panel of the module provide access to the generator windings, controller input and output, diode rectifier, and power resistors.

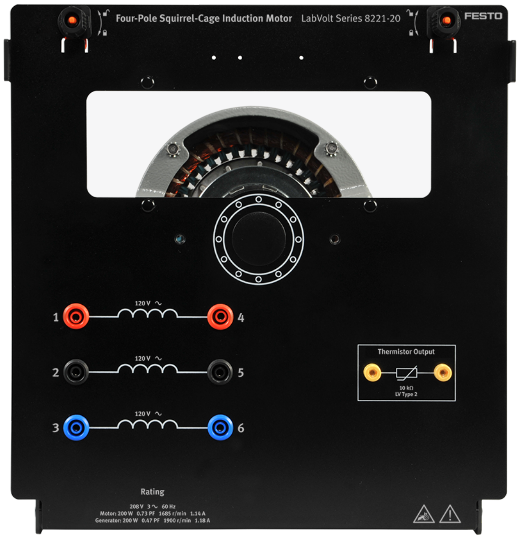
The generator in the Wind Turbine Generator/Controller is a three-phase permanent-magnet synchronous generator. The controller is a power electronics device that converts the three-phase power produced by the generator into dc power and ensures that the generator produces the maximum amount of power possible at any wind speed within the operating range.

The controller also performs voltage regulation to maintain a constant dc voltage output and prevents overcharging of the battery pack used to store the electrical energy produced by the wind turbine generator. A control knob on the module front panel allows the maximum charge voltage to be adjusted. A LED on the module front panel indicates the status (normal battery charging, voltage regulation, etc.) of the controller. Battery charging can be stopped anytime through a switch on the front panel.

Specifications

Parameter	Value
Wind Turbine Type	Direct-drive, fixed-pitch three blade rotor
Controller Output	
Power	200 W at a wind speed of 12.5 m/s (28 mph)
Charge Voltage Setpoint Range	54.4-68.0 V
Recommended Battery Pack Voltage	48 V
Diode Rectifier	600 V – 6 A
Power Resistors	
Ratings	15 Ω – 100 W (each resistor)
Quantity	3
Physical Characteristics	
Dimensions (H x W x D)	308 x 291 x 440 mm (2.1 x 11.5 x 17.3 in)
Net Weight	12.0 kg (26.4 lb)

Four-Pole Squirrel Cage Motor
586267 (8221-20)


Four-Pole Squirrel-Cage Induction Motor
LabVolt Series 8221-20
FESTO
1
4
120 V ~
2
5
120 V ~
3
6
120 V ~
Thermistor Output
10 kΩ
LV Type 2
Rating
208 V 3 ~ 60 Hz
Motor: 200 W 0.73 PF 1685 r/min 1.14 A
Generator: 200 W 0.47 PF 1900 r/min 1.18 A

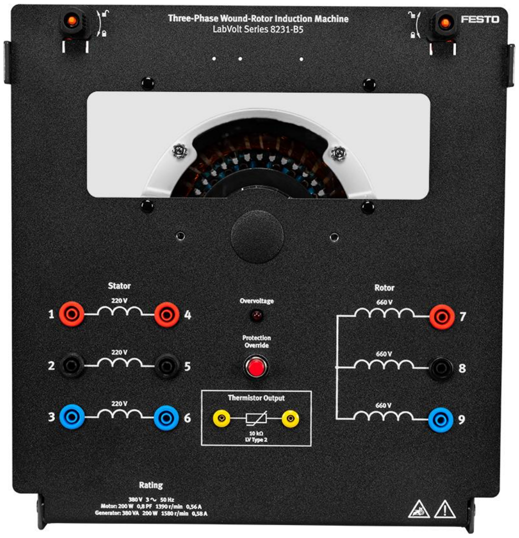
The Four-Pole Squirrel-Cage Induction Motor is a 0.2 kW squirrel-cage induction machine mounted in a full-size EMS module. The machine stator windings are independently connected (six jacks), allowing connection in either wye or delta configuration. Connections to the machine are made through color-coded safety banana jacks located on the front panel on the module. The machine has a thermistor output that allows monitoring of the machine internal temperature to prevent overheating. A tensioner bearing can be ordered as an option.

The front panel of the Four-Pole Squirrel-Cage Induction Motor module can be opened to install a Timing Belt on the pulley of the machine shaft. This permits mechanical coupling of this machine to the Four-Quadrant Dynamometer/Power Supply. When driven by a prime mover, the Four-Pole Squirrel-Cage Induction Motor operates as a three-phase asynchronous generator.

Specifications

Parameter	Value
Motor	
Stator Voltage	120/208 V, 3-phase
Mechanical Power	200 W
Nominal Speed	1685 r/min
Nominal Current	1.14 A
Power factor	0.73
Generator	
Stator Voltage	120/208 V, 3-phase
Output Power	200 W
Nominal Speed	1900 r/min
Nominal Current	1.18 A
Power factor	0.47
Protection	
Type	10 kΩ thermistor, type 2, in the stator windings
Physical Characteristics	
Dimensions (H x W x D)	308 x 287 x 440 mm (12.1 x 11.3 x 17.3 in)
Net Weight	TBE

Three-Phase Wound-Rotor Induction Machine (DFIG)
579497 (8231-B0)



The Three-Phase Wound-Rotor Induction Machine is an induction machine with a wound rotor mounted in a full-size EMS module. The module front panel is hinged and can be lowered for access to the machine. When closed, it is secured by quick-lock fasteners. A geared pulley is fitted to the shaft of the Three-Phase Wound-Rotor Induction Machine to allow mechanical coupling of two machines using a non-slip belt.

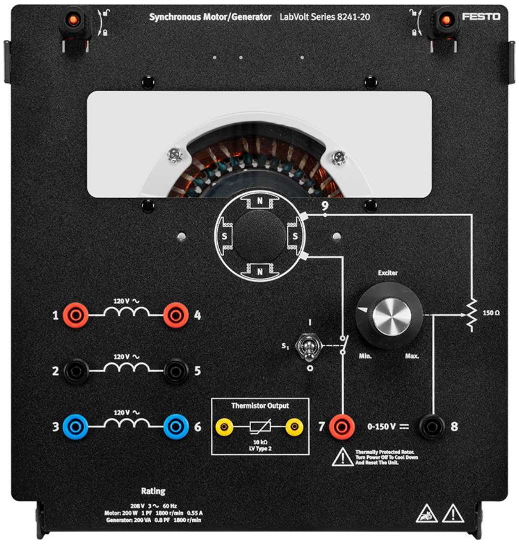
This model is to be used as a doubly-fed induction generator as it has a higher turn ratio on the rotor.

This model has a higher turn ratio on the rotor, to be used as a DFIG. There is another version that has a 2:1 turn ratio on the rotor, which is optimized for using with a rotor rheostat.

Specifications

Parameter	Value
Power Requirements	120/208 V
Motor	
Stator Voltage	120/208 V, 3-phase
Rotor Voltage	360/624 V, 3-phase
Mechanical Power	200 W
Nominal Speed	1720 r/min
Nominal Current	1.15 A
Power Factor	0.64
Generator	
Stator Voltage	120/208 V, 3-phase
Rotor Voltage	360/624 V, 3-phase
Power Input	480 VA
Power Output	200 W
Nominal Speed	1875 r/min
Nominal Current	1.33 A
Protections	
	Rotor overvoltage protection with push-button override
	Thermal protection with thermistor outputs, 10 kΩ, LV type 2
Physical Characteristics	
Dimensions (H x W x D)	308 x 291 x 440 mm (12.1 x 11.5 x 17.3 in)
Net Weight	TBE

Three-Phase Synchronous Motor/Generator 579502 (8241-20)


Synchronous Motor/Generator LabVolt Series 8241-20
FESTO
9
Exciter
150 Ω
120 V ~
1
4
2
5
3
6
S1
I
O
Min.
Max.
Thermistor Output
10 kΩ
LV Type 2
7
0-150 V ⎓
8
Thermally Protected Rotor. Turn Power Off To Cool Down And Reset The Unit.
Rating
208 V 3~ 60 Hz
Motor: 200 W 1 PF 1800 r/min 0.55 A
Generator: 200 VA 0.8 PF 1800 r/min

The Synchronous Motor/Generator is a 0.2 kW three-phase synchronous machine mounted in a full-size EMS module. This machine can be operated either as a three-phase motor or a three-phase generator. Each phase of the machine stator windings is independently terminated and identified on the front panel to allow operation in either wye or delta configuration. The machine rotor is equipped with a squirrel-cage damper. Variable dc excitation to the rotor field windings is fed through externally mounted slip rings and brushes that are wired to a rheostat and control switch located on the front panel.

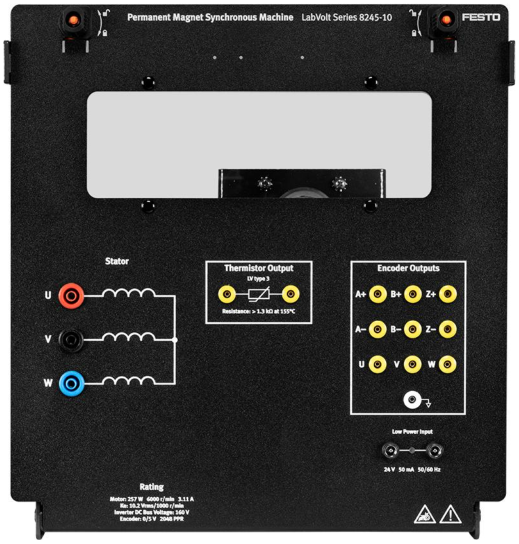
Connections to the machine are made through color-coded safety banana jacks located on the front panel of the module. This front panel of the module can be opened to install a Timing Belt, on the pulley of the machine shaft. This permits mechanical coupling of the machine to the Four-Quadrant Dynamometer/ Power Supply. The machine has a thermistor output that allows monitoring of the machine internal temperature to prevent overheating.

Note that the coupling can only be done on the right side of the machine. If you require a coupling on the left side, please contact your sales representative.

Specifications

Parameter	Value
Power Requirement	120/208 V
Motor	
Stator Voltage	120/208 V, three-phase
Rotor Voltage	0-150 V dc
Output Power	200 W
Synchronous Speed	1800 r/min
Full-Load Current	0.63 A
Power Factor	1
Generator	
Stator Voltage	120/208 V, three-phase
Rotor Voltage	0-150 V dc
Output Power	200 VA
Synchronous Speed	1800 r/min
Power Factor	0.8
Protection	
Type	10 kΩ thermistor, type 2, in the stator winding, and rotor field bimetal thermal protection
Physical Characteristics	
Dimensions (H x W x D)	308 x 291 x 440 mm (12.1 x 11.5 x 17.3 in)
Net Weight	TBE

Permanent Magnet Synchronous Machine
8190269 (8245-10)


Permanent Magnet Synchronous Machine LabVolt Series 8245-10
FESTO
Stator
U
V
W
Thermistor Output
LV type 3
Resistance: > 1.3 kΩ at 155°C
Encoder Outputs
A+
B+
Z+
A–
B–
Z–
U
V
W
Low Power Input
24 V 50 mA 50/60 Hz
Rating
Motor: 257 W 6000 r/min 3.11 A
Ke: 10.2 Vrms/1000 r/min
Inverter DC Bus Voltage: 160 V
Encoder: 0/5 V 2048 PPR

The Permanent Magnet Synchronous Machine, Model 8245, consists of a 260 W permanent magnet synchronous machine encased in a full-size module. The stator windings of the machine are connected in a wye configuration. Three banana jacks enable connection to each phase of the stator windings. Two thermistor outputs indicate when the machine temperature has reached a value that can be damaging, thus providing protection against overheating. An incremental shaft encoder is mounted on the machine shaft, enabling precise measurement of the machine speed and direction of rotation. Ten encoder outputs enable the signals provided by the shaft encoder to be used for control purposes. The operation of the shaft encoder requires the machine to be powered using a low-voltage 24 V ac power source.

Specifications

Parameter	Value
Motor	
Nominal Power	257 W (0.34 hp)
Nominal Speed	6000 rpm
Nominal Torque	0.41 N·m (3.6 lb·in)
Nominal Current	3.11 A
Back EMF	10.2 Vrm / krpm
Maximum Rated DC Bus Voltage	160 Vdc
Continuous Torque (Stall)	0.47 N·m (4.2 lb·in)
Peak Torque	1.49 N.m (13.2 lb.in)
Rotor Type	SPM (Surface Permanent Magnet)
Feedbacks	
Digital Encoder	2048 Pulses per revolution – 0/5 Vdc differential
Hall Effect Sensor	0/5 Vdc
Thermistor	Temperature protection to connect to Lab-Volt controller – Model 9063
Physical Characteristics	
Dimensions (H x W x D)	308 x 291 x 440 mm (12.1 x 11.5 x 17.3 in)

Resistive Load
763359 (8311-00)

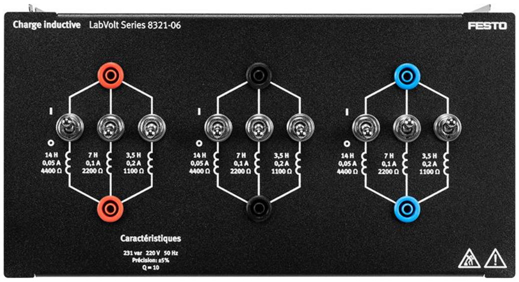
The Resistive Load consists of a module housing nine wire-wound power resistors arranged in three identical banks. Each bank consists of three resistors connected in parallel that can be switched on or off with toggle switches to obtain various resistance values. This allows the total (equivalent) resistance of each bank to be increased or decreased by steps. Six safety banana jacks on the module front panel provide access to each resistor bank. The three resistor banks can be connected separately for operation in three-phase circuits. Also, the three resistor banks can be connected together for operation in single-phase circuits.

The Resistive Load is commonly used in conjunction with other basic load modules, like the Inductive Load and the Capacitive Load to experiment with the effects of different types of loads on a circuit.

Specifications

Parameter	Value
Resistors	
Quantity	Three identical banks of three resistors
Resistance Values (Each Group)	300/600/1200 Ω
Nominal Voltage	120 V ac/dc
Resistance Value Accuracy	± 5%
Load at Nominal Voltage (Each Bank)	
Power	12-84 W
Current	0.1-0.7 A
Steps	Seven, of equal increment
Current Increment	0.1 A
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 410 mm (6.1 x 11.3 x 16.1 in)
Net Weight	4.5 kg (9.9 lb)
Color	
Front panel color	Black

Inductive Load
763362 (8321-00)


Charge inductive
LabVolt Series 8321-06
FESTO
I
O
14 H
0,05 A
4400 Ω
7 H
0,1 A
2200 Ω
3,5 H
0,2 A
1100 Ω
I
O
14 H
0,05 A
4400 Ω
7 H
0,1 A
2200 Ω
3,5 H
0,2 A
1100 Ω
I
O
14 H
0,05 A
4400 Ω
7 H
0,1 A
2200 Ω
3,5 H
0,2 A
1100 Ω
Caractéristiques
231 var 220 V 50 Hz
Précision: ±5%
Q = 10

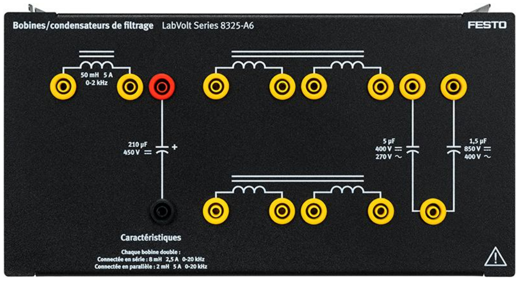
The Inductive Load consists of a module housing nine iron-core power inductors arranged in three identical banks. Each bank consists of three inductors connected in parallel that can be switched on or off with toggle switches to obtain various inductance values. This allows the equivalent inductance of each bank to be increased or decreased by steps. Six safety banana jacks on the module front panel provide access to each inductor bank. The three inductor banks can be connected separately for operation in three-phase circuits. Also, the three inductor banks can be connected together for operation in single-phase circuits.

The Inductive Load is commonly used in conjunction with other basic load modules, like the Resistive Load and the Capacitive Load to experiment with the effects of different types of loads on a circuit.

Specifications

Parameter	Value
Inductors	
Quantity	Three identical banks of three inductors
Inductance Values (Each Bank)	0.8/1.6/3.2 H
Reactance Values (Each Bank)	300/600/1200 Ω
Nominal Voltage	120 V – 60 Hz
Inductance Value Accuracy	± 5%
Load at Nominal Voltage (Each Bank)	
Reactive Power	12-84 var
Current	0.1-0.7 A
Steps	Seven, of equal increment
Current Increment	0.1 A
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 410 mm (6.1 x 11.3 x 16.1 in)
Net Weight	10.1 kg (22.3 lb)

Filtering Inductors/Capacitors
579523 (8325-A0)

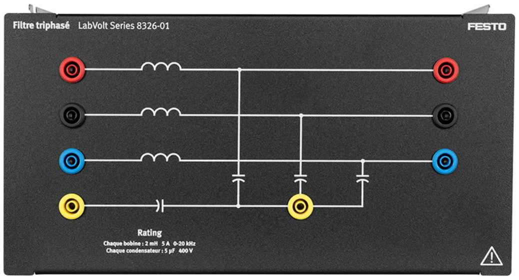

Bobines/condensateurs de filtrage LabVolt Series 8325-A6
FESTO
50 mH 5 A
0-2 kHz
210 µF
450 V ⎓
+
5 µF
400 V ⎓
270 V ~
1,5 µF
850 V ⎓
400 V ~
Caractéristiques
Chaque bobine double :
Connectée en série : 8 mH 2,5 A 0-20 kHz
Connectée en parallèle : 2 mH 5 A 0-20 kHz

This Filtering Inductors/Capacitors module consists of two separate filters enclosed in a half-size EMS module: a low-frequency filter and a high-frequency filter. The low-frequency filter consists of an inductor and a polarized capacitor, while the high-frequency filter consists of two inductors and a non-polarized capacitor. Internal electrical components are identified on the module front panel. 4 mm banana jacks provide access to the different components in the module.

Specifications

Parameter	Value
Low Frequency Filter	
Inductance	50 mH - 5 A - 0-2 kHz
Capacitor (Aluminium Electrolytic)	210 µF - 450 V
High Frequency Filter	
Inductance (2)	2 mH - 5 A - 0-20 kHz
Capacitor (Metallized Polypropylene)	5 µF - 400 V
Supplementary Capacitor (Met. Prop.)	N/A
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Net Weight	12.3 kg (27.12 lb)

Three-Phase Filter
579529 (8326-00)


Filtre triphasé LabVolt Series 8326-01
FESTO
Rating
Chaque bobine : 2 mH 5 A 0-20 kHz
Chaque condensateur : 5 µF 400 V

The Three-Phase Filters consists of three inductors and four capacitors enclosed in a half-size EMS module. Eight safety banana jacks on the module front panel provide access to the three-phase filter. The module is used to filter three-phase signals in power electronics applications.

Specifications

Parameter	Value
Inductors	
Number	3
Ratings	2 mH – 5 A – 0-20 kHz
Capacitors	
Number	4
Type	Metallized polypropylene
Ratings	5 µF – 400 V
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Net Weight	TBE

Line Inductors
763364 (8326-A0)

Line Inductors
LabVolt Series 8326-A0
FESTO
Rating

The Line Inductors module consists of three separate inductors enclosed in a half-size EMS module to be connected in series in a three-phase circuit. Six safety banana jacks provide individual access to each inductor. The Line Inductors are used to limit the rate of change of line currents in three-phase ac power systems.

Specifications

Parameter	Value
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Net Weight	TBE
Inductors	
Number	3
Ratings	25 mH – 1.5 A – 50/60 Hz

Three-Phase Transmission Line
579535 (8329-00)

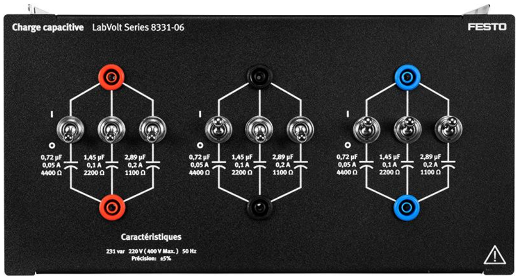
Three-Phase Transmission Line
LabVolt Series 8329-00
FESTO
1
2
3
N
4
5
6
N
Rating

The Three-Phase Transmission Line consists of three iron-core inductors enclosed in a half-size EMS module. The inductors are specifically designed to simulate a high-voltage ac transmission line (typically 315 kV lines). The line impedance can be adjusted to four different values using a selector switch mounted on the front panel. A three-pole switch is used to induce transients by momentarily interrupting the power flow. Both sides (sender and receiver) of the Three-Phase Transmission Line are terminated on the front panel by 4 mm color-coded safety banana jacks.

Specifications

Parameter	Value
Ratings	
Line Reactance Settings	0, 60, 120, and 180 Ω
Nominal Line Current	1 A
Line Simulated Lengths	175, 350 and 525 km (109, 217 and 326 miles)
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Net Weight	8.2 kg (18 lb)
Shipping Weight	9.8 kg (21.6 lb)

Capacitive Load
763366 (8331-00)


Charge capacitive LabVolt Series 8331-06
FESTO
I
O
0,72 µF 0,05 A 4400 Ω
1,45 µF 0,1 A 2200 Ω
2,89 µF 0,2 A 1100 Ω
Caractéristiques
231 var 220 V (400 V Max.) 50 Hz
Précision: ±5%

The Capacitive Load consists of a module housing nine capacitors arranged in three identical banks. Each bank consists of three capacitors connected in parallel that can be switched on or off with toggle switches to obtain various capacitance values. This allows the equivalent capacitance of each bank to be increased or decreased by steps. Six safety banana jacks on the module front panel provide access to each capacitor bank. The three capacitor banks can be connected separately for operation in three-phase circuits. Also, the three capacitor banks can be connected together for operation in single-phase circuits.

A permanently connected discharge resistor reduces the voltage across the terminals of each bank of capacitors to 5% of the applied voltage within 25 seconds after the load is disconnected from the supply. The Capacitive Load may be used with both dc and ac power.

The Capacitive Load is commonly used in conjunction with the other basic load modules, the Resistive Load and the Inductive Load to experiment with the effects of different types of loads on a circuit.

Specifications

Parameter	Value
Capacitors	
Quantity	Three identical banks of three capacitors
Capacitance Values (Each Bank)	2.2/4.4/8.8 µF
Reactance Values (Each Bank)	300/600/1200 Ω
Nominal Voltage	120 V – 60 Hz
Maximum Voltage	230 V
Capacitance Value Accuracy	± 5%
Load at Nominal Voltage (Each Bank)	
Reactive Power	12-84 var
Current	0.1-0.7 A
Steps	Seven, of equal increment
Current Increment	0.1 A
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 410 mm (6.1 x 11.3 x 16.1 in)
Net Weight	5.7 kg (12.6 lb)

SVC Reactors / Thyristor-Switched Capacitors
763368 (8334-00)

SVC Reactors / Thyristor-Switched Capacitors LabVolt Series 8334-00
Reactors
TSC 1
TSC 2
FESTO
TSC Switching Control Inputs
TSC 1
TSC 2
Rating
FESTO

The SVC Reactors / Thyristor-Switched Capacitors module consists of a set of three identical inductors to implement thyristor-controlled reactors (TCRs) using the Power Thyristors, Model 8841. The module contains two sets of three identical capacitors with a solid-state relay for each capacitor to implement two thyristor-switched capacitors (TSCs). Eleven safety banana jacks on the module front panel provide access to the TCRs and TSCs. The module also includes two digital inputs (TTL) to control the TSCs using a Data Acquisition and Control Interface, Model 9063.

Specifications

Parameter	Value
SVC Reactors	
Quantity	3
Impedance	465 Ω
Ratings	120 V - 60 Hz
Reactive Power	31 var
SVC Thyristor-Switched Capacitors	
Quantity	6
Impedance	600 Ω
Ratings	120 V - 60 Hz
Reactive Power	24 var
Switching Control Inputs	0/3.5 V (9 mA) and 0/5 V (15 mA)
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Net Weight	TBE

Three-Phase Transformer Bank
579559 (8348-40)

The Three-Phase Transformer Bank consists of three independent power transformers enclosed in a module. Safety banana jacks on the module front panel provide individual access to the windings of each power transformer, allowing connection in either wye or delta configuration. The transformer windings are polarized and the polarity of each winding is indicated by a small dot on the module front panel. Resettable fuses protect the primary and secondary windings of each transformer against overcurrent. Fuse status lamps on the module front panel turn on when the resettable fuses open.

Specifications

Parameter	Value
Rating (Each Transformer)	
Primary Voltage	208 V
Secondary Voltage	208/120 V
Power	250 VA
Full-Load Current	1.2 A
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 410 mm (6.1 x 11.3 x 16.1 in)
Net Weight	13.9 kg (30.6 lb)

Three-Phase Regulating Autotransformer
763369 (8349-00)

The Three-Phase Regulating Autotransformer consists of a three-phase autotransformer enclosed in a half-size EMS module. Eight safety banana jacks on the module front panel provide access to both sides of the regulating autotransformer. A buck-boost selector switch can be used to increase or decrease the autotransformer output voltage by 15%. A phase-shift selector switch can be used to set the phase shift produced by the autotransformer output voltage to ±15°. A phase sequence indicator on the module front panel indicates the phase sequence of the voltages across the autotransformer.

Specifications

Parameter	Value
Rating	
Line Voltage	120/208 V
Power	360 VA
Line Current	1 A
Buck-Boost Voltage	-15, 0, -15%
Phase Shift	-15, 0, -15°
Phase Sequence	1-2-3
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm; (6.1 x 11.3 x 17.3 in)
Net Weight	7.6 kg (16.7 lb)
Shipping Weight	9.2 kg (20.2 lb)

Transformer
763371 (8353-00)

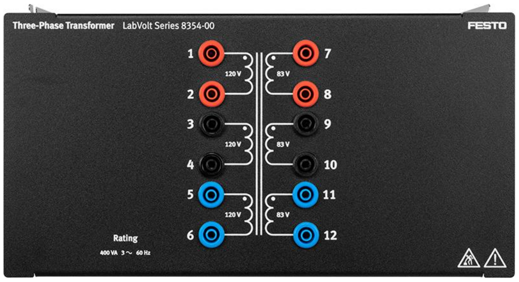
FESTO
Thermistor Output
1
2
3
4
5
6
7
8

The Transformer consists of a power transformer enclosed in a module. Both the primary and secondary sides of the Transformer are made of two identical separate windings. Banana jacks on the module front panel provide access to each winding, allowing connection in a variety of configurations. The Transformer has a turns ratio of 1:5, when considering the totality of its primary and secondary windings. The Transformer windings are polarized and the polarity of each winding is indicated by a small dot on the module front panel. A thermistor output allows monitoring of transformer temperature to prevent overheating. A typical application of the Transformer is to convert the energy stored in batteries to a suitable voltage level (for example, to the level of the ac power network voltage).

Specifications

Parameter	Value
Nominal Power	240 VA
Primary Rating (2 windings)	24 V AC – 5 A for each winding
Secondary Rating (2 windings)	120 V ac – 1 A for each winding
Protection	10 kΩ thermistor, type 2
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 16.1 in)
Net Weight	TBE

Three-Phase Transformer
763373 (8354-00)



The Three-Phase Transformer is a three-phase power tranformer, made up of a single magnetic core with three branches, enclosed in a half-size EMS module. It is used to adjust the ac power network voltage to a value more suitable for certain power electronics applications. For example, the Three-Phase Transformer is used to adapt the value of the three-phase ac power network voltage to the value of the dc bus voltage in three-phase PWM rectifiers/inverters. Twelve banana jacks on the module front panel provide individual access to each phase of the power transformer, allowing connection in wye or delta configuration.

Specifications

Parameter	Value
Rating (Each Phase Winding)	
Primary Voltage	120 V
Secondary Voltage	83 V
Power	200 VA
Primary Current	1.7 A
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Net Weight	TBE

Traffic Lights
579574 (8380-00)

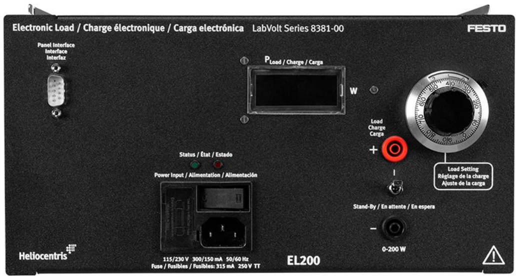
TRAFFIC LIGHTS
AUTO
OFF
ON
RATING
12 V ═ 0.7A

The Traffic Lights module simulates a real-world traffic light application that can be used as a load for a fuel cell system.

Specifications

Parameter	Value
Input Voltage	12 V dc
Power Consumption Max.	10 W
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Net Weight	TBE

Electronic Load
579575 (8381-00)


Electronic Load / Charge électronique / Carga electrónica LabVolt Series 8381-00
FESTO
Panel interface
Interface
Interfaz
P Load / Charge / Carga
W
Load
Charge
Carga
Status / État / Estado
Power Input / Alimentation / Alimentación
Load Setting
Réglage de la charge
Ajuste de la carga
Stand-By / En attente / En espera
0-200 W
Heliocentris
115/230 V 300/150 mA 50/60 Hz
Fuse / Fusibles / Fusibles: 315 mA 250 V TT
EL200

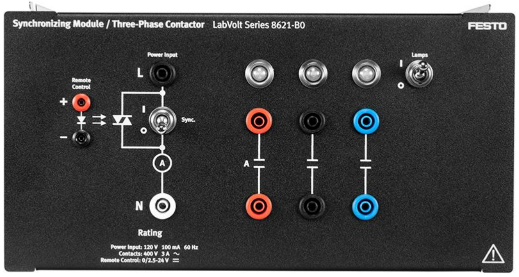
The Electronic Load provides manual or computer-assisted adjustment of constant rated currents that can be used to record the characteristic curves of a fuel cell system, allowing users to monitor the effects of different parameters.

Specifications

Parameter	Value
Maximum continuous power output	200 W
Load voltage	1.2 – 20 V dc
Load current	0 – 10 A
Mains connection	120 – 240 V (50 – 60 Hz)
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)

Parameter	Value
Net Weight	TBE

Synchronizing Module / Three-Phase Contactor
8204391 (8621-B0)

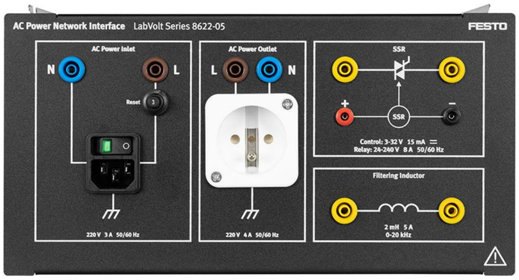

Synchronizing Module / Three-Phase Contactor LabVolt Series 8621-B0
FESTO
Power Input
L
N
Remote Control
+
–
I
O
Sync.
A
Lamps
Rating
Power Input: 120 V 100 mA 60 Hz
Contacts: 400 V 3 A ~
Remote Control: 0/2.5-24 V ⎓

The Synchronizing Module / Three-Phase Contactor is a half-size EMS module used to control various electric devices, or synchronize two ac power sources like a synchronous generator with an ac power network. The Synchronizing Module / Three-Phase Contactor consists of a three-phase contactor whose coil can be energized either manually with a toggle switch, or automatically with a thyristor fired by applying to the Remote Control input of the module, a low-level (TTL) signal from the Data Acquisition and Control Interface. Six safety banana jacks (one pair per phase) allow connection of electric devices or ac power sources across the contacts of the three-phase contactor. Three indicator lamps indicate the relative level of the voltage across their corresponding contact terminals.

Specifications

Parameter	Value
Contactor	
Power Input	120 V – 50 mA – 60 Hz
Contacts	400 V – 3 A ac
Remote Control Input	
Voltage	0/2.5-24 V dc
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Net Weight	3.6 kg (7.9 lb)
Shipping Weight	5.2 kg (11.4 lb)

AC Power Network Interface
579581 (8622-00)


AC Power Network Interface LabVolt Series 8622-05
FESTO
AC Power Inlet
N
L
Reset
3
220 V 3 A 50/60 Hz
AC Power Outlet
L
N
220 V 4 A 50/60 Hz
SSR
+
–
SSR
Control: 3-32 V 15 mA ⎓
Relay: 24-240 V 8 A 50/60 Hz
Filtering Inductor
2 mH 5 A
0-20 kHz

The AC Power Network Interface is used to interface the ac power network with EMS modules. It consists of an AC Power Inlet section comprising a C14 power cord inlet with 4 mm color-coded safety sockets for each terminal (line, neutral, and ground). The line is fuse-protected between the inlet and the safety jacks. The module also consists of an AC Power Outlet section comprising a standard ac outlet (country dependent) with direct connections to safety sockets. A solid-state relay used for network disconnection and a filtering inductor are also included in the model to complete the interface with the ac network.

All components of the AC Power Network Interface are industrial components and are mounted in the module to allow visual inspection. Where necessary, these components are protected against overload or short-circuit conditions by thermal-magnetic circuit breakers. The components are terminated on the module faceplate by 4 mm color-coded safety sockets and are identified by schematic symbols, numbered terminal codes, and electrical ratings.

Specifications

Parameter	Value
AC Power Inlet	
Rating	120 V - 2 A - 60 Hz
Type	C14 connector
Circuit Breaker	2 A
AC Power Outlet	
Rating	120 V - 8 A - 60 Hz
Type	NEMA 5-15 (type B)
Solid-State Relay	
Coil Rating	3 to 32 V dc - 15 mA
Contact Rating	24 to 240 V - 8 A - 60 Hz
Filtering Inductor	2 mH - 5 A - 0 to 20 kHz
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Net Weight	TBE

Lead-Acid Batteries
763374 (8801-00)

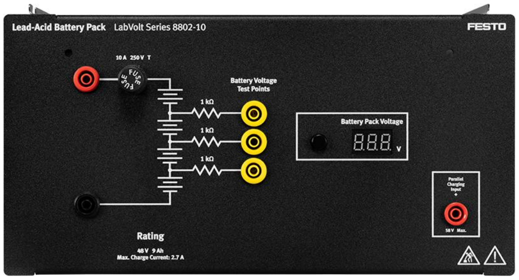
The Lead-Acid Batteries module consists of two 12 V valve-regulated, lead-acid (VRLA) batteries enclosed in a half-size EMS module. These batteries are part of the Electric Power Technology Training Program and are used to study lead-acid battery characteristics as well as the storage of electrical energy in various applications, such as solar power and wind power electricity generation. They can easily be charged using the Four-Quadrant Dynamometer/Power Supply, Model 8960-2.

The batteries can be connected in series or parallel. Connection to the batteries is through 4 mm safety banana jacks mounted on the front panel of the module. These jacks are used when large amounts of power are supplied to the batteries or drawn from the batteries. A pair of miniature (2 mm) banana jacks mounted on the front panel of the module provides access to one of the two batteries via a low-capacity auto-reset fuse. These miniature jacks are used to connect the battery to either the Solar Panel Test Bench, Model 8805, or the Solar Panel, Model 8806, when performing lab exercises dealing with the storage of electrical energy produced from solar power.

Specifications

Parameter	Value
Batteries	
Quantity	2
Type	Valve-regulated lead-acid
Voltage	12 V
Capacity	2.3 Ah
Maximum Charge Current	0.69 A
Maximum Discharge Current	5 A
Auto-Reset Protective Fuse	
Battery	5 A (hold current), 10 A (trip current)
Test Point	0.1 A (hold current), 0.2 A (trip current)
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Net Weight	4.6 kg (10.2 lb)

Lead-Acid Battery Pack
579591 (8802-10)



The Lead-Acid Battery Pack is a half-size EMS module housing four 12 V lead-acid batteries connected in series. The Lead-Acid Battery Pack thus provides a fixed dc voltage of 48 V, available at two color-coded safety banana jacks on the module front panel. Three battery voltage test points allow measurement of the voltage provided by each of the four 12 V batteries. A parallel charging input terminal permits the charging of several Lead Acid Battery Packs connected in parallel at the same time. The Lead-Acid Battery Pack is protected against overcurrent and short-circuits. The Lead-Acid Battery Pack can be used as a 48 V dc power source, and in energy production and storage applications implemented with the Electricity and New Energy Training Equipment.

Specifications

Parameter	Value
Battery Pack	
Type	4 valve-regulated lead-acid batteries
Voltage	48 V (12 V for each battery)
Capacity	9 Ah
Maximum Charge Current	2.7 A
Maximum Discharge Current	7 A
Parallel Charging Input	58 V maximum
Overcurrent Protection	
Battery Pack Fuse	10 A
Test Point Limiting Resistors (3)	1 kΩ
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Net Weight	13.8 kg (30.4 lb)

Hydrogen Fuel Cell
579593 (8803-00)

HYDROGEN FUEL CELL

The Hydrogen Fuel Cell module is a fuel cell stack comprising a fuel cell controller, a hydrogen flow meter, a dc-to-dc converter (required to obtain a regulated dc output from the fuel cell stack), an air supply, and seven LED displays for visualizing all essential system parameters (e.g., current, voltage, temperature, fuel, air supply).

A USB port on the front panel enables use of the included data acquisition software to perform further analysis on the fuel cell stack. This software provides support for the experiments (visualization, data logging, fully automated experiments) in the manual.

Specifications

Parameter	Value
Rated Output	40 W
Maximum Output	50 W
No-Load Voltage	9 V
Current at Rated Output	8 A
Hydrogen Consumption at Rated Output	580 sml/min
Hydrogen Purity for Operation	A minimum of 4.0 (99.99%)

Parameter	Value
Permissible Hydrogen Pressure	0.4 – 0.8 bar
Permissible Ambient Temperature during Operation	5–35°C (41-95°F)
Communication Port	USB
Pressure Regulator	
Description	Two-stage, hydrogen
Inlet Pressure	Max. 19 bar
Outlet Pressure	0.6 ± 0.1 bar
Accessories	
	Leak detection kit
	Safety connection leads
	Software
Physical Characteristics	
Dimensions (H x W x D)	307 x 579 x 533 mm (12.1 x 22.8 x 21 in)
Net Weight	TBE

Solar Panel Test Bench
579594 (8805-00)

The Solar Panel Test Bench is a full-size EMS module in which a Solar Panel, Model 8806 (not included, must be ordered separately), can be installed to perform a wide variety of tests and experiments. A powerful halogen lamp is used to illuminate the solar panel under test. The distance between the halogen lamp and solar panel can be changed to adjust the irradiance. A ventilation system is provided in the Solar Panel Test Bench to keep the solar panel at near room temperature and study the effects of temperature. The halogen lamp and ventilation system can be turned on and off through switches mounted on the front panel of the test bench. Pilot lamps on the front panel indicate the status (on or off) of the halogen lamp and ventilation system. The complete Solar Panel Test Bench is powered by a standard wall outlet.

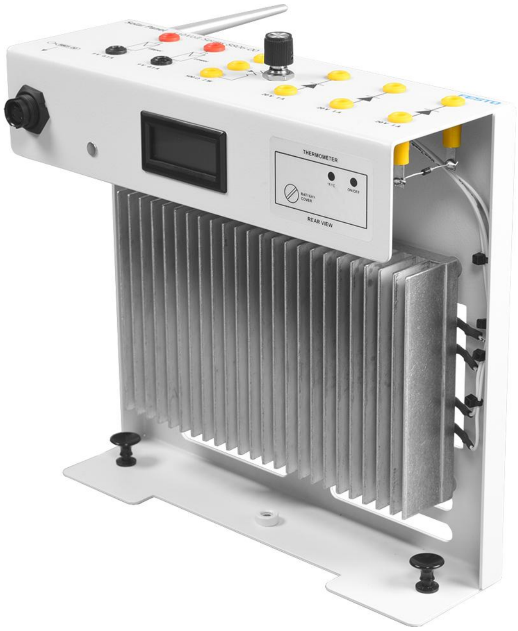
A potentiometer and a set of diodes are included in the Solar Panel Test Bench. The potentiometer is used to apply a variable electrical load to the output of the solar panel under test. The diodes can be connected to the solar panel to serve as either bypass diodes or blocking diodes. Access to the potentiometer and diodes is through miniature (2 mm) banana jacks mounted on the front panel of the test bench. Four other miniature banana jacks on the front panel of the test bench provide direct access to the output terminals of the solar panel to make connections easy. A set of connection leads terminated with miniature banana plugs is provided with the Solar Panel Test Bench.

Specifications

Parameter	Value
Power Requirements	
Current	3 A
Service Installation	Standard single-phase outlet
Halogen Lamp	
Power	300 W
Ventilation System	
Flow Rate	115 CFM
Potentiometer	Single Turn – 500 Ω – 2 W
Diodes	
Quantity	3
Peak Inverse Voltage	1000 V

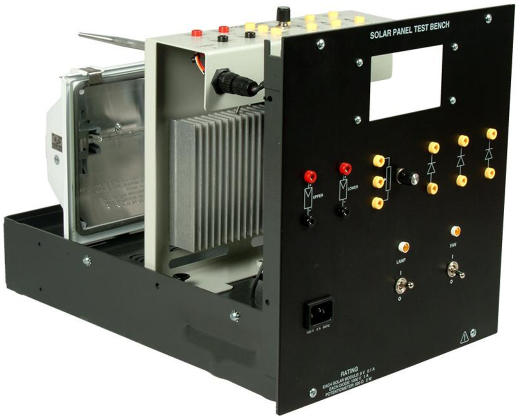
Parameter	Value
Maximum Current	1 A
Physical Characteristics	
Dimensions (H x W x D)	308 x 291 x 440 mm (2.1 x 11.5 x 17.3 in)
Net Weight	6.9 kg (15.2 lb)

Monocrystalline Silicon Solar Panel
579600 (8806-00)



The Monocrystalline Silicon Solar Panel consists of two independent photovoltaic (PV) modules mounted on a common metal chassis that can be installed in the Solar Panel Test Bench, Model 8805, when performing exercises indoors, or on a tripod when performing exercises outdoors. Both PV modules are made of high-quality monocrystalline silicon cells and protected by a coat of clear glass epoxy. Independent access to the output of each PV module is provided via a pair of miniature (2 mm) banana jacks mounted on the solar panel chassis to allow either series or parallel connection of the PV modules. A multi-pin connector on the solar panel chassis allows connection of the PV module outputs to four miniature banana jacks on the front panel of the Solar Panel Test Bench to allow PV module connection from the outside of the workstation.

Indoor Operation in the Solar Panel Test Bench



Monocrystalline Silicon Solar Panel installed in the Solar Panel Test Bench (setup for indoor exercises).

A digital thermometer attached to the solar panel chassis allows the temperature of the PV modules to be monitored. A transparent window in the front panel of the Solar Panel Test Bench allows temperature monitoring even when the solar panel is installed in the test bench.

Outdoor Operation On a Tripod

Monocrystalline Silicon Solar Panel installed on a tripod (setup for outdoor exercises).

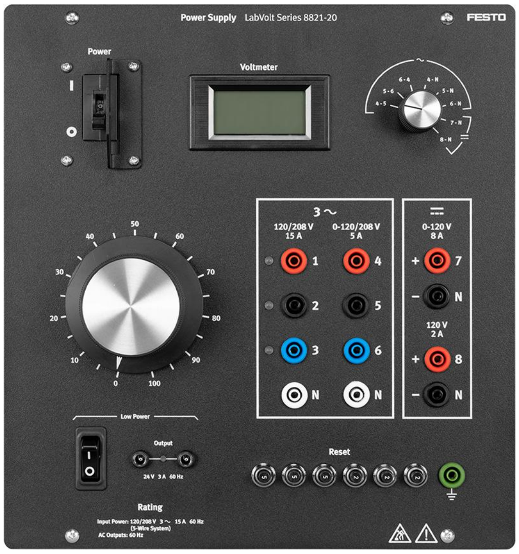
The surface of the metal chassis on which the PV modules lie is provided with a perpendicularly mounted metal pin and silk-screened angular markers. When performing exercises outdoors, the metal pin allows the orientation to be adjusted so that the solar panel is perfectly aimed at the Sun. The angular markers allow the solar panel orientation to be offset a certain angle with respect to the Sun direction when experimenting with solar panel orientation.

The Monocrystalline Silicon Solar Panel includes a potentiometer and a set of diodes. The potentiometer is used to apply a variable electrical load to the output of the solar panel. The diodes can be connected to the solar panel to serve as either bypass diodes or blocking diodes. These components are used when performing solar panel exercises outdoors (i.e., without the Solar Panel Test Bench). Access to the potentiometer and diodes is through miniature (2 mm) banana jacks mounted on the solar panel chassis.

Specifications

Parameter	Value
PV Module	
Quantity	2
Type	Monocrystalline Silicon
Number of Cells	18
Open-Circuit Voltage (VOC)	9 V @ STC
Short-Circuit Current (ISC)	100 mA @ STC
Potentiometer	Single Turn - 500 Ω - 2 W
Diodes	
Quantity	3
Peak Inverse Voltage	1000 V
Maximum Current	1 A
Thermometer	
Range	-50°C to +70°C (-58°F to +158°F)
Resolution	±0.1° from -19.9° to +199.9°, otherwise 1°
Accuracy	±1°C from -30°C to +70°C (±1.8°F from -22°F to +158°F)
Battery Voltage	1.5 V
Battery Type	A76 (LR44, G13) size or equivalent, 1 required
Angular Markers	
Range	65°
Interval	5°
Physical Characteristics	
Dimensions (H x W x D)	240 x 237 x 58 mm (9.4 x 9.3 x 2.3 in)
Net Weight	2.0 kg (4.4 lb)

Variable Three-Phase Power Supply
579603 (8821-20)

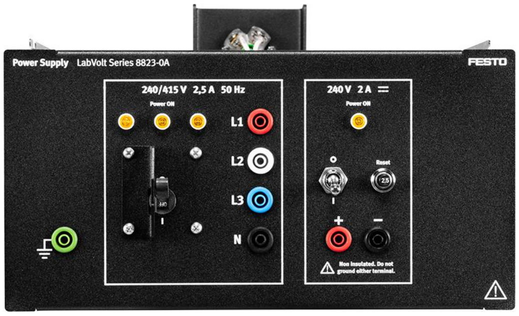


The Power Supply is enclosed in a full-size EMS module. It can be used to power most of the EMS modules of the Electricity and New Energy Training Equipment. This Power Supply provides dc power and ac power, both fixed and variable, single-phase and three-phase. Color-coded safety banana jacks provide access to all the power sources in the Power Supply. All these power sources can be used simultaneously, provided that the total current drawn does not exceed the maximum current rating. A built-in voltmeter with selector switch and liquid crystal display (LCD) indicates the voltage provided by any of the power sources. The input and outputs of the Power Supply are protected by independent circuit breakers.

Specifications

Parameter	Value
Module Requirements	
AC Power Network Installation	3 phases (120/208 V – 60 Hz), star (wye) configuration including neutral and ground wires, protected by a 20 A circuit breaker
AC Power Network Connector	NEMA L21-20
Maximum Current	15 A
Outputs (*see note)	
Three-Phase Fixed AC	120/208 V – 15 A - 60 Hz
Three-Phase Variable AC	0-120/208 V – 5 A - 60 Hz
Variable DC	0-120 V – 8 A (three-phase half-wave rectified without filtering capacitor)
Fixed DC	120 V – 2 A (three-phase half-wave rectified with 94µF capacitor)
Low Power AC	24 V – 3 A - 60 Hz
Included Accessories	
	3 m (10 ft) AC power cord (1)
	Padlock (1)
Physical Characteristics	
Dimensions (H x W x D)	308 x 287 x 495 mm (12.1 x 11.3 x 19.5 in)
Net Weight	18.4 kg (40.5 lb)
***Note**	The Power Supply cannot supply all the amounts of current indicated by the current ratings on its front panel at the same time. The current indicated for the fixed ac three-phase output section can only be obtained if no current is drawn from any other section, because this section is protected by the main circuit breaker common to every section. If currents flow in other sections, the available current for the fixed ac three-phase output section decreases. The variable ac output section and the variable dc output section are protected by a common set of circuit breakers placed after the fixed ac three-phase output section, which means that the current capacity has to be shared between the two sections. For instance, if current of the variable dc output section is at 70% of its nominal value, current drawn from the variable ac output section should not exceed 30% of its nominal value. The fixed dc output section is also protected by circuit breakers placed after the fixed ac three-phase output section.

Three-Phase Power Supply
579612 (8823-00)

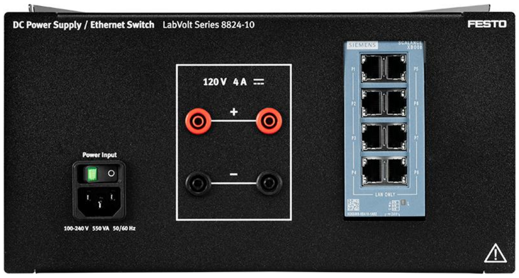

Power Supply LabVolt Series 8823-0A
FESTO
240/415 V 2,5 A 50 Hz
Power ON
L1
L2
L3
N
OFF
240 V 2 A ⎓
Power ON
Reset
2.5
+
−
Non insulated. Do not ground either terminal.

The Power Supply consists of a fixed-voltage three-phase ac power source and a fixed-voltage dc power source enclosed in a half-size EMS module. It can be used to power most of the EMS modules of the Electricity and New Energy Training Equipment. Color-coded safety banana jacks provide access to both power sources. Independent circuit breakers, with a reset button on the front panel of the module, protect the inputs and outputs from overcurrent conditions. Indicator lamps allow monitoring the presence of input voltage on each phase.

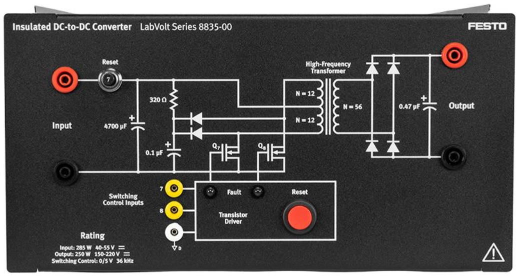
Specifications

Parameter	Value
Power Requirements	
Maximum Current	10 A
AC Power Network Installation	3 phases (120/208 V – 60 Hz), star (wye) configuration including neutral and ground wires, protected by a 20 A circuit breaker
AC Power Network Connector	NEMA L21-20
Outputs	
Fixed AC 3-Phase	120/208 V – 5 A
Fixed DC	120 V – 4 A
Included Power Cord	3 m (10 ft)
Physical Characteristics	
Dimensions (H x W x D)	212 x 287 x 496 mm (8.3 x 11.3 x 19.5 in)
Net Weight	5.7 kg (12.5 lb)

Ethernet Switch
8198102 (8824-10)


DC Power Supply / Ethernet Switch LabVolt Series 8824-10
FESTO
Power Input
100-240 V 550 VA 50/60 Hz
120 V 4 A ⎓
+
−
SIEMENS
SCALANCE XB008
LAN ONLY

Insulated DC-to-DC Converter
579618 (8835-00)

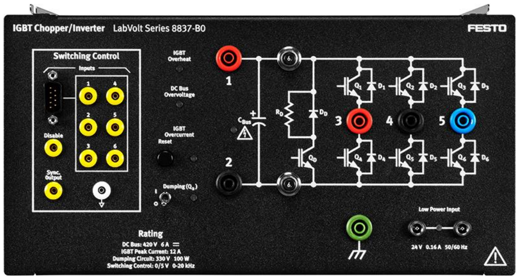

Insulated DC-to-DC Converter LabVolt Series 8835-00
FESTO
Reset
7
Input
4700 µF
320 Ω
0.1 µF
Q7
Q8
High-Frequency Transformer
N = 12
N = 12
N = 56
0.47 µF
Output
Switching Control Inputs
7
8
D
Fault
Reset
Transistor Driver
Rating
Input: 285 W 40-55 V ⎓
Output: 250 W 150-220 V ⎓
Switching Control: 0/5 V 36 kHz

The Insulated DC-to-DC Converter is used to convert a low-voltage dc source, such as the Battery Pack, Model 8802, into a high-voltage dc output suitable for ac conversion. This type of converter (push-pull) can be found in most switched-mode power supplies and commercial inverters. The Insulated DC-to-DC Converter mainly consists of two power MOSFETs and their respective drivers, an high-frequency power transformer and a full-wave diode bridge on the output side. The MOSFETs can be controlled using an external controller or the digital outputs of the Data Acquisition and Control Interface, Model 9063. Internal electrical components are identified on the module front panel by silkscreened symbols and terminated by 4 mm safety banana jacks.

Specifications

Parameter	Value
Input	
Rating	285 W - 40-55 V dc
Circuit Breaker	7 A
Output Rating	250 W - 150-220 V dc
Switching Control Inputs	
Quantity	2
Signal Level	0-5 V (TTL compatible)
Nominal Frequency	36 kHz
Maximum Duty Cycle per signal	45 %
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Net Weight	TBE

IGBT Chopper/Inverter
579623 (8837-B0)


IGBT Chopper/Inverter LabVolt Series 8837-B0
FESTO
Switching Control
Inputs
1
2
3
4
5
6
Disable
Sync. Output
IGBT Overheat
DC Bus Overvoltage
IGBT Overcurrent
Reset
Dumping (Q_D)
C_{Bus}
R_D
D_D
Q_D
Q_1 D_1 Q_2 D_2 Q_3 D_3
Q_4 D_4 Q_5 D_5 Q_6 D_6
1
2
3
4
5
6.
Low Power Input
24 V 0.16 A 50/60 Hz
Rating
DC Bus: 420 V 6 A
IGBT Peak Current: 12 A
Dumping Circuit: 330 V 100 W
Switching Control: 0/5 V 0-20 kHz

The IGBT Chopper/Inverter module consists of seven insulated-gate bipolar transistors (IGBT) mounted in a half-size EMS module. Six IGBTs are used to implement choppers and inverters. These IGBTs are protected against a variety of abnormal operating conditions, such as short-circuits, overvoltage, overcurrent, and overheat. The seventh IGBT and a dumping resistor allow smooth dissipation of excess energy at the dc bus. The dumping circuit can be activated through the use of a toggle switch on the front panel.

The module switching control section allows 0/5 V pulse signals from either the Data Acquisition and Control Interface, Model 9063, the Chopper/Inverter Control Unit, Model 9029, or any compatible 0/5 V control unit, to be applied to the gating circuits of the IGBTs. The signals are input in the IGBT Chopper/Inverter module through a nine-pin connector.

Six miniature banana jacks can be used as test points to monitor the pulse signals using an oscilloscope. These jacks can also be used to inject 0/5 V pulse signals from an alternate control unit, as well as to inhibit each gating circuit. The IGBT Chopper/Inverter module also includes a synchronization output to trigger an oscilloscope when observing the switching control signals, as well as a switching control disable input that allows all six IGBTs in the chopper/inverter section to be switched off.

Specifications

Parameter	Value
DC Bus	
Maximum Voltage	420 V
Maximum Current	6 A
Filtering Capacitor	1360 μF
Protections	
DC Bus Overvoltage	440 V
DC Bus Circuit Breaker	6 A
IGBT Electronic Overcurrent	12 A
IGBT Overheat	About 60°C
Dumping Circuit	
Voltage Threshold	330 V

Parameter	Value
Resistor	100 Ω, 100 W
Switching Control Signals	
Level	0/5 V
High Level Current	about 600 µA
Frequency Range	0-20 kHz
Minimum Dead Time	1.2 µs
Power Requirements	24 V, 0.16 A, 50/60 Hz
Accessories	
Accessories	24 V power cable (1)
	2 mm banana plug test leads (2)
	DB9 connector control cable (1)
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 410 mm (6.1 x 11.3 x 16.1 in)
Net Weight	6.8 kg (15 lb)

Power Thyristors
763376 (8841-20)

The Power Thyristors module consists of six power thyristors (SCRs) mounted in a half-size EMS enclosure. Each individual thyristor is protected against overcurrents and short-circuits. All the anodes and cathodes of the thyristors are terminated on the front panel by color-coded, 4 mm safety banana jacks. To reduce the number of external connections, the most typical thyristor configurations can be achieved through the use of two toggle switches on the front panel.

A firing control section allows six 0-5 V pulse signals from either the Data Acquisition and Control Interface, Model 9063, the Thyristor Firing Unit, Model 9030, or any compatible 0-5 V control unit, to be applied to the gating circuits of the thyristors. The signals are input in the Power Thyristors module through a nine-pin connector.

Six miniature banana jacks in this section are used as test points to monitor the firing control signals using an oscilloscope. They can also be used to inject 0-5 V pulse signals from an alternate firing unit, as well as to inhibit each gating circuit. The Power Thyristors module also includes a synchronization output to trigger an oscilloscope when observing the firing control signals as well as a firing control disable input that prevents all six power thyristors from being fired.

Specifications

Parameter	Value
Rating	
Peak Inverse Voltage	600 V
Maximum Current	2 A
Gate Control Signals	0-5 V Pulses (TTL compatible)
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Net Weight	5.6 kg (12.35 lb)

Rectifier and Filtering Capacitors
579630 (8842-A0)

This Rectifier and Filtering Capacitors module consists of a three-phase bridge rectifier and two separate capacitors enclosed in a half-size EMS module. The bridge allows the conversion of a three-phase voltage input into an unfiltered dc voltage. This dc voltage can then be filtered using the polarized capacitors (each one protected by a diode). Internal electrical components are identified on the module front panel by silkscreened symbols and terminated by 4 mm safety banana jacks.

Specifications

Parameter	Value
Electrical Characteristics	
Maximum Network Voltage	230 V - 3~ - 50/60 Hz
Maximum Diode Current	8 A
Each Capacitor	210 µF - 450 V dc
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 440 mm (6.1 x 11.3 x 17.3 in)
Net Weight	2.9 kg (6.4 lb)

Timing Belt
579637 (8942-00)

The Timing Belt is a high-quality industrial synchro-cog timing belt made of rubber whose teeth exactly mesh with the geared pulley fitted on the shaft of all 0.2 kW EMS machines. The Timing Belt is supplied in a fixed length appropriate for coupling two adjacent EMS machines together without slippage between them.

Specifications

Parameter	Value
Physical Characteristics	
Pitch	9.5 mm (0.375 in)
Pitch Length	819 mm (32.25 in)
Number of Teeth	86
Dimensions (Width)	12.7 mm (0.5 in)
Net Weight	0.1 kg (0.2 lb)

Connection Lead Set
586891 (8951-A0)

This Connection Lead Set consists of extra-flexible leads terminated with stacking 4 mm safety banana plugs. The leads are supplied in different lengths and are color-coded according to length.

4mm: 16 x 30 cm yellow, 16 x 60 cm red, 8 x 90 cm blue.

Specifications

Parameter	Value
4 mm Safety Banana Plug Leads Characteristics	
Cross Section	1 mm² (1974 cmil)
Rated Current	19 A
Rated Voltage	600 V, CAT II
4 mm Safety Banana Plug Leads Quantities	
Yellow, 30 cm (12 in)	16
Red, 60 cm (24 in)	16
Blue, 90 cm (36 in)	8

Connection Lead Set
579638 (8951-L0)

This Connection Lead Set consists of extra-flexible leads terminated with stacking 4 mm safety banana plugs. In addition, the set includes stacking 2 mm banana plug leads of the same length and color.

4mm: 20 x 30 cm yellow, 10 x 60 cm red, 4 x 90 cm blue. 2mm: 4 x 60 cm red.

Specifications

Parameter	Value
4 mm Safety Banana Plug Leads Characteristics	
Cross Section	1 mm² (1974 cmil)
Rated Current	19 A
Rated Voltage	600 V, CAT II
4 mm Safety Banana Plug Leads Quantities	
Yellow, 30 cm (12 in)	20
Red, 60 cm (24 in)	10
Blue, 90 cm (36 in)	4
2 mm Safety Banana Plug Leads Characteristics	
Cross Section	0.5 mm² (987 cmils)
Rated Current	10 A
Rated Voltage	30 V ac / 60 V dc
2 mm Safety Banana Plug Leads Quantities	
Red, 60 cm (24 in)	4

Connection Lead Set
579639 (8951-N0)

This Connection Lead and Accessory Set consists of extra-flexible leads terminated with stacking 4 mm safety banana plugs. The leads are supplied in different lengths.

579639 (8951-N0):

4mm: 14 x 30 cm yellow, 8 x 60 cm red, 4 x 90 cm blue. 4 x 60 cm 3 phase.

579640 (8951-NA):

4mm: 14 x 30 cm yellow, 8 x 60 cm red, 4 x 90 cm blue. 2mm: 10 x 60 cm red. 4 x 3 phase 60 cm.

Specifications

Parameter	Value
4 mm Safety Banana Plug Leads Characteristics	
Cross Section	1 mm² (1974 cmil)
Rated Current	19 A
Rated Voltage	600 V, CAT II
4 mm Safety Banana Plug Leads Quantities	
Yellow, 30 cm (12 in)	14
Red, 60 cm (24 in)	8

Parameter	Value
Blue, 90 cm (36 in)	4
Three-Phase 4 mm Safety Banana Plug Leads Characteristics	
Cross Section	1 mm² (1974 cmil)
Rated Current	19 A
Rated Voltage	600 V, CAT II
Three-Phase 4 mm Safety Banana Plug Leads Quantities	
Red/Black/Blue, 60 cm (24 in)	4

Connection Lead Set
586897 (8951-P0)

This Connection Lead Set consists of a three-phase shielded cable terminated with stacking 4 mm safety banana plugs as well as a bundle of shielded cables terminated with 2 mm banana plugs.

2 x 3 phase + ground 60 cm cable. 2 x (2mmx5).

Specifications

Parameter	Value
Three-Phase Shielded Cable Characteristics	
Number of Conductors per Cable	3 (shield not included)
Cross Section	1 mm² (1974 cmil)
Rated Current	8 A
Rated Voltage	600 V
Length	1 m
Three-Phase Shielded Cable Quantities	2
Shielded Cables Terminated with Stacking 2 mm Banana Plugs Characteristics	
Number of Conductors per Cable	4 (shield not included)
Cross Section	0.324 mm² (640 cmils)
Rated Current	2.2 A
Rated Voltage	30 V ac / 60 V dc
Length	0.9 m
Shielded Cables Terminated with Stacking 2 mm Banana Plugs Quantities	
Shielded Cables Terminated with Stacking 2 mm Banana Plug Leads Quantities	2

Connection Lead Set
8112387 (8951-S0)

This Connection Lead Set consists of extra-flexible leads terminated with stacking 4 mm safety banana plugs. The leads are supplied in different lengths and are color-coded according to length.

Specifications

Parameter	Value
4 mm Safety Banana Plug Leads Characteristics	
Cross Section	1 mm² (1974 cmil)
Rated Current	19 A
Rated Voltage	600 V, CAT II
4 mm Safety Banana Plug Leads Quantities	
White, 15 cm (6 in)	60
Yellow, 30 cm (12 in)	26
Red, 60 cm (24 in)	38
Blue, 90 cm (36 in)	8
2 mm Safety Banana Plug Leads Characteristics	
Cross Section	0.5 mm² (987 cmils)

Parameter	Value
Rated Current	10 A
Rated Voltage	30 V ac / 60 V dc
2 mm Safety Banana Plug Leads Quantities	
White, 15 cm (6 in)	4

Four-Quadrant Dynamometer/Power Supply with manual control
579641 (8960-B0)

Four-Quadrant Dynamometer / Power Supply
LabVolt Series 8960-20
FESTO
Operating Mode
Manual Control
Start/Stop
Function
Command
Status
Control
Function
Power Input
I/O For Advanced Functions
Shaft Encoder Outputs
Analog Outputs
Rating

The Four-Quadrant Dynamometer/Power Supply is a highly versatile USB peripheral designed to be used in the Electric Power Technology Training Systems. Two operating modes are available: Dynamometer and Power Supply. A wide variety of user-selectable functions is available in each operating mode.

In the Dynamometer mode, the unit becomes a four-quadrant dynamometer that can act as either a fully configurable brake (i.e., a mechanical load) or a fully configurable prime mover (i.e., a motor drive). In the Power Supply mode, the unit becomes a four-quadrant power supply that can act as a dc voltage source, dc current source, ac power source, etc.

In each operating mode, key parameters related to the selected function are displayed. Speed, torque, mechanical power, and energy are displayed in the Dynamometer mode while voltage, current, electrical power, and energy are displayed in the Power Supply mode. Optional functions, such as a small wind-turbine emulator, a hydraulic turbine emulator, a solar panel emulator, battery chargers, an SDK (Software Development Kit) etc., can be added to the standard functions to further enhance the training possibilities of the Four-Quadrant Dynamometer/Power Supply.

Two modes are available to control the function which the Four-Quadrant Dynamometer/Power Supply performs: Manual and Computer-Based.

In the Manual control mode, the module operates as a stand-alone unit, and the function performed is selected, set, and monitored using front-panel mounted controls and display. This mode provides access to all basic functions. In the Computer-Based control mode, the function performed by the module is selected, set, and monitored using the LVDAC-EMS software. In this mode, communication between the Four-Quadrant Dynamometer/Power Supply and the host computer running the LVDAC-EMS software is achieved through a USB connection. This mode provides access to all basic functions, as well as to additional advanced functions.

Includes the Four-Quadrant Dynamometer/Power Supply, with the Standard Functions (Manual Control)

The Four-Quadrant Dynamometer/Power Supply is powered from a standard wall receptacle via a line cord that connects to the module’s front panel. The module helps energy conservation by returning the mechanical or electrical energy it receives to the ac power network while maintaining a unity power factor.

Software

Qty	Description	Model number
1	Complete Function Set	581435 (8968-00)
1	Standard Functions (computer-based control) Set	581437 (8968-20)
1	Turbine/Engine Emulator Function Set	579783 (8968-30)

Qty	Description	Model number
1	Lead-Acid Battery Charger Function Set	581438 (8968-40)
1	Ni-MH Battery Charger Function Set	581439 (8968-50)
1	Solar Panel Emulator Function Set	581440 (8968-60)
1	SCADA for LVDAC-EMS	8094377 (8973-00) [98]

Specifications

Parameter	Value
Power Requirements	
Maximum Current	6 A
AC Power Network Installation	120 V - 60 Hz, must include live, neutral, and ground wires
Maximum Leakage Current	1.8 mA
Dynamometer Mode	
Magnetic Torque	0 to 3 N·m (0 to 27 lbf·in)
Direction of Rotation	CW / CCW
Speed	0 to 2500 r/min
Nominal Power	350 W
Power Supply Mode	
DC Voltage	0 to ± 150 V
AC Voltage (RMS)	0 to 105 V (no-load)
DC Current	0 to ± 5 A
AC Current (RMS)	0 to 3.5 A
Maximum Output Power	500 W
AC Frequency	10 to 120 Hz
Control Functions	
Activated Set	Standard Functions (Manual Control), Model 8968-1
Liquid-Crystal Display (LCD)	76 mm (3 in), monochrome, background-illuminated, 240 x 160 dots
Control Inputs	
Command Input	0 to ± 10 V
Thermistor Input	10 kΩ, type 1
Control Outputs	
Shaft Encoder	Quadrature encoder (A-B) - 360 pulses/revolution - TTL compatible
Torque Output Sensitivity	0.3 N·m/V (2.655 lbf·in/V)
Speed Output Sensitivity	500 r/min/V
Communication Port	
Type	USB 2.0
Physical Characteristics	
Dimensions (H x W x D)	308 x 287 x 437 mm (12.1 x 11.3 x 17.2 in)
Net Weight	19.5 kg (43.0 lb)

Standard Functions (manual control) Set
581436 (8968-10)

The Standard Functions (manual control) Set is a package of control functions that can be activated in the Four-Quadrant Dynamometer/Power Supply, enabling the module to perform a wide variety of functions in each of its two operating modes (Dynamometer and Power Supply).

The set allows only manual control of the functions. This means that the Four-Quadrant Dynamometer/Power Supply operates as a stand-alone unit, and the function performed is selected, set, and monitored using front-panel mounted controls and display. The following control functions are available in the set:

Dynamometer operating mode

- Two-Quadrant, Constant-Torque Brake

- Clockwise Prime Mover/Brake

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[98] Software allowing the monitoring of up to 5 Stations through OPC.

- Counterclockwise Prime Mover/Brake
- Clockwise Constant-Speed Prime Mover/Brake
- Counterclockwise Constant-Speed Prime Mover/Brake
- Positive Constant-Torque Prime Mover/Brake
- Negative Constant-Torque Prime Mover/Brake

Power Supply operating mode

- Positive Voltage Source
- Negative Voltage Source
- 200 V DC Bus
- Positive Current Source
- Negative Current Source
- 50 Hz Power Source
- 60 Hz Power Source
- Lead-Acid Battery Float Charger

Specifications

Parameter	Value
Control Functions	
Control Functions	Two-Quadrant, Constant-Torque Brake
	Clockwise Prime Mover/Brake
	Counterclockwise Prime Mover/Brake
	Clockwise Constant-Speed Prime Mover/Brake
	Counterclockwise Constant-Speed Prime Mover/Brake
	Positive Constant-Torque Prime Mover/Brake
	Negative Constant-Torque Prime Mover/Brake
	Positive Voltage Source
	Negative Voltage Source
	Positive Current Source
	Negative Current Source
	50 Hz Power Source
	60 Hz Power Source
	200 V DC Bus
	Lead-Acid Battery Float Charger
Two-Quadrant, Constant-Torque Brake	
Torque	0-3 N·m (26.55 lbf·in)
Clockwise/Counterclockwise Prime Mover/Brake	
Speed	0-2500 r/min
Clockwise/Counterclockwise Constant-Speed Prime Mover/Brake	
Speed	0-2500 r/min
Positive/Negative Constant-Torque Prime Mover/Brake	
Torque	0-3 N·m (26.55 lbf·in)
Positive/Negative Voltage Source	
Voltage	0 to ±150 V
Positive/Negative Current Source	
Current	0 to ±5 A
50 Hz/60 Hz Power Source	
No-Load Voltage	0-140 V
200 V DC Bus	

Parameter	Value
Status	On or off
Lead-Acid Battery Float Charger	
Float Voltage	0-150 V

Four-Quadrant Dynamometer / Power Supply with Manual and Computer-Based Control 579648 (8960-C0)

Four-Quadrant Dynamometer / Power Supply LabVolt Series 8960-20
SOLAR PANEL EMULATOR
WIND TURBINE EMULATOR
LEAD-ACID BATTERY CHARGER

The Four-Quadrant Dynamometer/Power Supply is a highly versatile USB peripheral designed to be used in the Electric Power Technology Training Systems. Two operating modes are available: Dynamometer and Power Supply. A wide variety of user-selectable functions is available in each operating mode.

In the Dynamometer mode, the unit becomes a four-quadrant dynamometer that can act as either a fully configurable brake (i.e., a mechanical load) or a fully configurable prime mover (i.e., a motor drive). In the Power Supply mode, the unit becomes a four-quadrant power supply that can act as a dc voltage source, dc current source, ac power source, etc.

In each operating mode, key parameters related to the selected function are displayed. Speed, torque, mechanical power, and energy are displayed in the Dynamometer mode while voltage, current, electrical power, and energy are displayed in the Power Supply mode. Optional functions, such as a small wind-turbine emulator, a hydraulic turbine emulator, a solar panel emulator, battery chargers, an SDK (Software Development Kit) etc., can be added to the standard functions to further enhance the training possibilities of the Four-Quadrant Dynamometer/Power Supply.

Two modes are available to control the function which the Four-Quadrant Dynamometer/Power Supply performs: Manual and Computer-Based.

In the Manual control mode, the module operates as a stand-alone unit, and the function performed is selected, set, and monitored using front-panel mounted controls and display. This mode provides access to all basic functions. In the Computer-Based control mode, the function performed by the module is selected, set, and monitored using the LVDAC-EMS software. In this mode, communication between the Four-Quadrant Dynamometer/Power Supply and the host computer running the LVDAC-EMS software is achieved through a USB connection. This mode provides access to all basic functions, as well as to additional advanced functions.

This model includes the Four-Quadrant Dynamometer/Power Supply with the following function sets activated:

- Standard Functions (Manual Control)

- Standard Functions (Computer-Based Control)

The Four-Quadrant Dynamometer/Power Supply is powered from a standard wall receptacle via a line cord that connects to the module’s front panel. The module helps energy conservation by returning the mechanical or electrical energy it receives to the ac power network while maintaining a unity power factor.

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Personal Computer	579785 (8990-00) [99]

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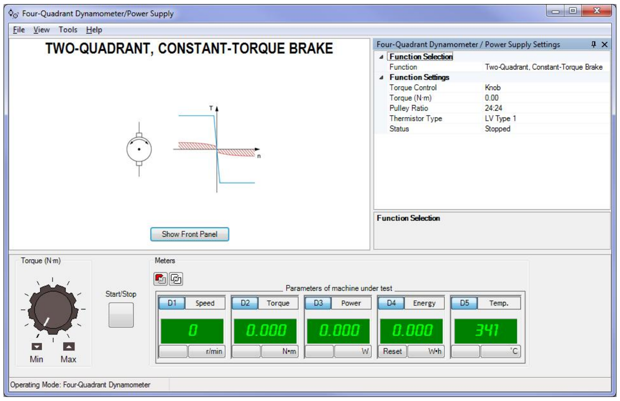
[99] Refer to the Computer Requirements in the System Specifications section of this datasheet if the computer is to be provided by the end-user. Note that only one computer is required per station.

Specifications

Parameter	Value
Dynamometer Mode	
Magnetic Torque	0 to 3 N·m (0 to 27 lbf·in)
Direction of Rotation	CW / CCW
Speed	0 to 2500 r/min
Nominal Power	350 W
Power Supply Mode	
DC Voltage	0 to ± 150 V
AC Voltage (RMS)	0 to 105 V (no-load)
DC Current	0 to ± 5 A
AC Current (RMS)	0 to 3.5 A
Maximum Output Power	500 W
AC Frequency	10 to 120 Hz
Control Functions	
Activated Sets	Standard Functions (Manual Control), Model 8968-1
	Standard Functions (Computer-Based Control), Model 8968-2
Liquid-Crystal Display (LCD)	76 mm (3 in), monochrome, background-illuminated, 240 x 160 dots
Control Inputs	
Command Input	0 to ± 10 V
Thermistor Input	10 kΩ, type 1
Control Outputs	
Shaft Encoder	Quadrature encoder (A-B) - 360 pulses/revolution - TTL compatible
Torque Output Sensitivity	0.3 N·m/V (2.655 lbf·in/V)
Speed Output Sensitivity	500 r/min/V
Communication Port	USB 2.0
Power Requirements	120 V - 6 A - 60 Hz, must include live, neutral, and ground wires
Computer Requirements	A currently available personal computer with USB 2.0 ports, running under one of the following operating systems: Windows® 7 or Windows® 8.
Physical Characteristics	
Dimensions (H x W x D)	308 x 287 x 490 mm (12.1 x 11.3 x 19.3 in)
Net Weight	19.5 kg (43.0 lb)

Standard Functions (computer-based control) Set
581437 (8968-20)


Four-Quadrant Dynamometer/Power Supply
File
View
Tools
Help
TWO-QUADRANT, CONSTANT-TORQUE BRAKE
T
n
Show Front Panel
Four-Quadrant Dynamometer / Power Supply Settings
Torque (N·m)
Min
Max
Start/Stop
Meters
Parameters of machine under test
D1
Speed
D2
Torque
D3
Power
D4
Energy
D5
Temp.
r/min
N•m
W
Reset
W•h
°C

Function Selection
Function: Two-Quadrant, Constant-Torque Brake
Function Settings
Torque Control: Knob
Torque (N·m): 0.00
Pulley Ratio: 24:24
Thermistor Type: LV Type 1
Status: Stopped
Function Selection

Speed: 0 r/min
Torque: 0.000 N•m
Power: 0.000 W
Energy: 0.000 W•h
Temp.: 341 °C

Operating Mode: Four-Quadrant Dynamometer

The Standard Functions (computer-based control) Set is a package of control functions that can be activated in the Four-Quadrant Dynamometer/Power Supply, enabling the module to perform a wide variety of functions in each of its two operating modes (Dynamometer and Power Supply).

The set allows only computer-based control of the functions. This means that the function performed by the Four-Quadrant Dynamometer/Power Supply is selected, set, and monitored using the LVDAC-EMS software. The following control functions are available in the set:

Dynamometer operating mode

- Two-Quadrant, Constant-Torque Brake

- Clockwise Prime Mover/Brake

- Counterclockwise Prime Mover/Brake
- Clockwise Constant-Speed Prime Mover/Brake
- Counterclockwise Constant-Speed Prime Mover/Brake
- Positive Constant-Torque Prime Mover/Brake
- Negative Constant-Torque Prime Mover/Brake
- Four-Quadrant Constant-Speed Prime Mover/Brake
- Speed Sweep

Power Supply operating mode

- Positive Voltage Source
- Negative Voltage Source
- DC Voltage Source
- Positive Current Source
- Negative Current Source
- DC Current Source
- 50 Hz Power Source
- 60 Hz Power Source
- AC Power Source
- Lead-Acid Battery Float Charger

Specifications

Parameter	Value
Control Functions	
Control Functions	Two-Quadrant, Constant-Torque Brake
	Clockwise Prime Mover/Brake
	Counterclockwise Prime Mover/Brake
	Clockwise Constant-Speed Prime Mover/Brake
	Counterclockwise Constant-Speed Prime Mover/Brake
	Positive Constant-Torque Prime Mover/Brake
	Negative Constant-Torque Prime Mover/Brake
	Four-Quadrant, Constant-Speed Prime Mover/Brake
	Speed Sweep
	Mechanical Load
	Positive Voltage Source
	Negative Voltage Source
	DC Voltage Source
	Positive Current Source
	Negative Current Source
	DC Current Source
	50 Hz Power Source
	60 Hz Power Source
	AC Power Source
	Lead-Acid Battery Float Charger
Two-Quadrant, Constant-Torque Brake	
Torque Control	Software knob, 8960 module knob, or 8960 command input
Torque	0-3 N·m (26.55 lbf·in)
Pulley Ratio	24:24, 24:12, or 24:32
Clockwise/Counterclockwise Prime Mover/Brake	

Parameter	Value
Speed Control	Software knob, 8960 module knob, or 8960 command input
Speed	0-2500 r/min
Pulley Ratio	24:24, 24:12, or 24:32
Clockwise/Counterclockwise Constant-Speed Prime Mover/Brake	
Speed Control	Software knob, 8960 module knob, or 8960 command input
Speed	0-2500 r/min
Pulley Ratio	24:24, 24:12, or 24:32
Positive/Negative Constant-Torque Prime Mover/ Brake	
Torque Control	Software knob, 8960 module knob, or 8960 command input
Torque	0-3 N·m (26.55 lbf·in)
Pulley Ratio	24:24, 24:12, or 24:32
Four-Quadrant, Constant-Speed Prime Mover/Brake	
Speed Control	Software knob, 8960 module knob, or 8960 command input
Speed	0-2500 r/min
Pulley Ratio	24:24, 24:12, or 24:32
Speed Sweep	
Start Speed	-3000 r/min to 3000 r/min
Finish Speed	-3000 r/min to 3000 r/min
Number of Steps	0-50 steps
Step Duration	2-10 s
Record Data to Table	Yes or no
Pulley Ratio	24:24, 24:12, or 24:32
Mechanical Load	
Load Type	Flywheel, fan, grinder, conveyor, calender, crane, user defined
Inertia	0.005-1 kg·m² (0.119-23.73 lb·ft²)
Friction Torque	0.05-3 N·m (0.44-26.55 lbf·in)
Pulley Ratio	24:24, 24:12, or 24:32
Positive/Negative Voltage Source	
Voltage Control	Software knob, 8960 module knob, or 8960 command input
Voltage	0 V to 147 V / -147 V to 0 V
DC Voltage Source	
Voltage Control	Software knob, 8960 module knob, or 8960 command input
Voltage	-147 V to 147 V
Positive/Negative Current Source	
Current Control	Software knob, 8960 module knob, or 8960 command input
Current	0 A to 5 A / -5 A to 0 A
DC Current Source	
Current Control	Software knob, 8960 module knob, or 8960 command input
Current	-5 A to 5 A
50 Hz/60 Hz Power Source	
Voltage Control	Software knob, 8960 module knob, or 8960 command input
No-Load Voltage	0-140 V
AC Power Source	
No-Load Voltage	0-140 V
DC Offset Correction	-1000 to 1000
Frequency	10-100 Hz
Lead-Acid Battery Float Charger	
Float Voltage	0-150 V

Four-Quadrant Dynamometer/Power Supply
579655 (8960-D0)

The Four-Quadrant Dynamometer/Power Supply is a highly versatile USB peripheral designed to be used in the Electric Power Technology Training Systems. Two operating modes are available: Dynamometer and Power Supply. A wide variety of user-selectable functions is available in each operating mode.

In the Dynamometer mode, the unit becomes a four-quadrant dynamometer that can act as either a fully configurable brake (i.e., a mechanical load) or a fully configurable prime mover (i.e., a motor drive). In the Power Supply mode, the unit becomes a four-quadrant power supply that can act as a dc voltage source, dc current source, ac power source, etc.

In each operating mode, key parameters related to the selected function are displayed. Speed, torque, mechanical power, and energy are displayed in the Dynamometer mode while voltage, current, electrical power, and energy are displayed in the Power Supply mode. Optional functions, such as a small wind-turbine emulator, a hydraulic turbine emulator, a solar panel emulator, battery chargers, an SDK (Software Development Kit) etc., can be added to the standard functions to further enhance the training possibilities of the Four-Quadrant Dynamometer/Power Supply.

Two modes are available to control the function which the Four-Quadrant Dynamometer/Power Supply performs: Manual and Computer-Based.

In the Manual control mode, the module operates as a stand-alone unit, and the function performed is selected, set, and monitored using front-panel mounted controls and display. This mode provides access to all basic functions. In the Computer-Based control mode, the function performed by the module is selected, set, and monitored using the LVDAC-EMS software. In this mode, communication between the Four-Quadrant Dynamometer/Power Supply and the host computer running the LVDAC-EMS software is achieved through a USB connection. This mode provides access to all basic functions, as well as to additional advanced functions.

Includes the Four-Quadrant Dynamometer/Power Supply, with the following function sets activated:

- Standard Functions (Manual Control)
- Standard Functions (Computer-Based Control)
- Turbine Emulator
- Lead-Acid Battery Charger

The Four-Quadrant Dynamometer/Power Supply is powered from a standard wall receptacle via a line cord that connects to the module’s front panel. The module helps energy conservation by returning the mechanical or electrical energy it receives to the ac power network while maintaining a unity power factor.

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Personal Computer	579785 (8990-00) [100]

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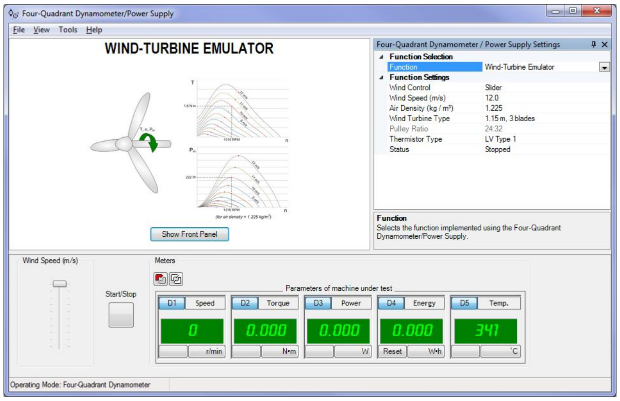
[100] Refer to the Computer Requirements in the System Specifications section of this datasheet if the computer is to be provided by the end-user. Note that only one computer is required per station.

Specifications

Parameter	Value
Dynamometer Mode	
Magnetic Torque	0 to 3 N·m (0 to 27 lbf·in)
Direction of Rotation	CW / CCW
Speed	0 to 2500 r/min
Nominal Power	350 W
Power Supply Mode	
DC Voltage	0 to ± 150 V
AC Voltage (RMS)	0 to 105 V (no-load)
DC Current	0 to ± 5 A
AC Current (RMS)	0 to 3.5 A
Maximum Output Power	500 W
AC Frequency	10 to 120 Hz
Control Functions	
Activated Sets	Standard Functions (Manual Control), Model 8968-1
	Standard Functions (Computer-Based Control), Model 8968-2
	Turbine Emulator, Model 8968-3
	Lead-Acid Battery Charger, Model 8968-4
Liquid-Crystal Display (LCD)	76 mm (3 in), monochrome, background-illuminated, 240 x 160 dots
Control Inputs	
Command Input	0 to ± 10 V
Thermistor Input	10 kΩ, type 1
Control Outputs	
Shaft Encoder	Quadrature encoder (A-B) - 360 pulses/revolution - TTL compatible
Torque Output Sensitivity	0.3 N·m/V (2.655 lbf·in/V)
Speed Output Sensitivity	500 r/min/V
Communication Port	USB 2.0
Power Requirements	120 V - 6 A - 60 Hz, must include live, neutral, and ground wires
Computer Requirements	A currently available personal computer with USB 2.0 ports, running under one of the following operating systems: Windows® 7 or Windows® 8.
Physical Characteristics	
Dimensions (H x W x D)	308 x 287 x 490 mm (12.1 x 11.3 x 19.3 in)
Net Weight	19.5 kg (43.0 lb)

Turbine/Engine Emulator Function Set
579783 (8968-30)


Four-Quadrant Dynamometer/Power Supply
File
View
Tools
Help
WIND-TURBINE EMULATOR
T
1.6 N·m
1315 RPM
n
Pm
222 W
1315 RPM
n
(for air density = 1.225 kg/m³)
Show Front Panel
Wind Speed (m/s)
Start/Stop
Meters
Parameters of machine under test
D1
Speed
r/min
D2
Torque
N•m
D3
Power
W
D4
Energy
Reset
W•h
D5
Temp.
°C

Four-Quadrant Dynamometer / Power Supply Settings

Function Selection

Function	Wind-Turbine Emulator

Function Settings

Wind Control	Slider
Wind Speed (m/s)	12.0
Air Density (kg / m³)	1.225
Wind Turbine Type	1.15 m, 3 blades
Pulley Ratio	24:32
Thermistor Type	LV Type 1
Status	Stopped

Function
Selects the function implemented using the Four-Quadrant Dynamometer/Power Supply.

D1 Speed	D2 Torque	D3 Power	D4 Energy	D5 Temp.
0	0.000	0.000	0.000	341

Operating Mode: Four-Quadrant Dynamometer

The Turbine/Engine Emulator Function Set is a package of control functions that can be activated in the Four-Quadrant Dynamometer/Power Supply, enabling the module to emulate the operation of various types of turbines and engines.

The control functions in the set are only available in computer-based mode. This means that the function performed by the Four-Quadrant Dynamometer/Power Supply is selected, set, and monitored using the LVDAC-EMS software. The following control functions are available in the set:

Dynamometer operating mode

- Small Wind-Turbine Emulator: this function makes the permanent-magnet dc motor of the Four-Quadrant Dynamometer/Power Supply faithfully reproduce the effect of wind on the bladed rotor of a small-scale wind turbine. The torque-speed characteristic at the shaft of the machine coupled to the Four-Quadrant Dynamometer/Power Supply is the same as the one that is obtained when wind blows at a certain speed on the rotor of the actual wind turbine. The user has control over the wind speed and air density.

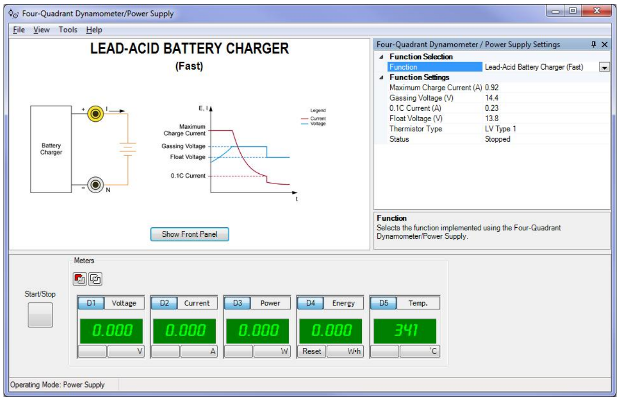
- Hydraulic Turbine Emulator: this function uses the permanent-magnet dc motor of the Four-Quadrant Dynamometer/Power Supply to recreate the behavior of an hydraulic turbine with a synchronous generator. The torque-speed characteristics at the shaft of the machine coupled to the Four-Quadrant Dynamometer/Power Supply is the same as that of a Francis-type hydraulic turbine. The user has control over the vane angle (manually or through the module analog input), the vane variation speed, and the inertia.

- Engine Emulator: this function uses the permanent-magnet dc motor of the Four-Quadrant Dynamometer/Power Supply to recreate the behavior of a diesel engine with a synchronous generator. The torque-speed characteristics at the shaft of the machine coupled to the Four-Quadrant Dynamometer/Power Supply is the same as a diesel generator. The user has control over the fuel rack position (%) (manually or through the module analog input) and the inertia.

Specifications

Parameter	Value
Control Functions	
Control Functions	Wind-Turbine Emulator
	Hydraulic-Turbine Emulator
	Engine Emulator
Wind-Turbine Emulator	
Wind Control	Software slider or 8960 command input
Wind Speed	3-12 m/s (6.7-26.8 mph)
Air Density	1.12-1.44 kg/m³ (0.07-0.09 lb/ft³)
Wind Turbine Type	1.15 m with 3 blades, 1.15 m with 3 blades and gearbox, 0.72 m with 3 blades and passive stall
Inertia J	0.02-0.4 kg·m² (0.475-9.492 lb·ft²) (only available for certain wind turbine types)
Gear Ratio R	0.5-2 (only available for certain wind turbine types)
Hydraulic-Turbine Emulator	
Vane Control	Software slider or 8960 command input
Turbine Type	300 W Francis
Vane Maximal Speed	0-100%/s
Runner Inertia	0.005-1 kg·m² (7.119 lb·ft²)
Engine Emulator	
Fuel Rack Position Control	Software slider or 8960 command input
Engine Type	300 W Diesel
Fuel Rack Position	0-100%
Engine Inertia	0.005-1 kg·m² (7.119 lb·ft²)

Lead-Acid Battery Charger Function Set
581438 (8968-40)



Four-Quadrant Dynamometer / Power Supply Settings

Function Selection	
Function	Lead-Acid Battery Charger (Fast)
Function Settings	
Maximum Charge Current (A)	0.92
Gassing Voltage (V)	14.4
0.1C Current (A)	0.23
Float Voltage (V)	13.8
Thermistor Type	LV Type 1
Status	Stopped

Function
Selects the function implemented using the Four-Quadrant Dynamometer/Power Supply.

The Lead-Acid Battery Charger Function Set is a package of control functions that can be activated in the Four-Quadrant Dynamometer/Power Supply, enabling the module to implement a lead-acid battery charger, as well as a battery discharger.

The Lead-Acid Battery Charger control function is only available in computer-based mode. This means that the function performed by the Four-Quadrant Dynamometer/Power Supply is selected, set, and monitored using the LVDAC-EMS software. The following control functions are available in the set:

Power Supply operating mode

- Lead-Acid Battery Charger (Fast):

This function uses the four-quadrant power supply to implement a battery charger that is able to rapidly charge lead-acid batteries of various capacities (typically in less than two hours). A three-step charge algorithm is used. Battery charging starts with a constant current corresponding to the battery maximum charge current until the battery gassing voltage is reached. At this point, battery charging continues with a constant voltage (close to gassing voltage) until the charge current decreases to 0.1 C. Then, constant-voltage charging continues but at a lower voltage (float charging voltage). The user has to specify the following four battery characteristics for the charger to achieve proper charge control: maximum charge current, gassing voltage, 0.1C current (10% of battery capacity), and float charging voltage. The function indicates the voltage, current, electrical power, and energy at the charger output. The function can also indicate battery temperature when the temperature sensor of the battery (if so equipped) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply. The function can also indicate battery temperature when the temperature sensor of the battery (if so equipped) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply. The license for the Lead-Acid Battery Charger, is required to activate the Lead-Acid Battery Charger (Fast) function in the Four-Quadrant Dynamometer/Power Supply.

- Battery Discharger (Constant-Current Timed Discharge with Voltage Cutoff):

This function uses the four-quadrant power supply to sink a constant current from a battery, thereby discharging the battery at a specific rate, during a specific period. The discharger also monitors the battery voltage during discharge. Battery discharging terminates immediately when the battery voltage decreases to a specific cutoff voltage. The user has to specify the discharge current, discharge duration, and cutoff voltage for the discharger to achieve proper discharge control. The function indicates the voltage, current, electrical power, and energy at the discharger output. The function can also indicate battery temperature when the temperature sensor of the battery (if so equipped) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply. The Battery Discharger function is perfectly suited to measure discharge characteristics of batteries at various rates as well as to bring a battery to a specific depth of discharge before a battery charging experiment. The license for the Lead-Acid Battery Charger, or the license for the Ni-MH Battery Chargers, is required to activate the Battery Discharger (Constant-Current Timed Discharge with Voltage Cutoff) function in the Four-Quadrant Dynamometer/Power Supply.

Specifications

Parameter	Value
Control Functions	
Control Functions	Lead-Acid Battery Charger (Fast)
	Battery Discharger (Constant-Current Timed Discharge with Voltage Cutoff)
Lead-Acid Battery Charger (Fast)	
Maximum Charge Current	0-5 A
Gassing Voltage	0-150 V
0.1C Current	0-5 A
Float Voltage	0-150 V
Battery Configuration	48V 3.4Ah (13S1P) or 10.2Ah (13S3P) auto detected
Battery Discharger (Constant-Current Timed Discharge with Voltage Cutoff)	
Discharge Current	0-5 A
Discharge Duration	0-2000 min
Cutoff Voltage	0-150 V

Four-Quadrant Dynamometer/Power Supply
579662 (8960-E0)

Four-Quadrant Dynamometer / Power Supply
LabVolt Series 8960-20
FESTO

The Four-Quadrant Dynamometer/Power Supply is a highly versatile USB peripheral designed to be used in the Electric Power Technology Training Systems. Two operating modes are available: Dynamometer and Power Supply. A wide variety of user-selectable functions is available in each operating mode.

In the Dynamometer mode, the unit becomes a four-quadrant dynamometer that can act as either a fully configurable brake (i.e., a mechanical load) or a fully configurable prime mover (i.e., a motor drive). In the Power Supply mode, the unit becomes a four-quadrant power supply that can act as a dc voltage source, dc current source, ac power source, etc.

In each operating mode, key parameters related to the selected function are displayed. Speed, torque, mechanical power, and energy are displayed in the Dynamometer mode while voltage, current, electrical power, and energy are displayed in the Power Supply mode. Optional functions, such as a small wind-turbine emulator, a hydraulic turbine emulator, a solar panel emulator, battery chargers, an SDK (Software Development Kit) etc., can be added to the standard functions to further enhance the training possibilities of the Four-Quadrant Dynamometer/Power Supply.

Two modes are available to control the function which the Four-Quadrant Dynamometer/Power Supply performs: Manual and Computer-Based.

In the Manual control mode, the module operates as a stand-alone unit, and the function performed is selected, set, and monitored using front-panel mounted controls and display. This mode provides access to all basic functions. In the Computer-Based control mode, the function performed by the module is selected, set, and monitored using the LVDAC-EMS software. In this mode, communication between the Four-Quadrant Dynamometer/Power Supply and the host computer running the LVDAC-EMS software is achieved through a USB connection. This mode provides access to all basic functions, as well as to additional advanced functions.

Includes the Four-Quadrant Dynamometer/Power Supply with the following function sets activated:

- Standard Functions (Manual Control)

- Standard Functions (Computer-Based Control)

- Lead-Acid Battery Charger

The Four-Quadrant Dynamometer/Power Supply is powered from a standard wall receptacle via a line cord that connects to the module's front panel. The module helps energy conservation by returning the mechanical or electrical energy it receives to the ac power network while maintaining a unity power factor.

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Personal Computer	579785 (8990-00) [101]

Specifications

Parameter	Value
Dynamometer Mode	
Magnetic Torque	0 to 3 N·m (0 to 27 lbf·in)
Direction of Rotation	CW / CCW
Speed	0 to 2500 r/min
Nominal Power	350 W
Power Supply Mode	
DC Voltage	0 to ± 150 V
AC Voltage (RMS)	0 to 105 V (no-load)
DC Current	0 to ± 5 A
AC Current (RMS)	0 to 3.5 A
Maximum Output Power	500 W
AC Frequency	10 to 120 Hz
Control Functions	
Activated Sets	Standard Functions (Manual Control), Model 8968-1
	Standard Functions (Computer-Based Control), Model 8968-2
	Lead-Acid Battery Charger, Model 8968-4
Liquid-Crystal Display (LCD)	76 mm (3 in), monochrome, background-illuminated, 240 x 160 dots
Control Inputs	
Command Input	0 to ± 10 V
Thermistor Input	10 kΩ, type 1
Control Outputs	
Shaft Encoder	Quadrature encoder (A-B) - 360 pulses/revolution - TTL compatible
Torque Output Sensitivity	0.3 N·m/V (2.655 lbf·in/V)
Speed Output Sensitivity	500 r/min/V
Communication Port	USB 2.0
Power Requirements	120 V - 6 A - 60 Hz, must include live, neutral, and ground wires
Computer Requirements	A currently available personal computer with USB 2.0 ports, running under one of the following operating systems: Windows® 7 or Windows® 8.
Physical Characteristics	
Dimensions (H x W x D)	308 x 287 x 490 mm (12.1 x 11.3 x 19.3 in)
Net Weight	19.5 kg (43.0 lb)

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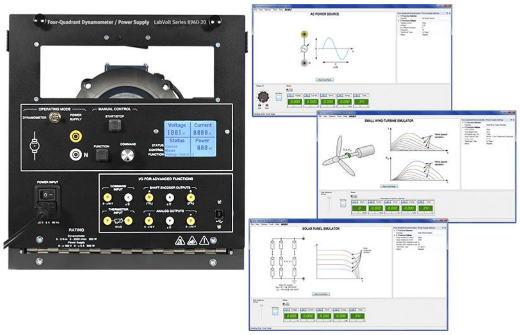
[101] Refer to the Computer Requirements in the System Specifications section of this datasheet if the computer is to be provided by the end-user. Note that only one computer is required per station.

Four-Quadrant Dynamometer/Power Supply
579669 (8960-F0)



The Four-Quadrant Dynamometer/Power Supply is a highly versatile USB peripheral designed to be used in the Electric Power Technology Training Systems. Two operating modes are available: Dynamometer and Power Supply. A wide variety of user-selectable functions is available in each operating mode.

In the Dynamometer mode, the unit becomes a four-quadrant dynamometer that can act as either a fully configurable brake (i.e., a mechanical load) or a fully configurable prime mover (i.e., a motor drive). In the Power Supply mode, the unit becomes a four-quadrant power supply that can act as a dc voltage source, dc current source, ac power source, etc.

In each operating mode, key parameters related to the selected function are displayed. Speed, torque, mechanical power, and energy are displayed in the Dynamometer mode while voltage, current, electrical power, and energy are displayed in the Power Supply mode. Optional functions, such as a small wind-turbine emulator, a hydraulic turbine emulator, a solar panel emulator, battery chargers, an SDK (Software Development Kit) etc., can be added to the standard functions to further enhance the training possibilities of the Four-Quadrant Dynamometer/Power Supply.

Two modes are available to control the function which the Four-Quadrant Dynamometer/Power Supply performs: Manual and Computer-Based.

In the Manual control mode, the module operates as a stand-alone unit, and the function performed is selected, set, and monitored using front-panel mounted controls and display. This mode provides access to all basic functions. In the Computer-Based control mode, the function performed by the module is selected, set, and monitored using the LVDAC-EMS software. In this mode, communication between the Four-Quadrant Dynamometer/Power Supply and the host computer running the LVDAC-EMS software is achieved through a USB connection. This mode provides access to all basic functions, as well as to additional advanced functions.

Includes the Four-Quadrant Dynamometer/Power Supply, with the following function sets activated:

- Standard Functions (Manual Control)
- Standard Functions (Computer-Based Control)
- Turbine Emulator
- Lead-Acid Battery Charger
- Solar Panel Emulator

The Four-Quadrant Dynamometer/Power Supply is powered from a standard wall receptacle via a line cord that connects to the module’s front panel. The module helps energy conservation by returning the mechanical or electrical energy it receives to the ac power network while maintaining a unity power factor.

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Personal Computer	579785 (8990-00) [102]

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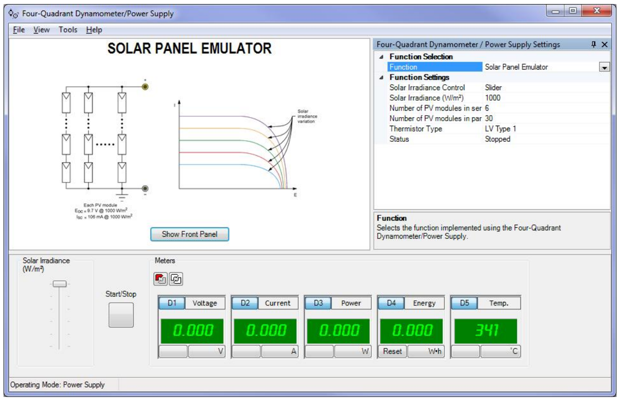
[102] Refer to the Computer Requirements in the System Specifications section of this datasheet if the computer is to be provided by the end-user. Note that only one computer is required per station.

Specifications

Parameter	Value
Dynamometer Mode	
Magnetic Torque	0 to 3 N·m (0 to 27 lbf·in)
Direction of Rotation	CW / CCW
Speed	0 to 2500 r/min
Nominal Power	350 W
Power Supply Mode	
DC Voltage	0 to ± 150 V
AC Voltage (RMS)	0 to 105 V (no-load)
DC Current	0 to ± 5 A
AC Current (RMS)	0 to 3.5 A
Maximum Output Power	500 W
AC Frequency	10 to 120 Hz
Control Functions	
Activated Sets	Standard Functions (Manual Control), Model 8968-1
	Standard Functions (Computer-Based Control), Model 8968-2
	Turbine Emulator, Model 8968-3
	Lead-Acid Battery Charger, Model 8968-4
	Solar Panel Emulator, Model 8968-6
Liquid-Crystal Display (LCD)	76 mm (3 in), monochrome, background-illuminated, 240 x 160 dots
Control Inputs	
Command Input	0 to ± 10 V
Thermistor Input	10 kΩ, type 1
Control Outputs	
Shaft Encoder	Quadrature encoder (A-B) - 360 pulses/revolution - TTL compatible
Torque Output Sensitivity	0.3 N·m/V (2.655 lbf·in/V)
Speed Output Sensitivity	500 r/min/V
Communication Port	USB 2.0
Power Requirements	120 V - 6 A - 60 Hz, must include live, neutral, and ground wires
Computer Requirements	A currently available personal computer with USB 2.0 ports, running under one of the following operating systems: Windows$^{®}$ 7 or Windows$^{®}$ 8.
Physical Characteristics	
Dimensions (H x W x D)	308 x 287 x 490 mm (12.1 x 11.3 x 19.3 in)
Net Weight	19.5 kg (43.0 lb)

Solar Panel Emulator Function Set
581440 (8968-60)


Four-Quadrant Dynamometer/Power Supply
File
View
Tools
Help
SOLAR PANEL EMULATOR
Each PV module
E_{OC} = 9.7 V @ 1000 W/m²
I_{SC} = 106 mA @ 1000 W/m²
I
E
Solar irradiance variation
Show Front Panel
Four-Quadrant Dynamometer / Power Supply Settings
Solar Irradiance (W/m²)
Start/Stop
Meters
D1
Voltage
0.000
V
D2
Current
0.000
A
D3
Power
0.000
W
D4
Energy
0.000
Reset
W·h
D5
Temp.
341
°C

Function Selection
Function: Solar Panel Emulator
Function Settings
Solar Irradiance Control: Slider
Solar Irradiance (W/m²): 1000
Number of PV modules in ser: 6
Number of PV modules in par: 30
Thermistor Type: LV Type 1
Status: Stopped

Function
Selects the function implemented using the Four-Quadrant Dynamometer/Power Supply.

Operating Mode: Power Supply

The Solar Panel Emulator Function Set is a function that can be activated in the Four-Quadrant Dynamometer/ Power Supply enabling the module to emulate a solar panel.

The Solar Panel Emulator control function is only available in computer-based mode. This means that the function performed by the Four-Quadrant Dynamometer/Power Supply is selected, set, and monitored using the LVDAC-EMS software. The function emulates a solar panel consisting of an array of photovoltaic (PV) modules. The current-voltage characteristic of each PV module emulated is the same as that of the PV module used in the Monocrystalline Silicon Solar Panel. The function allows the user to determine the size of the PV module array emulated, by selecting the number of PV modules connected in series and in parallel. A sliding control in the Solar Panel Emulator interface provides the user full control of solar irradiance.

Specifications

Parameter	Value
Control Functions	Solar Panel Emulator
Solar Panel Emulator	
Solar Irradiance Control	Software slider or 8960 command input
Solar Irradiance	1-1000 W/m²
Number of PV Modules in Series	1-7 modules
Number of PV Modules in Parallel	5-45 modules

Four-Quadrant Dynamometer/Power Supply
579674 (8960-G0)

The Four-Quadrant Dynamometer/Power Supply is a highly versatile USB peripheral designed to be used in the Electric Power Technology Training Systems. Two operating modes are available: Dynamometer and Power Supply. A wide variety of user-selectable functions is available in each operating mode.

In the Dynamometer mode, the unit becomes a four-quadrant dynamometer that can act as either a fully configurable brake (i.e., a mechanical load) or a fully configurable prime mover (i.e., a motor drive). In the Power Supply mode, the unit becomes a four-quadrant power supply that can act as a dc voltage source, dc current source, ac power source, etc.

In each operating mode, key parameters related to the selected function are displayed. Speed, torque, mechanical power, and energy are displayed in the Dynamometer mode while voltage, current, electrical power, and energy are displayed in the Power Supply mode. Optional functions, such as a small wind-turbine emulator, an hydraulic turbine emulator, a solar panel emulator, battery chargers, an SDK (Software Development Kit) etc., can be added to the standard functions to further enhance the training possibilities of the Four-Quadrant Dynamometer/Power Supply. Refer to the Optional Equipment section of this data sheet for more information about the optional functions currently available.

Two modes are available to control the function which the Four-Quadrant Dynamometer/Power Supply performs: Manual and Computer-Based.

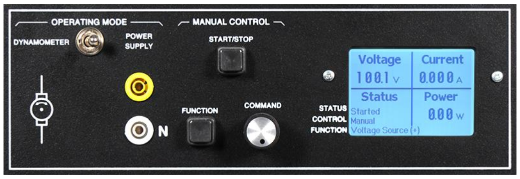
In the Manual control mode, the module operates as a stand-alone unit, and the function performed is selected, set, and monitored using front-panel mounted controls and display. This mode provides access to all basic functions. In the Computer-Based control mode, the function performed by the module is selected, set, and monitored using the LVDAC-EMS software. In this mode, communication between the Four-Quadrant Dynamometer/Power Supply and the host computer running the LVDAC-EMS software is achieved through a USB connection. This mode provides access to all basic functions, as well as to additional advanced functions.

Four-Quadrant Dynamometer/Power Supply

The Four-Quadrant Dynamometer/Power Supply mainly consists of a permanent-magnet dc motor, a four-quadrant power supply, and an onboard microcontroller enclosed in a full-size EMS module. A toggle switch on the front panel allows selection of the operating mode (Dynamometer or Power Supply).

In the Dynamometer mode, the unit operates as a four-quadrant dynamometer that can act as either a fully configurable brake (i.e., a mechanical load), a fully configurable prime mover (i.e., a motor drive), a small wind turbine emulator (optional), depending on the control function selected by the user. A pulley on the machine shaft allows mechanical coupling to any EMS rotating machine.

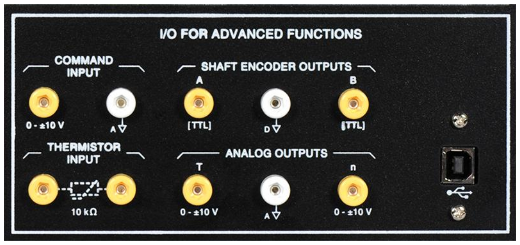
In the Power Supply mode, the four-quadrant power supply operates as a four-quadrant power supply that can act as a dc voltage source, dc current source, ac power source, etc., depending on the control function selected by the user. Two 4 mm safety banana jacks on the front panel provide access to the four-quadrant power supply terminals.


OPERATING MODE
DYNAMOMETER
POWER SUPPLY
MANUAL CONTROL
START/STOP
N
FUNCTION
COMMAND
Voltage
100.1 V
Current
0.000 A
Status
Power
0.00 W
STATUS
CONTROL
FUNCTION
Started
Manual
Voltage Source (+)

Controls, power supply terminals, and display on the front panel.

In the Manual control mode, two push buttons (FUNCTION and START/STOP), a control knob (COMMAND), and an LCD mounted on the front panel of the module allow the function performed by the unit to be selected, set, and monitored.

The Four-Quadrant Dynamometer/Power Supply is provided with a set of low-level (0 to ±10 V) inputs and outputs for advanced functions. Access to these inputs and outputs is through miniature banana jacks on the front panel.



Low-level inputs and outputs for advanced control functions and USB port connector on the front panel.

The Command Input allows an analog signal to be injected into the module. The voltage of this signal determines the command (e.g., the current command of a DC current source) of the function implemented by the module when the Command Input is selected as the source of command (option available in the Computer-Based control mode). The Thermistor Input allows connection of an external temperature sensor (thermistor) for temperature measurement using the Four-Quadrant Dynamometer/Power Supply. Temperature measurement is required for some advanced functions such as the Ni-MH battery chargers. The Shaft Encoder Outputs provide the digital signals (A-B output type) produced by the shaft encoder mounted on the PM DC motor. Finally, the T and n Analog Outputs provide analog signals proportional to the torque and speed measured at the shaft of the permanent-magnet dc motor. These outputs are designed to be connected to the corresponding inputs on data acquisition modules (Models 9061, 9062, and 9063) for torque and speed measurement using the LVDAC-EMS or LVDAM-EMS software.

A USB port connector mounted on the front panel allows the Four-Quadrant Dynamometer/Power Supply to be connected to a USB port of the computer running the LVDAC-EMS software (USB cable included with the module). A main power connector mounted on the front panel is used to connect the Four-Quadrant Dynamometer/Power Supply to a standard wall receptacle using a conventional line cord (included with the module). All inputs and outputs of the Four-Quadrant Dynamometer/Power Supply are protected against improper connections and overvoltage/overcurrent conditions.

The internal friction of the permanent-magnet dc machine and the friction of the belt coupling are measured after assembly for each Four-Quadrant Dynamometer/Power Supply. The measured friction data is stored in the microcontroller memory and used to compensate the effect of friction in order to achieve accurate torque measurements. An auxiliary function of the Four-Quadrant Dynamometer/Power Supply allows the user to easily recalibrate the friction compensation. Recalibration of the friction compensation is useful to maintain optimal torque measurement accuracy as the internal friction of the machine decreases slightly with usage. The Zero Friction Machine, Model 8969, is required to perform recalibration of the friction compensation.

The optional functions currently available for the Four-Quadrant Dynamometer/Power Supply are described in the Optional Module Functions section of this data sheet. To activate a specific optional function, a license for that function, Model 8968-X, must be ordered for each Four-Quadrant Dynamometer/Power Supply that will be used to perform this function.

Model Variants

The Four-Quadrant Dynamometer/Power Supply is available in several model variants. Each variant consists of the Four-Quadrant Dynamometer/Power Supply, Model 8960-3, plus a unique combination of functions pre-activated in the module. The model variants currently available are listed in the following table. Other model variants will be added as they become available.

Control Function Sets		Model Variants						
Model	**Name**	**8960-A**	**8960-B**	**8960-C**	**8960-D**	**8960-E**	**8960-F**	**8960-G**
8968-0	Complete Function Set	●						
8968-1	Standard Functions (Manual Control)	●	●	●	●	●	●	●
8968-2	Standard Functions (Computer-Based Control)	●		●	●	●	●	●
8968-3	Turbine Emulator	●			●		●	
8968-4	Lead-Acid Battery Charger	●			●	●	●	
8968-5	Ni-MH Battery Charger	●						
8968-6	Solar Panel Emulator	●					●	●
8968-7	Software Development Kit (SDK)	●						

Model 8960-B is the basic variant of the Four-Quadrant Dynamometer/Power Supply and is designed to operate as a stand-alone unit (no computer required). It includes all standard functions available in the Manual control mode only (Model 8968-1). Model 8960-B is a direct replacement for the older Prime Mover / Dynamometer, Model 8960-1, used in the 0.2 kW Computer-Assisted Electromechanical Training System, Model 8006.

Model 8960-C is a step-up variant that includes all standard functions available in the Manual control mode (Model 8968-1) plus all standard functions available in the Computer-Based control mode (Model 8968-2). Model 8960-C is the minimal variant that allows the addition of optional functions required to perform certain courses in the Electric Power Technology Training Program, Series 8010. For instance, Model 8960-D consists of the Four-Quadrant Dynamometer/Power Supply, Model 8960-C, plus the licenses for the Turbine Emulator, Model 8968-3, and the Lead-Acid Battery Charger, Model 8968-4, which are required to perform several lab exercises in the Basic Renewable Energy Training System, Model 8010-5.

Model 8960-A is the fully equipped variant including all optional functions currently available for the Four-Quadrant Dynamometer/Power Supply.

Four-Quadrant Dynamometer/Power Supply modules with a specific combination of pre-activated optional functions other than those listed above can also be ordered. To order a customized Four-Quadrant Dynamometer/Power Supply, request Model 8960-C and add each desired optional function (8968-X).

LVDAC-EMS Software

The LVDAC-EMS software is a freeware which can be downloaded from website www.labvolt.com. It is a user-friendly tool that facilitates the use of the various functions which can be implemented with USB peripherals such as the Four-Quadrant Dynamometer/Power Supply, Model 8960-3, and the Data Acquisition and Control Interface, Model 9063.

The LVDAC-EMS software also includes a firmware update for the Four-Quadrant Dynamometer/Power Supply. When a Four-Quadrant Dynamometer/Power Supply is connected to a newer version of LVDAC-EMS, the user can easily update the module using a simple update wizard.

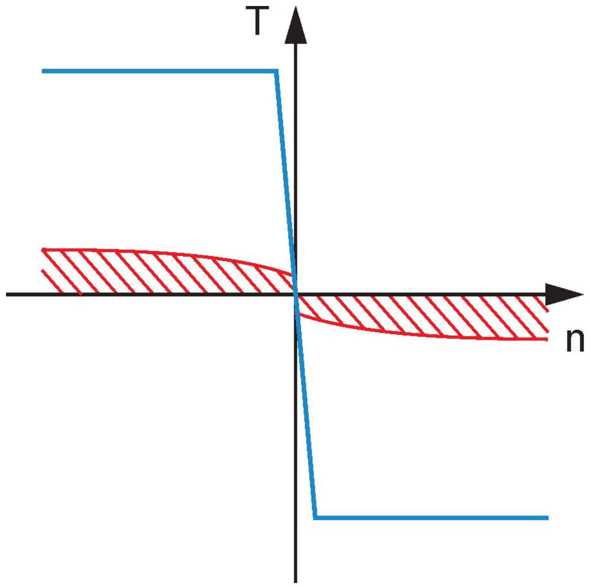
Using LVDAC-EMS with the Four-Quadrant Dynamometer/Power Supply provides access to the basic functions available in the Manual control mode plus a broad selection of advanced functions not available in the Manual control mode. Furthermore, extra information is provided for each control function. All parameters related to the function performed by the Four-Quadrant Dynamometer/Power Supply can be monitored using the computer-based instruments in LVDAC-EMS and exported to the LVDAC-EMS Data Table and Graph tool for further analysis.

Module Functions

The Four-Quadrant Dynamometer/Power Supply can perform a wide variety of functions in each of the two operating modes (Dynamometer and Power Supply). The standard functions available in each operating mode are described below. A table at the end of this section lists the standard functions available in each of the two control modes (Manual and Computer-Based).

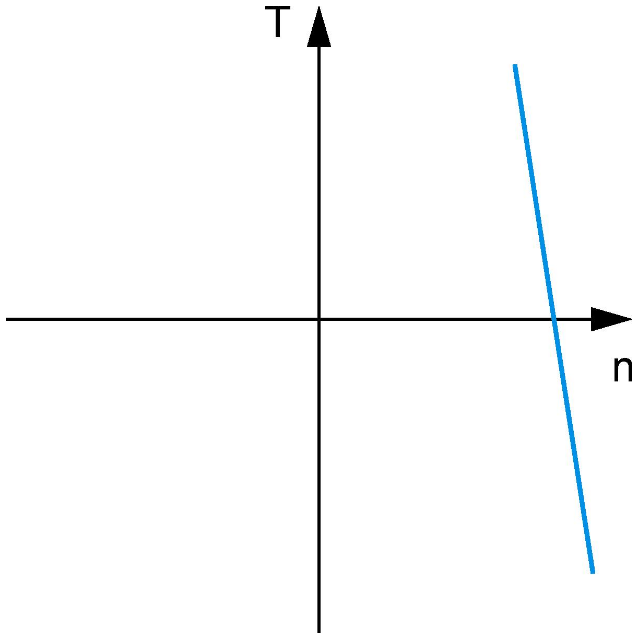
Function Description (Dynamometer Operating Mode)

Two-Quadrant, Constant-Torque Brake



This function makes the permanent-magnet dc machine operate as a generator to produce a constant opposition to the rotation of the machine coupled to the Four-Quadrant Dynamometer/Power Supply (i.e., the machine under test). Closed-loop control is used to maintain the opposition torque constant when the rotation speed changes. A torque command entered by the user determines the value (magnitude) of the torque opposing rotation of the machine under test. The function indicates the speed, torque, mechanical power, and energy measured at the shaft of the machine under test. The function can also indicate the machine temperature when the temperature sensor of the machine under test (if so equipped) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/ Power Supply.

Clockwise Prime Mover/Brake

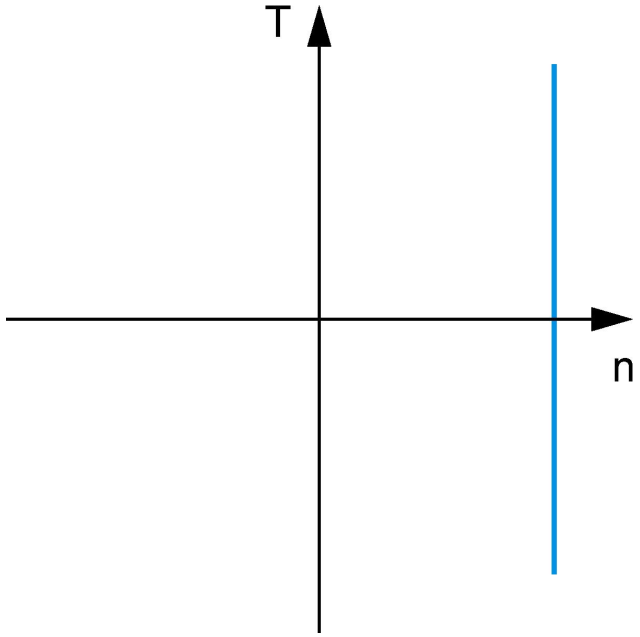


This function uses the permanent-magnet dc machine to make the machine coupled to the Four-Quadrant Dynamometer/Power Supply (i.e., the machine under test) rotate clockwise at a certain speed. A speed command entered by the user determines the no-load rotation speed of the machine under test. The function indicates the speed, torque, mechanical power, and energy measured at the shaft of the machine under test. The function can also indicate the machine temperature when the temperature sensor of the machine under test (if so equipped) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply. This function is well suited for the study of AC generator synchronization.

Counterclockwise Prime Mover/Brake

Same as the Clockwise Prime Mover/Brake function except for the direction of rotation.

Clockwise Constant-Speed Prime Mover/Brake

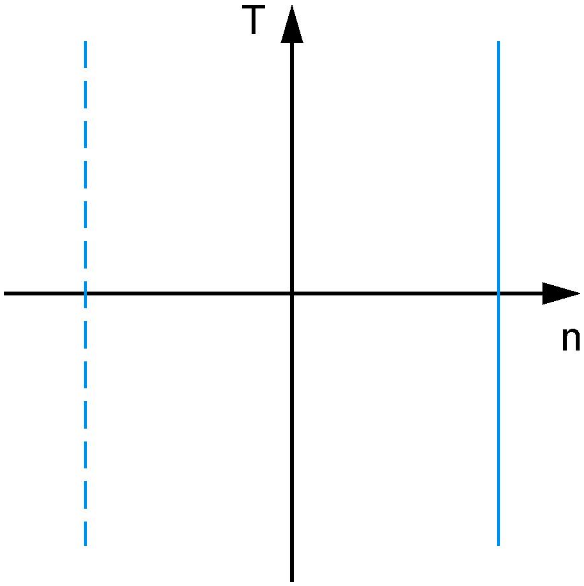


This function uses the permanent-magnet dc machine to make the machine coupled to the Four-Quadrant Dynamometer/Power Supply (i.e., the machine under test) rotate clockwise at a fixed speed. Closed-loop control is used to maintain the rotation speed constant under varying load conditions. A speed command entered by the user determines the rotation speed of the machine under test. The function indicates the speed, torque, mechanical power, and energy measured at the shaft of the machine under test. The function can also indicate the machine temperature when the temperature sensor of the machine under test (if so equipped) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply.

Counterclockwise Constant-Speed Prime

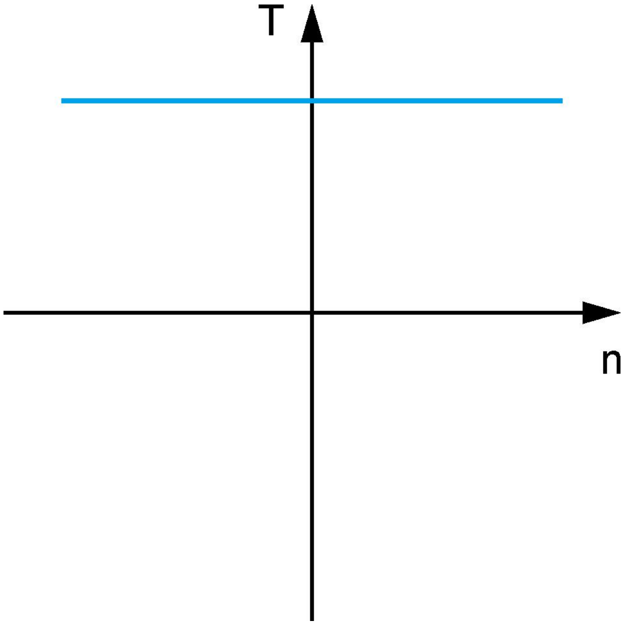
Mover/Brake Same as the Clockwise Constant-Speed Prime Mover/Brake except for the direction of rotation.

Four-Quadrant, Constant-Speed Prime Mover/Brake



This function uses the permanent-magnet dc machine to make the machine coupled to the Four-Quadrant Dynamometer/Power Supply (i.e., the machine under test) rotate at a fixed rotation speed. Closed-loop control is used to maintain the rotation speed constant under varying load conditions. A speed command entered by the user determines the value (direction and magnitude) of the speed at which the machine under test rotates. The function indicates the speed, torque, mechanical power, and energy measured at the shaft of the machine under test. The function can also indicate the machine temperature when the temperature sensor of the machine under test (if so equipped) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply.

Positive Constant-Torque Prime Mover/Brake



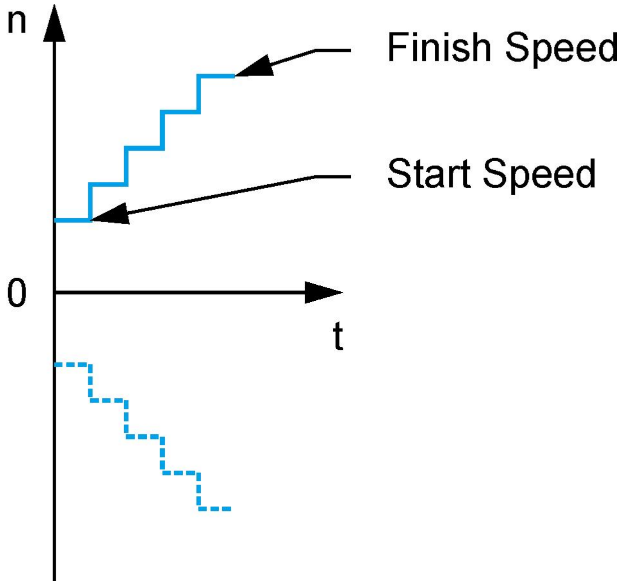
This function uses the permanent-magnet dc machine to apply a positive (i.e., applied in clockwise direction) constant torque to the machine coupled to the Four-Quadrant Dynamometer/Power Supply (i.e., the machine under test). Closed-loop control is used to maintain the torque constant as the rotation speed changes, no matter the machine under test operates as a motor or a brake (i.e., a generator). A torque command entered by the user determines the torque applied to the machine under test. The function indicates the speed, torque, mechanical power, and energy measured at the shaft of the machine under test. The function can also indicate the machine temperature when the temperature sensor of the machine under test (if so equipped) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply.

Negative Constant-Torque Prime Mover/Brake

Same as the Positive Constant-Torque Prime Mover/Brake except that the torque is negative (i.e., applied in counterclockwise direction).

Mechanical Load

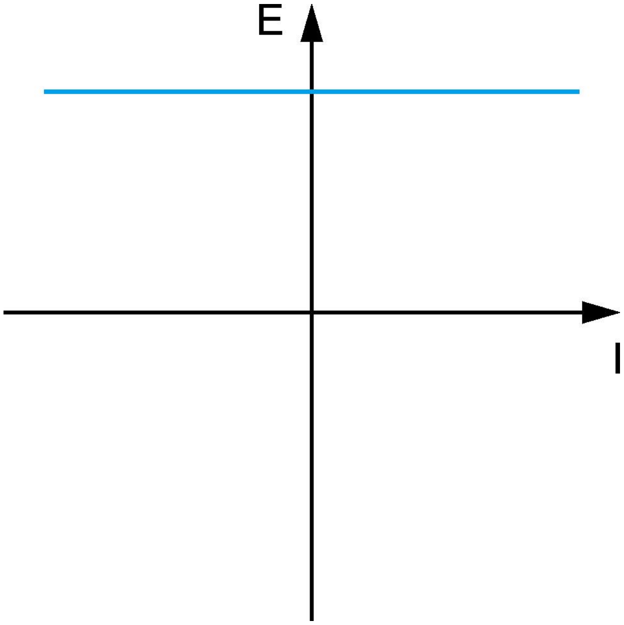
Speed Sweep



This function uses the permanent-magnet dc machine to make the machine coupled to the Four-Quadrant Dynamometer/Power Supply (i.e., the machine under test) rotate at various speeds within a specific range, in a certain number of steps and in a certain time interval. Closed-loop control is used to ensure accurate speed sweep. The speed sweep performed is defined entirely by the user with only four parameters (start speed, end speed, number of steps, and step duration). The function indicates the speed, torque, mechanical power, and energy measured at the shaft of the machine under test. The function can also indicate the machine temperature when the temperature sensor of the machine under test (if so equipped) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/ Power Supply. The Speed Sweep function is useful to measure how parameters related to the machine under test vary as a function of the rotation speed. The parameters measured throughout the speed sweep can be recorded to a data table automatically.

Function Description (Power Supply Operating Mode)

Positive Voltage Source

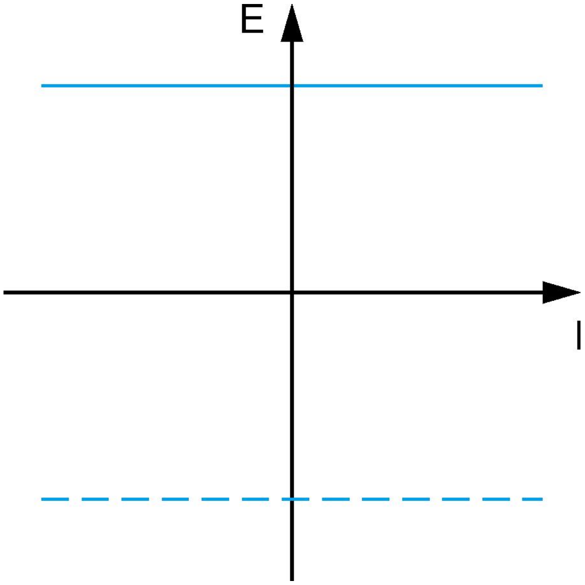


This function uses the four-quadrant power supply to implement a DC voltage source having a positive polarity. The source can either source or sink current (two-quadrant operation). A voltage command entered by the user determines the value of the source voltage. The function indicates the voltage, current, electrical power, and energy at the source output. The function can also indicate circuit temperature (e.g., battery temperature) when a temperature sensor is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply.

Negative Voltage Source

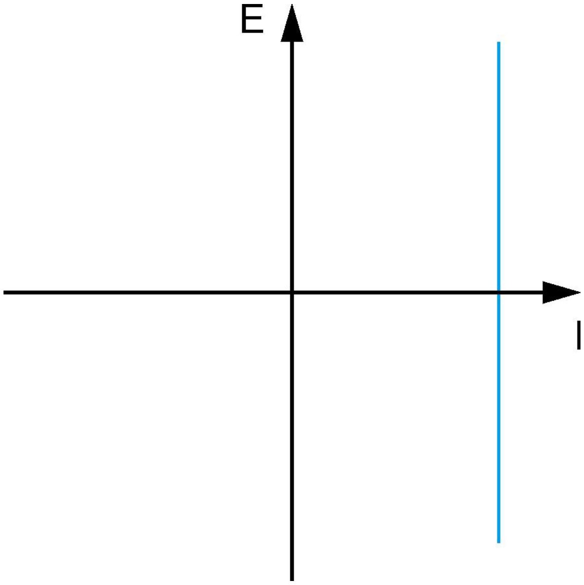
Same as the Positive Voltage Source function except for the polarity.

DC Voltage Source



This function uses the four-quadrant power supply to implement a DC voltage source having either positive or negative polarity. The source can either source or sink current no matter if the source voltage polarity is positive or negative (four-quadrant operation). A voltage command entered by the user determines the polarity and value of the source voltage. The function indicates the voltage, current, electrical power, and energy at the source output. The function can also indicate circuit temperature (e.g., battery temperature) when a temperature sensor is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply.

Positive Current Source

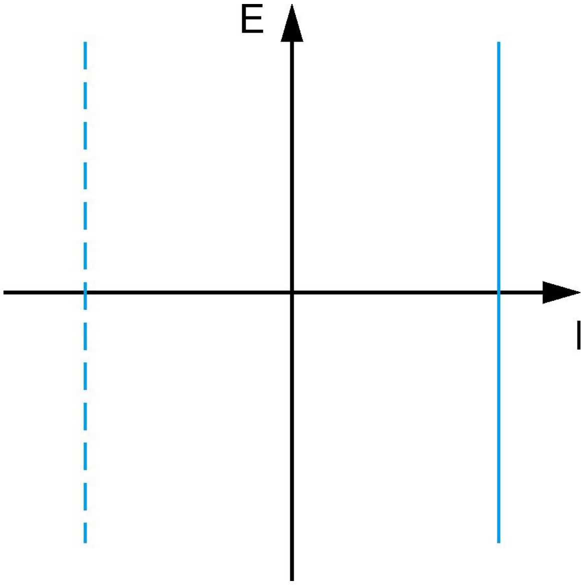


This function uses the four-quadrant power supply to implement a DC current source that sources current at its output. The polarity of the voltage across the source can be either positive or negative (two-quadrant operation). A current command entered by the user determines the value of the source current. The function indicates the voltage, current, electrical power, and energy at the source output. The function can also indicate circuit temperature (e.g., battery temperature) when a temperature sensor is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply.

Negative Current Source

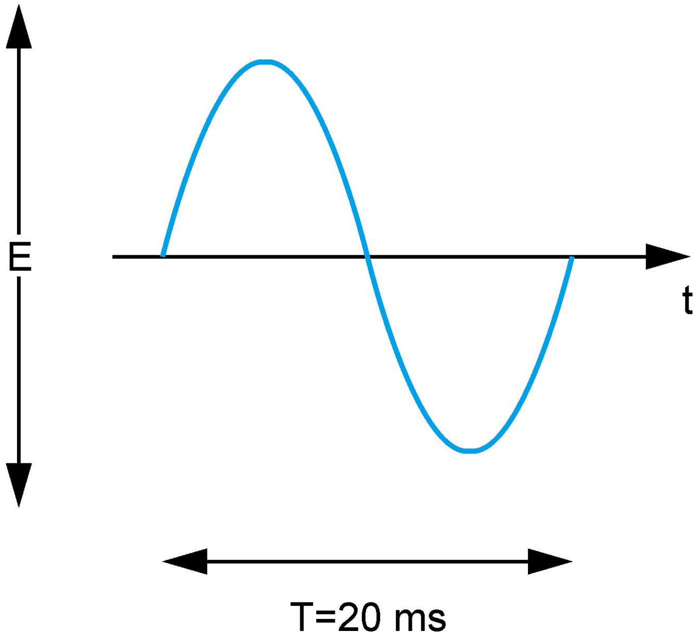
Same as the Positive Current Source function except for the direction of current flow.

DC Current Source



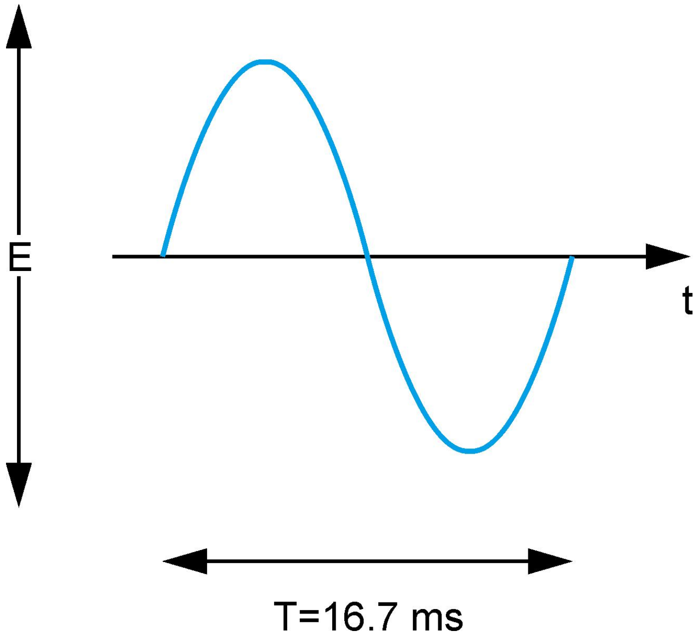
This function uses the four-quadrant power supply to implement a DC current source that either sources current (positive polarity) or sinks current (negative polarity) at its output. The polarity of the voltage across the source can be either positive or negative no matter the direction of the source current (four-quadrant operation). A current command entered by the user determines the direction (polarity) and value of the source current. The function indicates the voltage, current, electrical power, and energy at the source output. The function can also indicate circuit temperature (e.g., battery temperature) when a temperature sensor is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply.

50 Hz Power Source



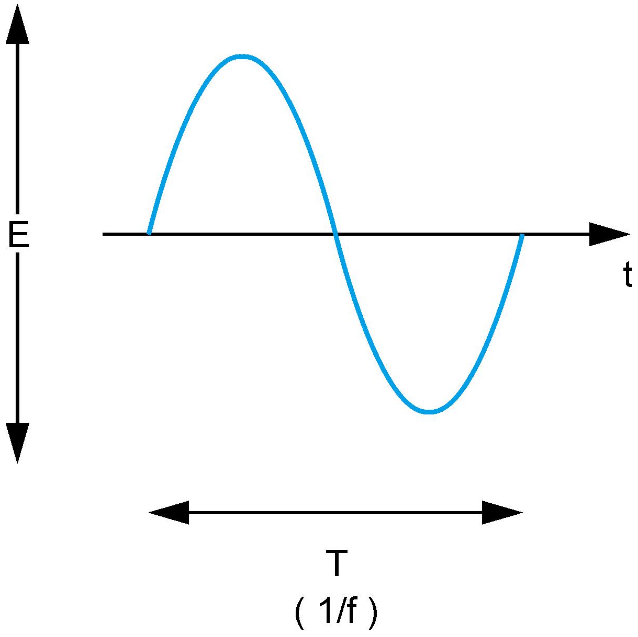
This function uses the four-quadrant power supply to implement a non-regulated variable-voltage 50 Hz power source. A voltage command entered by the user determines the rms value of the "no-load" source voltage. The source can either source or sink current no matter if the source voltage polarity (instantaneous) is positive or negative (four-quadrant operation). The function indicates the circuit temperature (e.g., transformer core temperature) when a temperature sensor is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply.

60 Hz Power Source



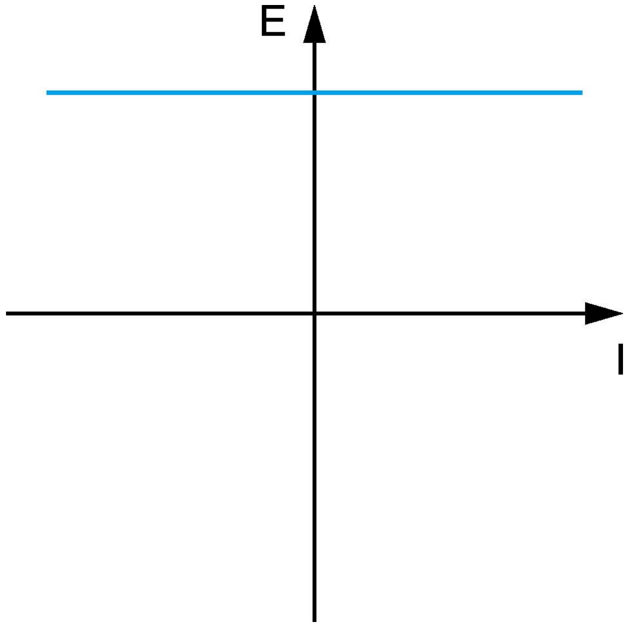
Same as the 50 Hz Power Source function except for the frequency.

AC Power Source



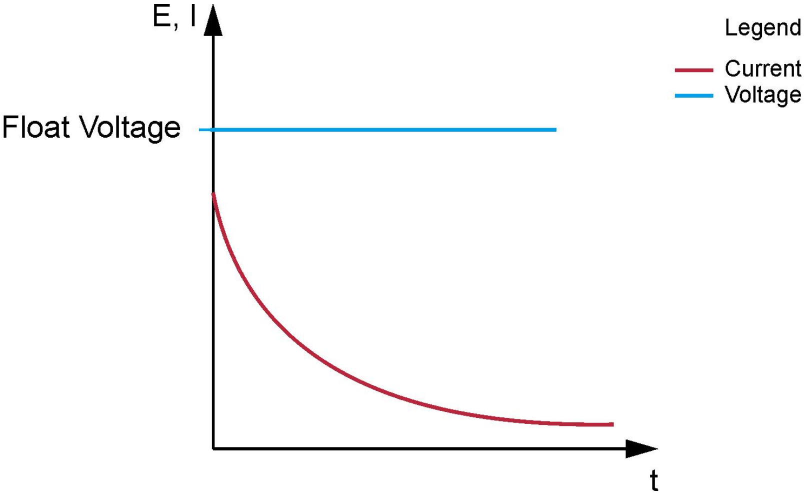
This function uses the four-quadrant power supply to implement a non-regulated variable-voltage, variable-frequency AC power source. The source can either source or sink current no matter if the source voltage polarity (instantaneous) is positive or negative (four-quadrant operation). Voltage and frequency commands entered by the user determine the rms value and frequency of the "no-load" source voltage. The function indicates the circuit temperature (e.g., transformer core temperature) when a temperature sensor is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply.

200 V DC Bus



This function uses the four-quadrant power supply to implement a fixed-voltage dc bus of 200 V. The dc bus can either source or sink current (two-quadrant operation). The function indicates the voltage, current, and power at the source output.

Lead-Acid Battery Float Charger



This function uses the four-quadrant power supply to implement a lead-acid battery float charger. This charger applies a constant voltage to the battery. The user only has to specify the battery float charging voltage. The function indicates the voltage, current, and electrical power at the charger output. The Lead-Acid Battery Float Charger function is well suited to charge several lead-acid batteries connected in parallel overnight so they are ready for next-day lab sessions.

Control Functions	Control Mode	
	Manual (Stand-Alone)	Computer-Based (LVDAC-EMS)
Dynamometer Operating Mode		
Two-Quadrant, Constant-Torque Brake	●	●
Clockwise Prime Mover/Brake	●	●
Counterclockwise Prime Mover/Brake	●	●
Clockwise Constant-Speed Prime Mover/Brake	●	●
Counterclockwise Constant-Speed Prime Mover/Brake	●	●
Positive Constant-Torque Prime Mover/Brake	●	●
Negative Constant-Torque Prime Mover/Brake	●	●
Four-Quadrant, Constant-Speed Prime Mover/Brake		●
Mechanical Load		●
Speed Sweep		●
Power Supply Operating Mode		
Positive Voltage Source	●	●
Negative Voltage Source	●	●
DC Voltage Source		●
Positive Current Source	●	●
Negative Current Source	●	●
DC Current Source		●
50 Hz Power Source	●	●
60 Hz Power Source	●	●
AC Power Source		●
200 V DC Bus	●	●
Lead-Acid Battery Float Charger	●	●

Standard control functions available in Power Supply mode.

Optional Module Functions

The Four-Quadrant Dynamometer/Power Supply can perform a wide variety of functions in each of the two operating modes (Dynamometer and Power Supply). The optional functions currently available in each operating mode are described below. The license (Model 8968-X) required to activate each optional function is also indicated. A table at the end of this section lists the optional functions available. All optional functions can be accessed through the computer-based control mode only.

This emulator enables the study of synchronous generation in small and large-scale hydraulic installations. The license for the Turbine Emulator, Model 8968-3, is required to activate the function in the Four-Quadrant Dynamometer/Power Supply.

Optional Function Description (Dynamometer Operating Mode)

Small Wind-Turbine Emulator, Model 8968-3

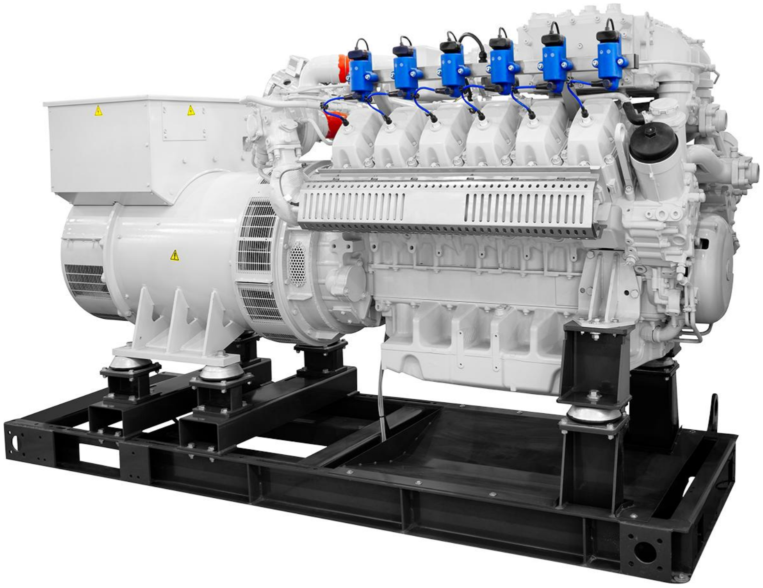
This function uses the permanent-magnet dc machine to faithfully reproduce the effect of wind on the bladed rotor of a small-scale wind turbine (3 blade rotor, fixed pitch, 1.15 m [46 in] diameter). The torque-speed characteristic at the shaft of the machine coupled to the Four-Quadrant Dynamometer/Power Supply (e.g., the wind turbine generator in the Wind Turbine Generator/Controller, Model 8216) is the same as the one that is obtained when wind blows at a certain speed on the rotor of the actual wind turbine. The user has control over the windspeed and air density. The function indicates the speed, torque, mechanical power, and energy measured at the shaft of the wind turbine generator. The function can also indicate the generator temperature when the temperature sensor of the wind turbine generator under test (if so equipped) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply. The Small Wind-Turbine Emulator function makes the study of wind turbine generator operation independent of weather conditions (you do not have to wait for wind) and much safer as there is no rotating bladed rotor (a potential cause of injuries). The license for the Turbine Emulator, Model 8968-3, is required to activate the function in the Four-Quadrant Dynamometer/Power Supply.

Hydraulic Turbine Emulator, Model 8968-3

This function uses the permanent-magnet dc machine to recreate the behavior of a hydraulic turbine with a synchronous generator. The torque-speed characteristics at the shaft of the machine coupled to the Four-Quadrant Dynamometer/Power Supply (e.g. the Synchronous Generator, Model 8241) is the same as that of a Francis-type hydraulic turbine. The user has control over the vane angle (manually or through the module analog input), the vane variation speed, and the inertia.

This emulator enables the study of synchronous generation in small and large-scale hydraulic installations. The license for the Turbine Emulator, Model 8968-3, is required to activate the function in the Four-Quadrant Dynamometer/Power Supply.

Engine Emulator, Model 8968-3

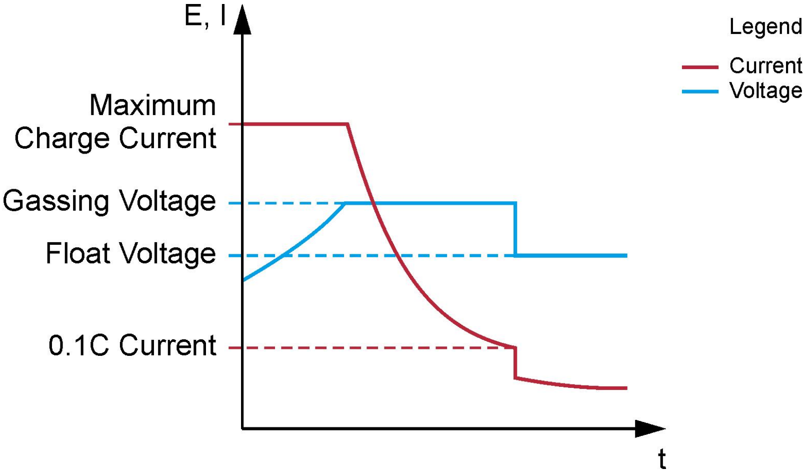


This function uses the four-quadrant dynamometer to recreate the behavior of an engine (such as a diesel-powered engine) with a synchronous generator. The torque-speed characteristics at the shaft of the machine coupled to the Four-Quadrant Dynamometer/Power Supply (e.g. the Synchronous Generator, Model 8241) is the same as that of the selected engine type. The user has control over parameters relevant to the engine type, such as the fuel rack position in a diesel engine.

This emulator enables the study of various engine types in the production of electricity. The license for the Turbine Emulator, Model 8968-3, is required to activate the function in the Four-Quadrant Dynamometer/Power Supply.

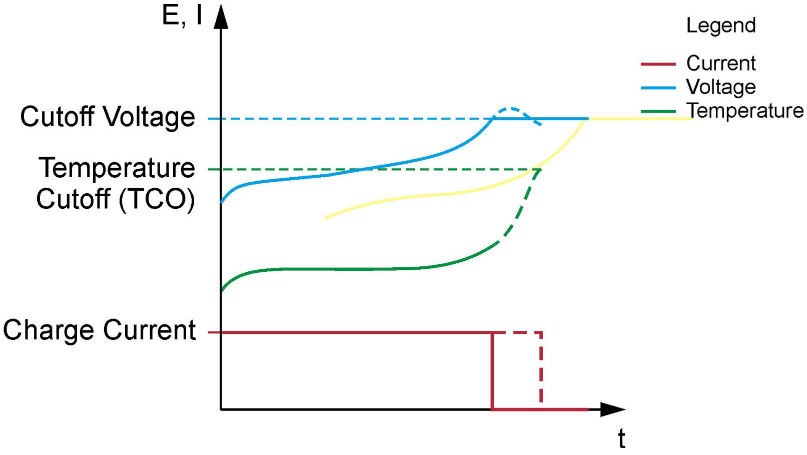
Optional Function Description (Power Supply Operating Mode)

Lead-Acid Battery Charger (Fast), Model 8968-4



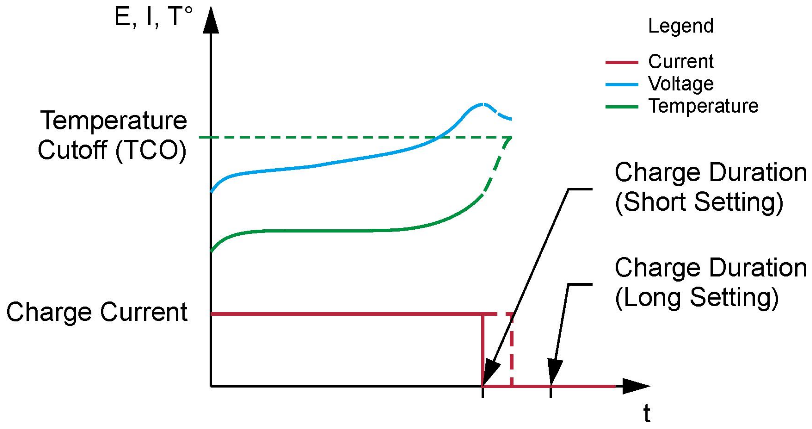
This function uses the four-quadrant power supply to implement a battery charger that is able to rapidly charge lead-acid batteries of various capacities (typically in less than two hours). A three-step charge algorithm is used. Battery charging starts with a constant current corresponding to the battery maximum charge current until the battery gassing voltage is reached. At this point, battery charging continues with a constant voltage (close to gassing voltage) until the charge current decreases to 0.1 C. Then, constant-voltage charging continues but at a lower voltage (float charging voltage). The user has to specify the following four battery characteristics for the charger to achieve proper charge control: maximum charge current, gassing voltage, 0.1C current (10% of battery capacity), and float charging voltage. The function indicates the voltage, current, electrical power, and energy at the charger output. The function can also indicate battery temperature when the temperature sensor of the battery (if so equipped) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply. The function can also indicate battery temperature when the temperature sensor of the battery (if so equipped) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply. The license for the Lead-Acid Battery Charger, Model 8968-4, is required to activate the Lead-Acid Battery Charger (Fast) function in the Four-Quadrant Dynamometer/Power Supply.

Ni-MH Battery Charger (Constant-Current Charge with Voltage Cutoff and TCO), Model 8968-5



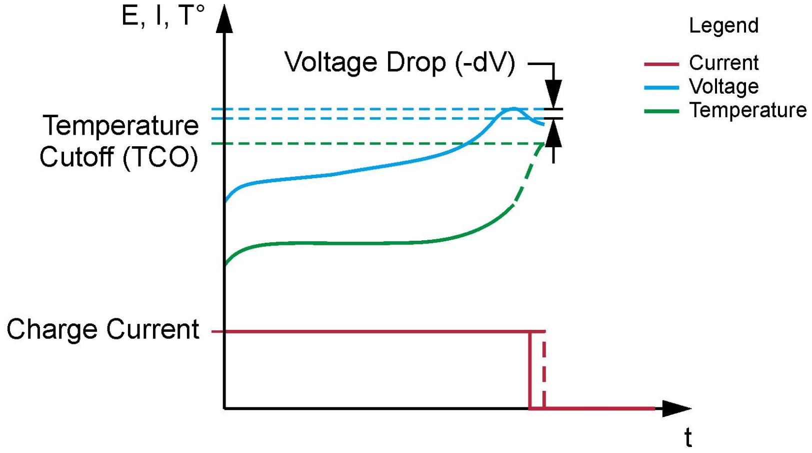
This function uses the four-quadrant power supply to implement a basic Ni-MH battery charger. This charger forces a constant charge (current value of 0.1C or less) in the battery until the battery voltage reaches a certain value at which the charge terminates. The charger also monitors the battery temperature during charge. Battery charging is terminated immediately when the battery temperature reaches a specific cutoff temperature. The user has to specify the charge current, cutoff voltage, and cutoff temperature for the charger to achieve proper charge control. The function indicates the voltage, current, electrical power, and energy at the charger output as well as the battery temperature. This method of charging Ni-MH batteries is the slowest one but requires less surveillance. The license for the Ni-MH Battery Chargers, Model 8968-5, is required to activate the Ni-MH Battery Charger (Constant-Current Charge with Voltage Cutoff and TCO) function in the Four-Quadrant Dynamometer/Power Supply.

Ni-MH Battery Charger (Constant-Current Timed Charge with TCO), Model 8968-5



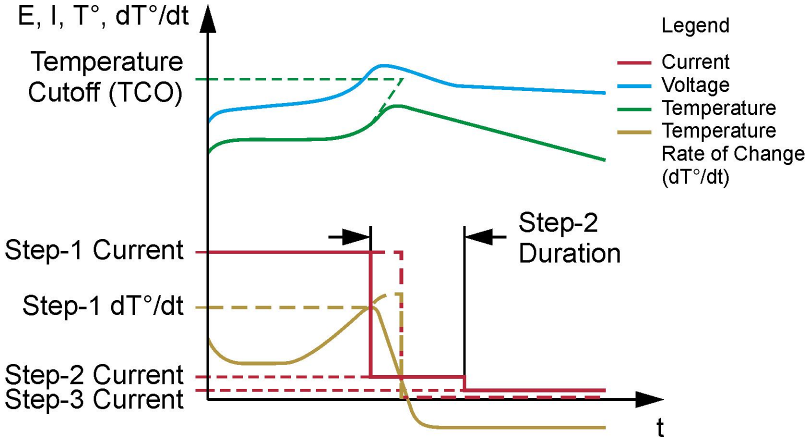
This function uses the four-quadrant power supply to implement a time-controlled Ni-MH battery charger. This charger forces a constant charge current in the battery during a specific period of time and then turns off. The charger also monitors the battery temperature during charge. Battery charging is terminated immediately when the battery temperature reaches a specific cutoff temperature. The user has to specify the charge current, charge duration, and cutoff temperature for the charger to achieve proper charge control. The function indicates the voltage, current, electrical power, and energy at the charger output as well as the battery temperature. The license for the Ni-MH Battery Chargers, Model 8968-5, is required to activate the Ni-MH Battery Charger (Constant-Current Timed Charge with TCO) function in the Four-Quadrant Dynamometer/Power Supply.

Ni-MH Battery Charger (Constant-Current Charge with -dV and TCO), Model 8968-5



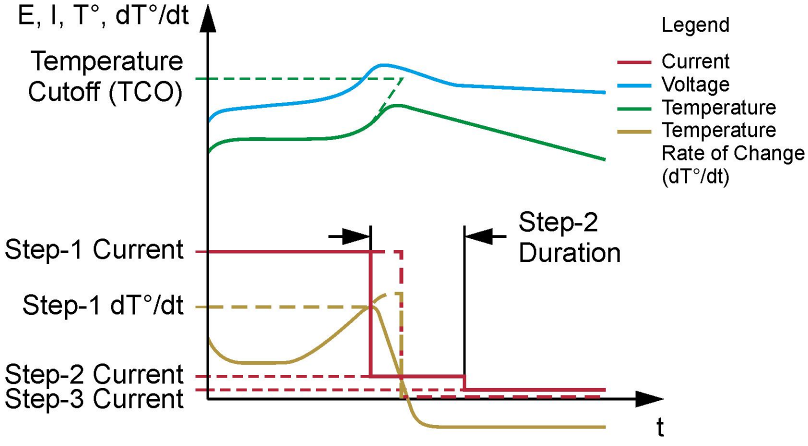
This function uses the four-quadrant power supply to implement an advanced Ni-MH battery charger. This charger forces a constant charge current in the battery until the battery voltage, which increases steadily from the beginning of charge, reaches a plateau and decreases by a certain amount (-dV), at which point the charge terminates. The charger also monitors the battery temperature during charge. Battery charging is terminated immediately when the battery temperature reaches a specific cutoff temperature. The user has to specify the charge current, voltage drop (-dV), and cutoff temperature for the charger to achieve proper charge control. The function indicates the voltage, current, electrical power, and energy at the charger output as well as the battery temperature. The license for the Ni-MH Battery Chargers, Model 8968-5, is required to activate the Ni-MH Battery Charger (Constant-Current Charge with -dV and TCO) function in the Four-Quadrant Dynamometer/Power Supply.

Ni-MH Battery Charger (Constant-Current Charge with dT°/dt and TCO), Model 8968-5



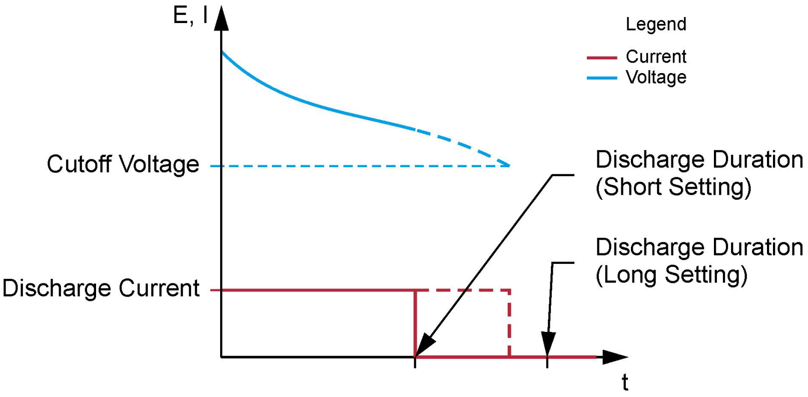
This function uses the four-quadrant power supply to implement an advanced Ni-MH battery charger. This charger monitors the battery temperature and forces a constant charge current in the battery until the rate of increase of the battery temperature (dT°/dt) reaches a specific value, at which point the charge terminates. Battery charging can also terminate when the battery temperature reaches a specific cutoff temperature. The user has to specify the charge current, maximum rate of temperature increase (dT°/dt), and cutoff temperature for the charger to achieve proper charge control. The function indicates the voltage, current, electrical power, and energy at the charger output as well as the battery temperature. The license for the Ni-MH Battery Chargers, Model 8968-5, is required to activate the Ni-MH Battery Charger (Constant-Current Charge with dT°/dt and TCO) function in the Four-Quadrant Dynamometer/Power Supply.

Ni-MH Battery Charger (three-step Charge with TCO), Model 8968-5



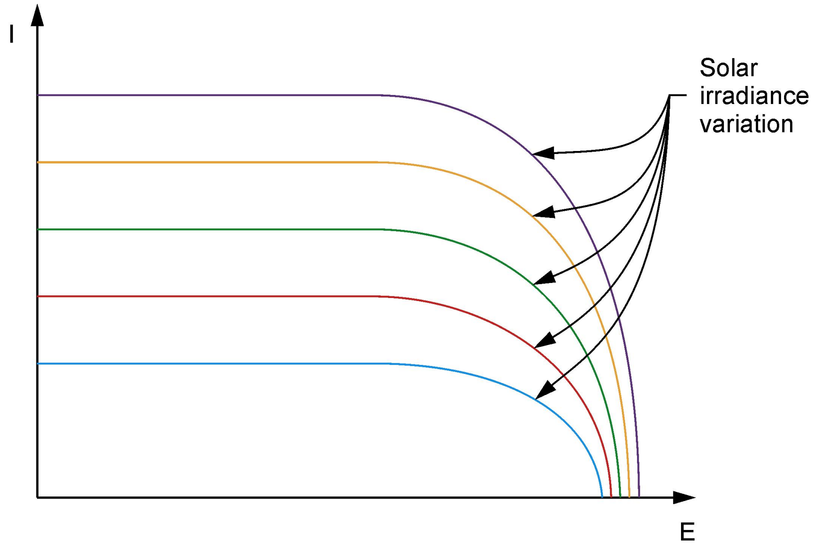
This function uses the four-quadrant power supply to implement a fast Ni-MH battery charger (three-step charge algorithm). Battery charging begins by forcing a constant charge current (about 1C) in the battery until the rate of increase of the battery temperature (dT°/dt) reaches a specific value. At this point, the charger enters the second phase of the charge process and continues battery charging with a constant current having a lower value (about 0.1 C) for a specific period. After this period, battery charging continues with a constant current of very low value (about 0.03 C). The charger monitors the battery temperature during charge. Battery charging can also terminate when the battery temperature reaches a specific cutoff temperature. The user has to specify the following parameters for the charger to achieve proper charge control: charge current for each of the three phases of the charging process, maximum rate of temperature increase (dT°/dt) used during the first phase of charge, duration of the second phase of charge, and cutoff temperature. The function indicates the voltage, current, electrical power, and energy at the charger output as well as the battery temperature. The license for the Ni-MH Battery Chargers, Model 8968-5, is required to activate the Ni-MH Battery Charger (3-Step Charge with TCO) function in the Four-Quadrant Dynamometer/Power Supply.

Battery Discharger (Constant-Current Timed Discharge with Voltage Cutoff), Model 8968-4 or Model 8968-5



This function uses the four-quadrant power supply to sink a constant current from a battery, thereby discharging the battery at a specific rate, during a specific period. The discharger also monitors the battery voltage during discharge. Battery discharging terminates immediately when the battery voltage decreases to a specific cutoff voltage. The user has to specify the discharge current, discharge duration, and cutoff voltage for the discharger to achieve proper discharge control. The function indicates the voltage, current, electrical power, and energy at the discharger output. The function can also indicate battery temperature when the temperature sensor of the battery (if so equipped) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply. The Battery Discharger function is perfectly suited to measure discharge characteristics of batteries at various rates as well as to bring a battery to a specific depth of discharge before a battery charging experiment. The license for the Lead-Acid Battery Charger, Model 8968-4, or the license for the Ni-MH Battery Chargers, Model 8968-5, is required to activate the Battery Discharger (Constant-Current Timed Discharge with Voltage Cutoff) function in the Four-Quadrant Dynamometer/Power Supply.

Solar Panel Emulator, Model 8968-6



This function uses the four-quadrant power supply to emulate a solar panel consisting of an array of photovoltaic (PV) modules. The current-voltage characteristic of each PV module emulated is the same as that of the PV module used in the Monocrystalline Silicon Solar Panel, Model 8806. The function allows the user to determine the size of the PV module array emulated, by selecting the number of PV modules connected in series and in parallel. A sliding control in the Solar Panel Emulator interface provides the user full control of solar irradiance. The function indicates the voltage, current, power, and energy provided by the Solar Panel Emulator. The function can also indicate temperature when a temperature sensor is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply. The Solar Panel Emulator function makes the study of electricity production using solar panels independent of weather conditions (you do not have to wait for sunny periods). The license for the Solar Panel Emulator, Model 8968-6, is required to activate the function in the Four-Quadrant Dynamometer/Power Supply.

Software Development Kit (SDK), Model 8968-70

The Software Development Kit offers the possibility to control the Four-Quadrant Dynamometer/Power Supply, Model 8960-3, with third-party rapid prototyping software like Mathworks® MATLAB, National Instruments® LabVIEW or other programming tools that support Microsoft® .NET Framework 3.5. The functions available in the Software Development Kit allow control of the Four-Quadrant Dynamometer/Power Supply in both the Dynamometer and Power Supply operating modes.

The SDK includes DLL files to communicate with the Four-Quadrant Dynamometer/Power Supply, functions documentation, MATLAB (2010 or later) and LabVIEW (2009 or later) example programs.

Available functions in the Dynamometer Operating Mode:

- Two-Quadrant, Constant Torque Brake
- CW and CCW, Prime Mover/Brake
- CW and CCW, Constant-Speed Prime Mover/Brake
- Positive and Negative, Constant-Torque Prime Mover/Brake
- Four-Quadrant, Constant-Speed Prime Mover/Brake

Available functions in the Power Supply Operating Mode:

- Voltage Control
- Current Control
- AC Power Source

Important note: A Software Development Kit must be ordered for each Four-Quadrant Dynamometer/Power Supply, Model 8960-3, to unlock the SDK features.

Optional Control Functions	**Control Mode**	
	Manual (Stand-Alone)	**Computer-Based (LVDAC-EMS)**
Dynamometer Operating Mode		
Small Wind-Turbine Emulator		X
Hydraulic and Diesel Turbine Emulators		X
Power Supply Operating Mode		
Lead-Acid Battery Charger (Fast)		X
Ni-MH Battery Charger (Constant-Current Charge with Voltage Cutoff and TCO)		X
Ni-MH Battery Charger (Constant-Current Timed Charge with TCO)		X
Ni-MH Battery Charger (Constant-Current Charge with -ΔV and TCO)		X
Ni-MH Battery Charger (Constant-Current Charge with ΔT°/Δt and TCO)		X
Ni-MH Battery Charger (Three-Step Charge with TCO)		X
Battery Discharger (Constant-Current Timed Discharge with Voltage Cutoff)		X
Solar Panel Emulator		X

Optional module functions available in each control mode.

Topic Coverage

- Speed and Torque
- Voltage and Current
- Mechanical and Electrical Power
- Energy

Features & Benefits

- State-of-the-art, multipurpose device combining power supply, prime mover, dynamometer, metering and emulator properties
- USB port computer-based mode allows the user to completely control every function directly from the computer
- Supports learning of electromechanical and renewable energy
- Can be connected with other EMS equipment to enhance the training possibilities

Data Acquisition and Control Interface
579677 (9063-00)

The Data Acquisition and Control Interface (DACI) is a versatile USB peripheral used for measuring, observing, analyzing, and controlling electrical and mechanical parameters in electric power systems and power electronics circuits. For these purposes, a set of computer-based instruments as well as a variety of control functions are available for the DACI. These instruments and control functions are accessed through the LVDAC-EMS software. The LVDAC-EMS software, as well as all available upgrades, is free and can be downloaded anytime on the Festo Didactic website.

Together, the DACI and the LVDAC-EMS software allow training in various areas such as electric power technology, ac/dc machines, renewable energy, transmission lines, and power electronics using modern and versatile measuring instruments and control functions. LVDAC-EMS also offers the possibility to use pre-built SCADA interfaces for several applications to ease the view and understanding of the process taking place. The user guide provided allows students to quickly become familiar with the instruments and control functions available.

Model 9063-0 includes only the DACI, Model 9063, with no control function set activated. This enables the user to customize the DACI by individually picking the computer-based instruments and control function sets that he wants to activate in the DACI.

Alternately, variant 9063-0 is also used in several courses as an extension module. This means that it is used in conjunction to another DACI in which particular control function sets are activated. Both DACIs are connected to a single computer running LVDAC-EMS. When used in such a way, variant 9063-0 shares all control function sets activated in the other DACI. For example, if the Computer-Based Instrumentation Function, Model 9069-1, and the Three-Phase PWM Rectifier/Inverter Control Function Set, Model 9069-5, are activated in the other DACI, these function sets will also be available in variant 9063-0. This enables the user to perform courses requiring the use of more than one DACI without having to activate the same control function sets in all DACIs.

Manual

Description	Manual number
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)

Table of Contents of the Manual(s)

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

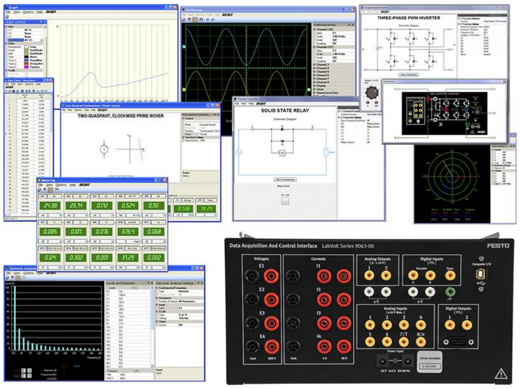
- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer

- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Personal Computer	579785 (8990-00) [103]

Data Acquisition and Control Interface
579680 (9063-B0)



The Data Acquisition and Control Interface (DACI) is a versatile USB peripheral used for measuring, observing, analyzing, and controlling electrical and mechanical parameters in electric power systems and power electronics circuits. For these purposes, a set of computer-based instruments as well as a variety of control functions are available for the DACI. These instruments and control functions are accessed through the LVDAC-EMS software. The LVDAC-EMS software, as well as all available upgrades, is free and can be downloaded anytime on the Festo Didactic website.

Together, the DACI and the LVDAC-EMS software allow training in various areas such as electric power technology, ac/dc machines, renewable energy, transmission lines, and power electronics using modern and versatile measuring instruments and control functions. LVDAC-EMS also offers the possibility to use pre-built SCADA interfaces for several applications to ease the view and understanding of the process taking place. The user guide provided allows students to quickly become familiar with the instruments and control functions available.

This model includes the function set "Computer-Based Instrumentation Function".

Manual

Description	Manual number
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)

Table of Contents of the Manual(s)

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

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[103] Refer to the Computer Requirements in the System Specifications section of this datasheet if the computer is to be provided by the end-user. Only one computer is required per station. This model is available in multiple voltage- and frequency dependent variants. Contact a Festo representative to obtain the correct part number.

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	AC 24 V Wall Mount Power Supply	579698 (30004-2A) [104]

Software

Qty	Description	Model number
1	SCADA for LVDAC-EMS	8094377 (8973-00) [105]
1	Complete Function Set	581451 (9069-00)
1	Chopper/Inverter Control Function Set	581453 (9069-20)
1	Thyristor Control Function Set	581454 (9069-30)
1	Home Energy Production Control Function Set	581455 (9069-40)
1	Three-Phase PWM Rectifier/Inverter Control Function Set	581456 (9069-50)
1	BLDC Motor/PMSM Control Function Set	581457 (9069-60)
1	High-Voltage DC (HVDC) Transmission System Control Function Set	579790 (9069-70)
1	Static Var Compensator (SVC) Control Function Set	581458 (9069-80)
1	Software Development Kit (SDK)	581459 (9069-90) [106]
1	Synchronous Generator Control Function Set	579788 (9069-A0)
1	Static Synchronous Compensator (STATCOM) Control Function Set	581460 (9069-B0)
1	Synchroscope Function	579789 (9069-C0)
1	Doubly-Fed Induction Generator (DFIG) Control Function Set	587056 (9069-D0)
1	Power Line Series Compensation Function Set	581461 (9069-S0)

Specifications

Parameter	Value
Insulated Voltage Inputs (4)	
Range (Low / High Scales)	-80 to +80 V / -800 to + 800 V (user-selectable through software)
Impedance (Low / High Scales)	326.6 kΩ / 3.25 MΩ
Bandwidth	DC to 65 kHz (-3 dB)
Accuracy	1% (dc to 10 kHz)
Insulation	800 V
Maximum Voltage (Any Terminal vs GND)	283 V ac / 400 V dc
Measurement Category	CAT II (283 V ac/400 V dc versus ground)
Insulated Current Inputs (4)	
Range (Low / High Scales)	-4 to +4 A / -40 to + 40 A (25 A rms)
Impedance (Low / High Scales)	5 mΩ / 50 mΩ
Bandwidth	DC to 65 kHz (-3 dB)
Accuracy	1% (dc to 10 kHz)
Insulation	800 V
Maximum Voltage (Any Terminal vs GND)	283 V ac / 400 V dc
Measurement Category	CAT II (283 V ac/400 V dc versus ground)
Analog Inputs (8)	
Voltage Range	-10 to +10 V
Impedance	> 10 MΩ
Bandwidth	DC to 125 kHz
Measured Parameters	User-selectable through software
Parameter-to-Voltage Ratio	User-determined through software
A/D Converter for Insulated and Analog Inputs (16)	
Type	Successive approximation

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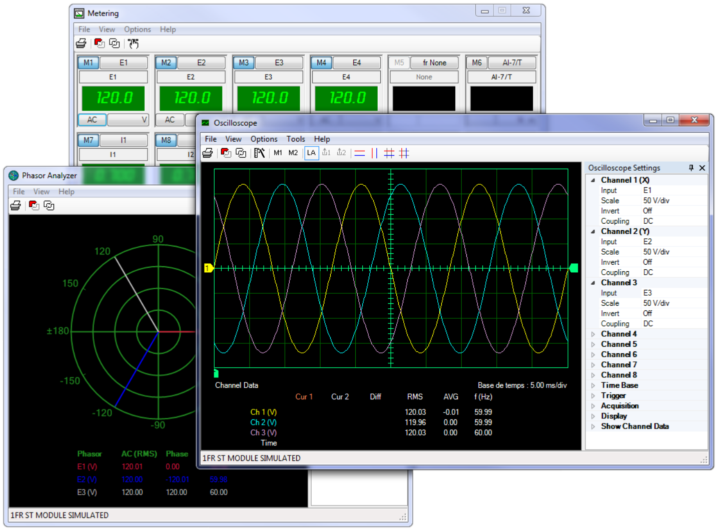
[104] Not required if another 24 VAC source is included, such as the variable three-phase power supply.

[105] Software allowing the monitoring of up to 5 Stations through OPC.

[106] For MatLab, LabView, etc.

Parameter	Value
Resolution	12 bits
Integral Non-Linearity	≤ ±1.5 LSB
Differential Non-Linearity	≤ ±1 LSB
Maximum Sampling Rate	600 ksamples/s (one channel)
FIFO Buffer Size	16 ksamples
Analog Outputs (2)	
Voltage Range	-10 to +10 V
Operational Load Impedance	> 600 Ω
D/A Converter for Analog Outputs (2)	
Type	Resistor string
Resolution	12 bits
Integral Non-Linearity	≤ ±8 LSB
Differential Non-Linearity	-0.5 to +0.7 LSB
Digital Inputs (3)	
Types	Encoder (2), synchronization (1)
Signal Level	0-5 V (TTL compatible)
Maximum Input Frequency	50 kHz
Impedance	5 kΩ
Digital Outputs (9)	
Types	Control (6 on a DB9 connector and 2 on 2 mm banana jacks), synchronization (1 on a DB9 connector)
Signal Level	0-5 V (TTL compatible)
Maximum Output Frequency	20 kHz (software-limited)
Impedance	200 Ω
Control Functions	
Activated Set	Computer-Based Instrumentation Function, Model 9069-1
Computer I/O Interface	USB 2.0 full speed via type-B receptacle
Power Requirements	24 V - 0.4 A - 50/60 Hz
Accessories	
Included Accessories	2 m USB interconnection cable (1)
	24 V power cable (1)
	2 mm banana plug test leads (3)
	DB9 connector control cable (1)
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 410 mm (6.1 x 11.3 x 16.1 in)
Net Weight	3.9 kg (8.6 lb)

Acquisition functions
581452 (9069-10)



Oscilloscope Settings

Channel 1 (X)
Input E1
Scale 50 V/div
Invert Off
Coupling DC
Channel 2 (Y)
Input E2
Scale 50 V/div
Invert Off
Coupling DC
Channel 3
Input E3
Scale 50 V/div
Invert Off
Coupling DC
Channel 4
Channel 5
Channel 6
Channel 7
Channel 8
Time Base
Trigger
Acquisition
Display
Show Channel Data

Channel Data

Base de temps : 5.00 ms/div

	Cur 1	Cur 2	Diff	RMS	AVG	f (Hz)
Ch 1 (V)				120.03	-0.01	59.99
Ch 2 (V)				119.96	0.00	59.99
Ch 3 (V)				120.03	0.00	60.00
Time						

Phasor	AC (RMS)	Phase	
E1 (V)	120.01	0.00	
E2 (V)	120.00	-120.01	59.98
E3 (V)	120.00	120.00	60.00

1FR ST MODULE SIMULATED

1FR ST MODULE SIMULATED

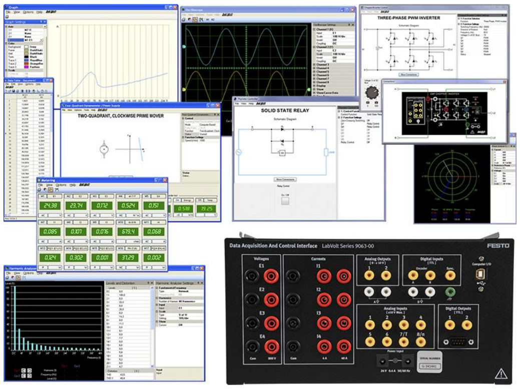
The Computer-Based Instrumentation Function Set, includes the following computer-based instruments:

- Metering
- Data Table and Graph
- Oscilloscope
- Phasor Analyzer
- Harmonic Analyzer

Specifications

Parameter	Value
Metering	
Number of Meters	18
Sampling Window	266.7 ms or user adjusted through software (11.4-819 ms)
Sampling Frequency (each meter)	7.68 kHz or user adjusted through software (2.5-179.2 kHz)
Display Type	Digital or analog, user selectable through software
Oscilloscope	
Number of Channels	8
Vertical Sensitivity	2-500 V/div.
Time Base	0.0001-10 s/div.
Sampling Window	20 x selected time base (software triggering) / 10 x selected time base (hardware triggering)
Sampling Frequency	512 samples per measured parameter per horizontal sweep, up to a maximum of 512 kHz
Phasor Analyzer	
Voltage Sensitivity	2-200 V/div.
Current Sensitivity	0.1-5 A/div.
Sampling Window	2-409 ms
Sampling Frequency (Each Phasor)	5-102.4 kHz
Harmonic Analyzer	
Fundamental-Frequency Range	1-1400 Hz
Number of Harmonic Components	5 to 40, user selectable through software
Vertical Scale (Relative Scale)	0.1-10%/div.
Vertical Scale (Absolute Scale)	0.1-50 V/div., 0.01-10 A/div.
Sampling Window	10 ms to 1 s
Sampling Frequency	16-102 kHz

Data Acquisition and Control Interface
579683 (9063-C0)



The Data Acquisition and Control Interface (DACI) is a versatile USB peripheral used for measuring, observing, analyzing, and controlling electrical and mechanical parameters in electric power systems and power electronics circuits. For these purposes, a set of computer-based instruments as well as a variety of control functions are available for the DACI. These instruments and control functions are accessed through the LVDAC-EMS software. The LVDAC-EMS software, as well as all available upgrades, is free and can be downloaded anytime on the Festo Didactic website.

Together, the DACI and the LVDAC-EMS software allow training in various areas such as electric power technology, ac/dc machines, renewable energy, transmission lines, and power electronics using modern and versatile measuring instruments and control functions. LVDAC-EMS also offers the possibility to use pre-built SCADA interfaces for several applications to ease the view and understanding of the process taking place. The user guide provided allows students to quickly become familiar with the instruments and control functions available.

Model 9063-C includes the DACI, Model 9063, with the following function sets activated:

- Computer-Based Instrumentation Function, Model 9069-1

- Chopper/Inverter Control Function Set, Model 9069-2

Manual

Description	Manual number
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)

Table of Contents of the Manual(s)

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Personal Computer	579785 (8990-00) [107]
1	AC 24 V Wall Mount Power Supply	579696 (30004-20) [108]

Specifications

Parameter	Value
Insulated Voltage Inputs (4)	
Range (Low / High Scales)	-80 to +80 V / -800 to + 800 V (user-selectable through software)
Impedance (Low / High Scales)	326.6 kΩ / 3.25 MΩ
Bandwidth	DC to 65 kHz (-3 dB)
Accuracy	1% (dc to 10 kHz)
Insulation	800 V
Measurement Category	CAT II (283 V ac/400 V dc versus ground)
Insulated Current Inputs (4)	
Range (Low / High Scales)	-4 to +4 A / -40 to + 40 A (25 A rms)
Impedance (Low / High Scales)	5 mΩ / 50 mΩ
Bandwidth	DC to 65 kHz (-3 dB)
Accuracy	1% (dc to 10 kHz)
Insulation	800 V
Measurement Category	CAT II (283 V ac/400 V dc versus ground)
Analog Inputs (8)	
Voltage Range	-10 to +10 V
Impedance	> 10 MΩ
Bandwidth	DC to 125 kHz
Measured Parameters	User-selectable through software
Parameter-to-Voltage Ratio	User-determined through software
A/D Converter for Insulated and Analog Inputs (16)	
Type	Successive approximation
Resolution	12 bits

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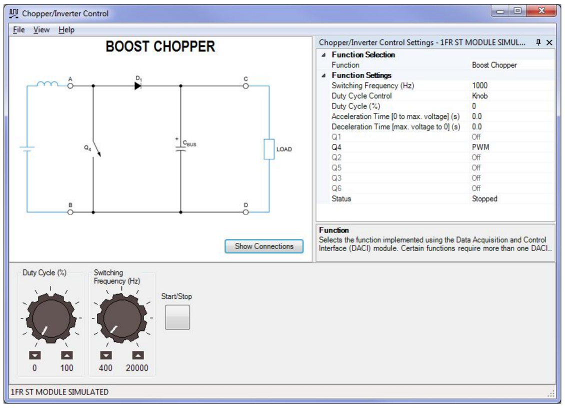
[107] Refer to the Computer Requirements in the System Specifications section of this datasheet if the computer is to be provided by the end-user. Only one computer is required per station. This model is available in multiple voltage- and frequency dependent variants. Contact a Festo representative to obtain the correct part number.

[108] Required if power is not supplied by the Power Supply, Model 8821-2. This model is available in multiple voltage- and frequency dependent variants. Contact a Festo representative to obtain the correct part number.

Parameter	Value
Integral Non-Linearity	≤ ±1.5 LSB
Differential Non-Linearity	≤ ±1 LSB
Maximum Sampling Rate	600 ksamples/s (one channel)
FIFO Buffer Size	16 ksamples
Analog Outputs (2)	
Voltage Range (2)	-10 to +10 V
Operational Load Impedance	› 600 Ω
D/A Converter for Analog Outputs (2)	
Type	Resistor string
Resolution	12 bits
Integral Non-Linearity	≤ ±8 LSB
Differential Non-Linearity	-0.5 to +0.7 LSB
Digital Inputs (3)	
Types	Encoder (2), synchronization (1)
Signal Level	0-5 V (TTL compatible)
Maximum Input Frequency	50 kHz
Impedance	5 kΩ
Digital Outputs (9)	
Types	Control (6 on a DB9 connector and 2 on 2 mm banana jacks), synchronization (1 on a DB9 connector)
Signal Level	0-5 V (TTL compatible)
Maximum Output Frequency	20 kHz (software-limited)
Impedance	200 Ω
Control Functions	
Activated Sets	Computer-Based Instrumentation Function, Model 9069-1
	Chopper/Inverter Control Function Set, Model 9069-2
Computer I/O Interface	USB 2.0 full speed via type-B receptacle
Power Requirements	24 V - 0.4 A - 50/60 Hz
Accessories	
Included Accessories	2 m USB interconnection cable (1)
	24 V power cable (1)
	2 mm banana plug test leads (3)
	DB9 connector control cable (1)
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 410 mm (6.1 x 11.3 x 16.1 in)
Net Weight	3.9 kg (8.6 lb)

Chopper/Inverter Control Function Set
581453 (9069-20)



Chopper/Inverter Control Settings - 1FR ST MODULE SIMUL...

Function Selection	
Function	Boost Chopper
Function Settings	
Switching Frequency (Hz)	1000
Duty Cycle Control	Knob
Duty Cycle (%)	0
Acceleration Time [0 to max. voltage] (s)	0.0
Deceleration Time [max. voltage to 0] (s)	0.0
Q1	Off
Q4	PWM
Q2	Off
Q5	Off
Q3	Off
Q6	Off
Status	Stopped

Function
Selects the function implemented using the Data Acquisition and Control Interface (DACI) module. Certain functions require more than one DACI...

The Chopper/Inverter Control Function Set enables the following choppers and inverters to be implemented using the Data Acquisition and Control Interface, the IGBT Chopper/Inverter and the Insulated DC-to-DC Converter:

- Buck Chopper (high-side switching)
- Buck Chopper (low-side switching)
- Buck/Boost Chopper
- Boost Chopper
- Four-Quadrant Chopper
- Buck Chopper with Feedback
- Boost Chopper with Feedback

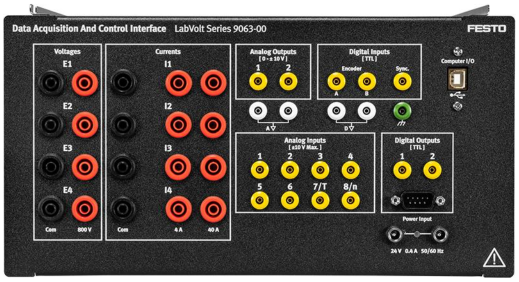
- Single-Phase, 180° Modulation Inverter
- Single-Phase PWM Inverter
- Three-Phase, 180° Modulation Inverter
- Three-Phase PWM Inverter
- Three-Phase Inverter (constant V/f ratio)
- Insulated DC-to-DC Converter
- Four-Quadrant DC Motor Drive without Current Control
- Four-Quadrant DC Motor Drive

Specifications

Parameter	Value
Control Functions	
Control Functions	Buck Chopper (high-side switching)
	Buck Chopper (low-side switching)
	Buck/Boost Chopper
	Boost Chopper
	Four-Quadrant Chopper
	Buck Chopper with Feedback
	Boost Chopper with Feedback
	Single-Phase, 180° Modulation Inverter
	Single-Phase PWM Inverter
	Three-Phase, 180° Modulation Inverter
	Three-Phase PWM Inverter
	Three-Phase PWM Inverter (constant V/f ratio)
	Insulated DC-to-DC Converter
	Four-Quadrant DC Motor Drive without Current Control
	Four-Quadrant DC Motor Drive
Buck Chopper (high-side switching), Buck Chopper (low-side switching), Buck/Boost Chopper, Boost Chopper, Four-Quadrant Chopper	
Switching Frequency	400 Hz to 20 kHz
Duty Cycle Control	Knob or analog input on the DACI
Duty Cycle	0-100%
Acceleration Time (0 to Max. Voltage)	0-100 s
Deceleration Time (Max. Voltage to 0)	0-100 s
IGBTs Q1 to Q6	PWM, on, off (certain IGBTs are unavailable depending on the selected chopper control function)
Buck Chopper with Feedback, Boost Chopper with Feedback	
Switching Frequency	2-20 kHz
Command Input	Knob or analog input on the DACI
Command	0-100%
Feedback Input	Voltage, current, speed, power, or low-power analog signal
Feedback Filter Cutoff Frequency	100-4900 Hz
Feedback Range (100% Value =)	10-400 V
Acceleration Time (0 to 100%)	0-100 s
Deceleration Time (100% to 0)	0-100 s
Single-Phase, 180° Modulation Inverter	
DC Bus	Unipolar or bipolar
Frequency	0-120 Hz
IGBTs Q1 to Q6	180° Modulation, on, or off (certain IGBTs are unavailable)
Single-Phase PWM Inverter	
DC Bus	Unipolar or bipolar
Switching Frequency	400 Hz to 20 kHz
Frequency	0-120 Hz
Peak Voltage	0-100% of dc bus
IGBTs Q1 to Q6	PWM, on, or off (certain IGBTs are unavailable)
Three-Phase, 180° Modulation Inverter	
Phase Sequence	Forward (1-2-3), reverse (1-3-2), or forward/reverse
Frequency	0-120 Hz
IGBTs Q1 to Q6	180° Modulation, on, or off
Three-Phase PWM Inverter	
Switching Frequency	400 Hz to 20 kHz
Phase Sequence	Forward (1-2-3), reverse (1-3-2), or forward/reverse
Frequency	0-120 Hz
Peak Voltage	0-117% of dc bus/2

Parameter	Value
Modulation Type	Sinusoidal pulse-width modulation or space vector
IGBTs Q1 to Q6	PWM, on, or off
Three-Phase PWM Inverter (Constant V/f Ratio)	
Switching Frequency	400 Hz to 20 kHz
Phase Sequence	Forward (1-2-3), reverse (1-3-2), or forward/reverse
Frequency	0-120°
Knee Peak Voltage	0-117% of dc bus voltage/2
Knee Frequency	1-120 Hz
Modulation Type	Sinusoidal pulse-width modulation or space vector
Acceleration Time (0 to Knee)	0-100 s
Deceleration Time (Knee to 0)	0-100 s
Insulated DC-to-DC Converter	
Duty Cycle	0-45%
Four-Quadrant DC Motor Drive with and without Current Control	
Switching Frequency	2-20 kHz
Speed Command Input	Knob or analog input on the DACI
Speed Command	-5000 r/min to 5000 r/min
Pulley Ratio	24:12 or 24:24
Acceleration Time (0 to Max. Speed)	0-100 s
Deceleration Time (Max. Speed to 0)	0-100 s
Current Feedback Range	4 A or 40 A (only available in current control)
Current Feedback Filter Cutoff Frequency	100-4900 Hz (only available in current control)
Current Command Limit	0-40 A (only available in current control)

Data Acquisition and Control Interface
579686 (9063-D0)



The Data Acquisition and Control Interface (DACI) is a versatile USB peripheral used for measuring, observing, analyzing, and controlling electrical and mechanical parameters in electric power systems and power electronics circuits. For these purposes, a set of computer-based instruments as well as a variety of control functions are available for the DACI. These instruments and control functions are accessed through the LVDAC-EMS software. The LVDAC-EMS software, as well as all available upgrades, is free and can be downloaded anytime on the Festo Didactic website.

Together, the DACI and the LVDAC-EMS software allow training in various areas such as electric power technology, ac/dc machines, renewable energy, transmission lines, and power electronics using modern and versatile measuring instruments and control functions. LVDAC-EMS also offers the possibility to use pre-built SCADA interfaces for several applications to ease the view and understanding of the process taking place. The user guide provided allows students to quickly become familiar with the instruments and control functions available.

Model 9063-D includes the DACI, Model 9063, with the following function sets activated:

- Computer-Based Instrumentation Function, Model 9069-1

- Chopper/Inverter Control Function Set, Model 9069-2

- Thyristor Control Function Set, Model 9069-3

Manual

Description	Manual number
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)

Table of Contents of the Manual(s)

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Personal Computer	579785 (8990-00) [109]
1	AC 24 V Wall Mount Power Supply	579696 (30004-20) [110]

Specifications

Parameter	Value
Insulated Voltage Inputs (4)	
Range (Low / High Scales)	-80 to +80 V / -800 to + 800 V (user-selectable through software)
Impedance (Low / High Scales)	326.6 kΩ / 3.25 MΩ
Bandwidth	DC to 65 kHz (-3 dB)
Accuracy	1% (dc to 10 kHz)
Insulation	800 V
Measurement Category	CAT II (283 V ac/400 V dc versus ground)
Insulated Current Inputs (4)	
Range (Low / High Scales)	-4 to +4 A / -40 to + 40 A (25 A rms)
Impedance (Low / High Scales)	5 mΩ / 50 mΩ
Bandwidth	DC to 65 kHz (-3 dB)
Accuracy	1% (dc to 10 kHz)
Insulation	800 V
Measurement Category	CAT II (283 V ac/400 V dc versus ground)
Analog Inputs (8)	
Voltage Range	-10 to +10 V
Impedance	› 10 MΩ
Bandwidth	DC to 125 kHz
Measured Parameters	User-selectable through software
Parameter-to-Voltage Ratio	User-determined through software
A/D Converter for Insulated and Analog Inputs (16)	
Type	Successive approximation
Resolution	12 bits
Integral Non-Linearity	≤ ±1.5 LSB
Differential Non-Linearity	≤ ±1 LSB
Maximum Sampling Rate	600 ksamples/s (one channel)

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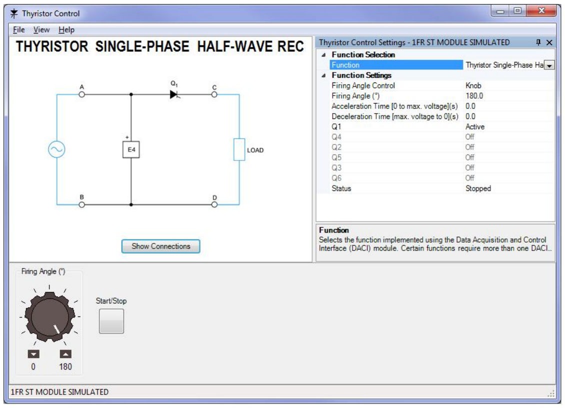
[109] Refer to the Computer Requirements in the System Specifications section of this datasheet if the computer is to be provided by the end-user. Only one computer is required per station. This model is available in multiple voltage- and frequency dependent variants. Contact a Festo representative to obtain the correct part number.

[110] Required if power is not supplied by the Power Supply, Model 8821-2. This model is available in multiple voltage- and frequency dependent variants. Contact a Festo representative to obtain the correct part number.

Parameter	Value
FIFO Buffer Size	16 ksamples
Analog Outputs (2)	
Voltage Range (2)	-10 to +10 V
Operational Load Impedance	> 600 Ω
D/A Converter for Analog Outputs (2)	
Type	Resistor string
Resolution	12 bits
Integral Non-Linearity	≤ ±8 LSB
Differential Non-Linearity	-0.5 to +0.7 LSB
Digital Inputs (3)	
Types	Encoder (2), synchronization (1)
Signal Level	0-5 V (TTL compatible)
Maximum Input Frequency	50 kHz
Impedance	5 kΩ
Digital Outputs (9)	
Types	Control (6 on a DB9 connector and 2 on 2 mm banana jacks), synchronization (1 on a DB9 connector)
Signal Level	0-5 V (TTL compatible)
Maximum Output Frequency	20 kHz (software-limited)
Impedance	200 Ω
Control Functions	
Activated Sets	Computer-Based Instrumentation Function, Model 9069-1
	Chopper/Inverter Control Function Set, Model 9069-2
	Thyristor Control Function Set, Model 9069-3
Computer I/O Interface	USB 2.0 full speed via type-B receptacle
Power Requirements	24 V - 0.4 A - 50/60 Hz
Accessories	
Included Accessories	2 m USB interconnection cable (1)
	24 V power cable (1)
	2 mm banana plug test leads (3)
	DB9 connector control cable (1)
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 410 mm (6.1 x 11.3 x 16.1 in)
Net Weight	3.9 kg (8.6 lb)

Thyristor Control Function Set
581454 (9069-30)



Thyristor Control Settings - 1FR ST MODULE SIMULATED

Function Selection	
Function	Thyristor Single-Phase Ha
Function Settings	
Firing Angle Control	Knob
Firing Angle (°)	180.0
Acceleration Time [0 to max. voltage](s)	0.0
Deceleration Time [max. voltage to 0](s)	0.0
Q1	Active
Q4	Off
Q2	Off
Q5	Off
Q3	Off
Q6	Off
Status	Stopped

Function
Selects the function implemented using the Data Acquisition and Control Interface (DACI) module. Certain functions require more than one DACI...

The Thyristor Control Function Set enables the following thyristor-based devices to be implemented using the Data Acquisition and Control Interface, and the Power Thyristors:

- Thyristor Single-Phase Half-Wave Rectifier
- Thyristor Single-Phase Bridge
- Thyristor Three-Phase Bridge
- Thyristor Three-Phase Bridge with Feedback
- Solid-State Relay
- Thyristor Single-Phase AC Power Control

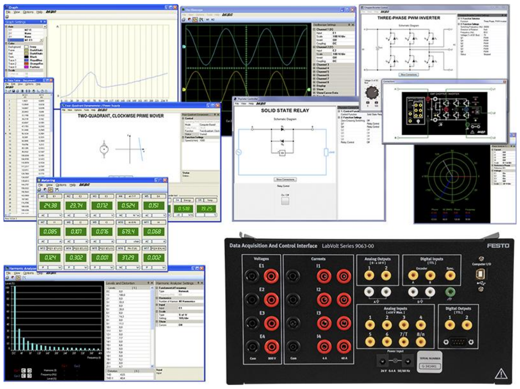
- Thyristor Three-Phase AC Power Control
- Direct-On-Line Starter
- Soft Starter

Specifications

Parameter	Value
Control Functions	
Control Functions	Thyristor Single-Phase Half-Wave Rectifier
	Thyristor Single-Phase Bridge
	Thyristor Three-Phase Bridge
	Thyristor Three-Phase Bridge with Feedback
	Solid-State Relay
	Thyristor Single-Phase AC Power Control
	Thyristor Three-Phase AC Power Control
	Direct-On-Line Starter
	Soft Starter
Thyristor Single-Phase Half-Wave Rectifier, Thyristor Single-Phase Bridge, Thyristor Three-Phase Bridge	
Firing Angle Control	Knob or analog input on the DACI
Firing Angle	0-180°
Acceleration Time (0 to Max. Voltage)	0-100 s
Deceleration Time (Max. Voltage to 0)	0-100 s
Thyristors Q1 to Q6	Active, on, or off (certain thyristors are unavailable depending on the selected thyristor control function)
Thyristor Three-Phase Bridge with Feedback	
Command Input	On or off
Command	Knob or analog input on the DACI
Inverter Limit	100-180°
Arc-Cosine	On or off
Feedback Input	Voltage, rms voltage, current, speed, power, or low-power analog signal
Feedback Range (Voltage Input Only)	80-800 V
Current Feedback Range (Current Input Only)	0.4-4 A
Speed Feedback Range (Speed Input Only)	250-2500 r/min
Analog Feedback Range (Analog Input Only)	1-10 V
Power Feedback Range (Power Input Only)	32-3200 W
Feedback Filter Cutoff Frequency	10-180 Hz
Acceleration Time (0 to 100%)	0-100 s
Deceleration Time (100% to 0)	0-100 s
Thyristors Q1 to Q6	Active, on, or off
Solid-State Relay	
Zero-Voltage Switching	On or off
Relay Control	Open or close
Thyristors Q1 to Q6	Active, on, or off (certain thyristors are unavailable)
Thyristor Single-Phase AC Power Control	
Control Mode	Phase control, synchronous burst fire control, or asynchronous burst fire control
Firing Angle Control	Knob or analog input on the DACI
Firing Angle	0-180°
Thyristors Q1 to Q6	Active, on, or off (certain thyristors are unavailable)
Thyristor Three-Phase AC Power Control	
Load Configuration	3 wires star (3S), 3 wires delta (3D), 4 wires star (4S), or 6 wires delta (6D)
Control Mode	Phase control or synchronous burst fire control (certain control modes are unavailable depending on the selected thyristor control function)
Firing Angle Control	Knob or analog input on the DACI
Acceleration Time (0 to Max. Voltage)	0-100 s
Deceleration Time (Max. Voltage to 0)	0-100 s
Thyristors Q1 to Q6	Active, on, or off
Direct-On-Line Starter	
Motor Full-Load Current	0.4-2 A
Overload	On or off

Parameter	Value
Overload Class	5, 10, 15, 20, 25, 30, 35, or 40
Soft Starter	
Mode	Soft Start or current-limit start
Motor Full-Load Current	0.4-2 A
Initial Torque	15%, 25%, 35%, or 65% of LRT
Start Time	2-200 s
Kick-Start Time	0 s, 0.5 s, 1 s, or 1.5 s
Soft Stop	0, 1, 2, or 3 times the start time
Overload	On or off
Overload Class	5, 10, 15, 20, 25, 30, 35, or 40

Data Acquisition and Control Interface
579689 (9063-E0)



The Data Acquisition and Control Interface (DACI) is a versatile USB peripheral used for measuring, observing, analyzing, and controlling electrical and mechanical parameters in electric power systems and power electronics circuits. For these purposes, a set of computer-based instruments as well as a variety of control functions are available for the DACI. These instruments and control functions are accessed through the LVDAC-EMS software. The LVDAC-EMS software, as well as all available upgrades, is free and can be downloaded anytime on the Festo Didactic website.

Together, the DACI and the LVDAC-EMS software allow training in various areas such as electric power technology, ac/dc machines, renewable energy, transmission lines, and power electronics using modern and versatile measuring instruments and control functions. LVDAC-EMS also offers the possibility to use pre-built SCADA interfaces for several applications to ease the view and understanding of the process taking place. The user guide provided allows students to quickly become familiar with the instruments and control functions available.

Model 9063-E includes the DACI, Model 9063, with the following function sets activated:

- Computer-Based Instrumentation Function, Model 9069-1

- Chopper/Inverter Control Function Set, Model 9069-2

- Home Energy Production Control Function Set, Model 9069-4

Manual

Description	Manual number
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)

Table of Contents of the Manual(s)

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Personal Computer	579785 (8990-00) [111]
1	AC 24 V Wall Mount Power Supply	579696 (30004-20) [112]

Specifications

Parameter	Value
Insulated Voltage Inputs (4)	
Range (Low / High Scales)	-80 to +80 V / -800 to + 800 V (user-selectable through software)
Impedance (Low / High Scales)	326.6 kΩ / 3.25 MΩ
Bandwidth	DC to 65 kHz (-3 dB)
Accuracy	1% (dc to 10 kHz)
Insulation	800 V
Measurement Category	CAT II (283 V ac/400 V dc versus ground)
Insulated Current Inputs (4)	
Range (Low / High Scales)	-4 to +4 A / -40 to + 40 A (25 A rms)
Impedance (Low / High Scales)	5 mΩ / 50 mΩ
Bandwidth	DC to 65 kHz (-3 dB)
Accuracy	1% (dc to 10 kHz)
Insulation	800 V
Measurement Category	CAT II (283 V ac/400 V dc versus ground)
Analog Inputs (8)	
Voltage Range	-10 to +10 V
Impedance	> 10 MΩ
Bandwidth	DC to 125 kHz
Measured Parameters	User-selectable through software
Parameter-to-Voltage Ratio	User-determined through software
A/D Converter for Insulated and Analog Inputs (16)	
Type	Successive approximation
Resolution	12 bits
Integral Non-Linearity	≤ ±1.5 LSB
Differential Non-Linearity	≤ ±1 LSB
Maximum Sampling Rate	600 ksamples/s (one channel)
FIFO Buffer Size	16 ksamples
Analog Outputs (2)	
Voltage Range (2)	-10 to +10 V
Operational Load Impedance	> 600 Ω
D/A Converter for Analog Outputs (2)	
Type	Resistor string
Resolution	12 bits
Integral Non-Linearity	≤ ±8 LSB
Differential Non-Linearity	-0.5 to +0.7 LSB
Digital Inputs (3)	
Types	Encoder (2), synchronization (1)
Signal Level	0-5 V (TTL compatible)
Maximum Input Frequency	50 kHz
Impedance	5 kΩ
Digital Outputs (9)	
Types	Control (6 on a DB9 connector and 2 on 2 mm banana jacks), synchronization (1 on a DB9 connector)
Signal Level	0-5 V (TTL compatible)
Maximum Output Frequency	20 kHz (software-limited)

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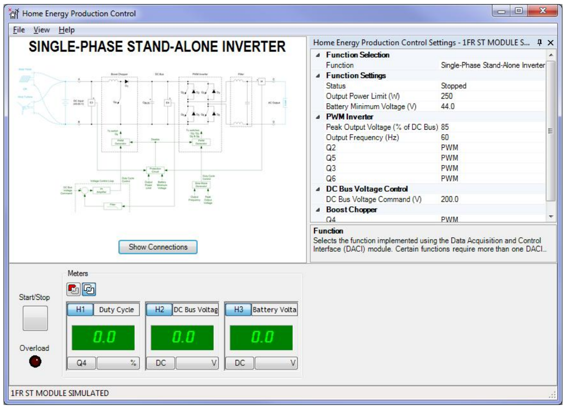
[111] Refer to the Computer Requirements in the System Specifications section of this datasheet if the computer is to be provided by the end-user. Only one computer is required per station. This model is available in multiple voltage- and frequency dependent variants. Contact a Festo representative to obtain the correct part number.

[112] Required if power is not supplied by the Power Supply, Model 8821-2. This model is available in multiple voltage- and frequency dependent variants. Contact a Festo representative to obtain the correct part number.

Parameter	Value
Impedance	200 Ω
Control Functions	
Activated Sets	Computer-Based Instrumentation Function, Model 9069-1
	Chopper/Inverter Control Function Set, Model 9069-2
	Home Energy Production Control Function Set, Model 9069-4
Computer I/O Interface	USB 2.0 full speed via type-B receptacle
Power Requirements	24 V - 0.4 A - 50/60 Hz
Accessories	
Included Accessories	2 m USB interconnection cable (1)
	24 V power cable (1)
	2 mm banana plug test leads (3)
	DB9 connector control cable (1)
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 410 mm (6.1 x 11.3 x 16.1 in)
Net Weight	3.9 kg (8.6 lb)

Home Energy Production Control Function Set
581455 (9069-40)



Home Energy Production Control Settings - 1FR ST MODULE S...

Function Selection	
Function	Single-Phase Stand-Alone Inverter
Function Settings	
Status	Stopped
Output Power Limit (W)	250
Battery Minimum Voltage (V)	44.0
PWM Inverter	
Peak Output Voltage (% of DC Bus)	85
Output Frequency (Hz)	60
Q2	PWM
Q5	PWM
Q3	PWM
Q6	PWM
DC Bus Voltage Control	
DC Bus Voltage Command (V)	200.0
Boost Chopper	
Q4	PWM

Function
Selects the function implemented using the Data Acquisition and Control Interface (DACI) module. Certain functions require more than one DACI...

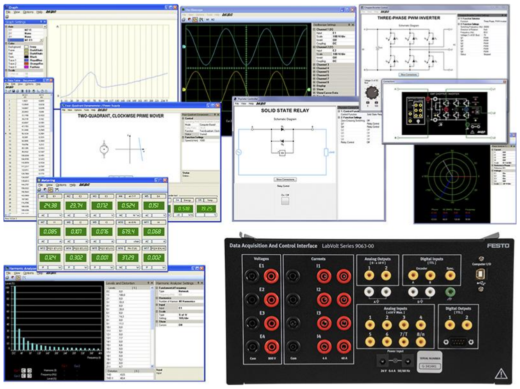
The Home Energy Production Control Function Set enables the following devices required for home energy production to be implemented using the Data Acquisition and Control Interface, the IGBT Chopper/Inverter, and the Insulated DC-to-DC Converter:

- Single-Phase Stand-Alone Inverter
- Single-Phase Grid-Tied Inverter
- Solar Power Inverter (LF Transformer)
- Solar/Wind Power Inverter (HF Transformer)

Specifications

Parameter	Value
Control Functions	
Control Functions	Single-Phase Stand-Alone Inverter
	Single-Phase Grid-Tied Inverter
	Single-Phase Grid-Tied Inverter (LF Transformer)
	Solar/Wind Power Inverter (HF Transformer)
Single-Phase Stand-Alone Inverter Function	
Output Power Limit	50-250 W
Battery Minimum Voltage	35-55 V
PWM Inverter Peak Output Voltage	50-95% of dc bus voltage
PWM Inverter Output Frequency	50 or 60 Hz
DC Bus Voltage Command	100-400 V
Single-Phase Grid-Tied Inverter Function	
Active Current Command	-2 to 2 A
Reactive Current Command	-2 to 2 A
DC Bus Voltage Command	100-400 V
Solar Power Inverter (LF Transformer)	
MPP Tracker	On or off
Active Current Command	-10 A to 10 A (only available when the MPP Tracker parameter is switched to Off)
Reactive Current Command	-10 A to 10 A
Solar/Wind Power Inverter (HF Transformer)	
MPP Tracker Type	Solar panel or wind turbine

Data Acquisition and Control Interface
579692 (9063-G0)



The Data Acquisition and Control Interface (DACI) is a versatile USB peripheral used for measuring, observing, analyzing, and controlling electrical and mechanical parameters in electric power systems and power electronics circuits. For these purposes, a set of computer-based instruments as well as a variety of control functions are available for the DACI. These instruments and control functions are accessed through the LVDAC-EMS software. The LVDAC-EMS software, as well as all available upgrades, is free and can be downloaded anytime on the Festo Didactic website.

Together, the DACI and the LVDAC-EMS software allow training in various areas such as electric power technology, ac/dc machines, renewable energy, transmission lines, and power electronics using modern and versatile measuring instruments and control functions. LVDAC-EMS also offers the possibility to use pre-built SCADA interfaces for several applications to ease the view and understanding of the process taking place. The user guide provided allows students to quickly become familiar with the instruments and control functions available.

This model includes the DACI with the following function sets activated:

- Computer-Based Instrumentation Function

- Synchroscope Function

Manual

Description	Manual number
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)

Table of Contents of the Manual(s)

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Personal Computer	579785 (8990-00) [113]

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[113] Refer to the Computer Requirements in the System Specifications section of this datasheet if the computer is to be provided by the end-user. Only one computer is required per station. This model is available in multiple voltage- and frequency dependent variants. Contact a Festo representative to obtain the correct part number.

Qty	Description	Model number
1	AC 24 V Wall Mount Power Supply	579696 (30004-20) [114]

Specifications

Parameter	Value
Insulated Voltage Inputs (4)	
Range (Low / High Scales)	-80 to +80 V / -800 to + 800 V (user-selectable through software)
Impedance (Low / High Scales)	326.6 kΩ / 3.25 MΩ
Bandwidth	DC to 65 kHz (-3 dB)
Accuracy	1% (dc to 10 kHz)
Insulation	800 V
Measurement Category	CAT II (283 V ac/400 V dc versus ground)
Insulated Current Inputs (4)	
Range (Low / High Scales)	-4 to +4 A / -40 to + 40 A (25 A rms)
Impedance (Low / High Scales)	5 mΩ / 50 mΩ
Bandwidth	DC to 65 kHz (-3 dB)
Accuracy	1% (dc to 10 kHz)
Insulation	800 V
Measurement Category	CAT II (283 V ac/400 V dc versus ground)
Analog Inputs (8)	
Voltage Range	-10 to +10 V
Impedance	> 10 MΩ
Bandwidth	DC to 125 kHz
Measured Parameters	User-selectable through software
Parameter-to-Voltage Ratio	User-determined through software
A/D Converter for Insulated and Analog Inputs (16)	
Type	Successive approximation
Resolution	12 bits
Integral Non-Linearity	≤ ±1.5 LSB
Differential Non-Linearity	≤ ±1 LSB
Maximum Sampling Rate	600 ksamples/s (one channel)
FIFO Buffer Size	16 ksamples
Analog Outputs (2)	
Voltage Range (2)	-10 to +10 V
Operational Load Impedance	> 600 Ω
D/A Converter for Analog Outputs (2)	
Type	Resistor string
Resolution	12 bits
Integral Non-Linearity	≤ ±8 LSB
Differential Non-Linearity	-0.5 to +0.7 LSB
Digital Inputs (3)	
Types	Encoder (2), synchronization (1)
Signal Level	0-5 V (TTL compatible)
Maximum Input Frequency	50 kHz
Impedance	5 kΩ
Digital Outputs (9)	
Types	Control (6 on a DB9 connector and 2 on 2 mm banana jacks), synchronization (1 on a DB9 connector)
Signal Level	0-5 V (TTL compatible)
Maximum Output Frequency	20 kHz (software-limited)
Impedance	200 Ω
Control Functions	
Activated Sets	Computer-Based Instrumentation Function, Model 9069-1
	Synchroscope Function, Model 9069-C
Computer I/O Interface	USB 2.0 full speed via type-B receptacle
Power Requirements	24 V - 0.4 A - 50/60 Hz

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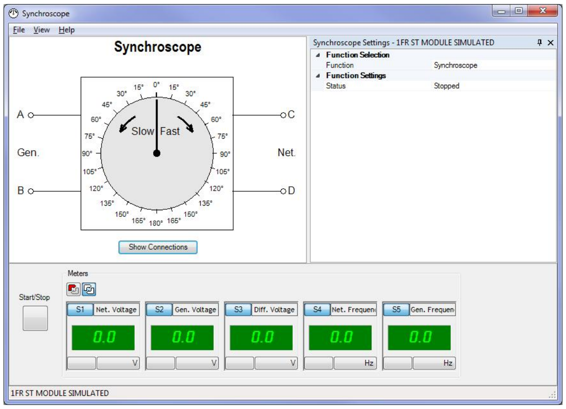
[114] Required if power is not supplied by the Power Supply, Model 8821-2. This model is available in multiple voltage- and frequency dependent variants. Contact a Festo representative to obtain the correct part number.

Parameter	Value
Accessories	
Included Accessories	2 m USB interconnection cable (1)
	24 V power cable (1)
	2 mm banana plug test leads (3)
	DB9 connector control cable (1)
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 410 mm (6.1 x 11.3 x 16.1 in)
Net Weight	3.9 kg (8.6 lb)

Synchroscope Function
579789 (9069-C0)


Synchroscope
File
View
Help
Synchroscope
A
Gen.
B
C
Net.
D
0°
15°
30°
45°
60°
75°
90°
105°
120°
135°
150°
165°
180°
Slow
Fast
Show Connections
Meters
Start/Stop
S1
Net. Voltage
S2
Gen. Voltage
S3
Diff. Voltage
S4
Net. Frequen
S5
Gen. Frequen
0.0
V
Hz
1FR ST MODULE SIMULATED

Synchroscope Settings - 1FR ST MODULE SIMULATED

Function Selection

Function: Synchroscope

Function Settings

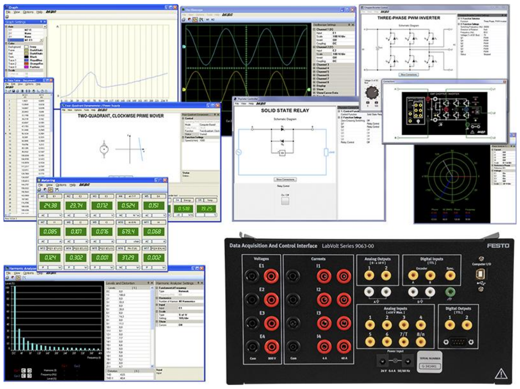
Status: Stopped

The Synchroscope Function is used for the synchronization of synchronous generators. This function emulates the operation of an actual synchroscope by showing on-screen the dial indicating the phase angle difference between the generator voltage and the network voltage. In addition, the Synchroscope Function includes meters displaying various parameters important to generator synchronization (e.g., network voltage and frequency, generator voltage and frequency, voltage difference).

Specifications

Parameter	Value
Monitored Values (in Addition to Phase Difference Dial)	
Monitored Values (in Addition to Phase Difference Dial)	Network voltage
	Network frequency
	Generator voltage
	Generator frequency
	Voltage difference

Data Acquisition and Control Interface
579694 (9063-H0)



The Data Acquisition and Control Interface (DACI) is a versatile USB peripheral used for measuring, observing, analyzing, and controlling electrical and mechanical parameters in electric power systems and power electronics circuits. For these purposes, a set of computer-based instruments as well as a variety of control functions are available for the DACI. These instruments and control functions are accessed through the LVDAC-EMS software. The LVDAC-EMS software, as well as all available upgrades, is free and can be downloaded anytime on the Festo Didactic website.

Together, the DACI and the LVDAC-EMS software allow training in various areas such as electric power technology, ac/dc machines, renewable energy, transmission lines, and power electronics using modern and versatile measuring instruments and control functions. LVDAC-EMS also offers the possibility to use pre-built SCADA interfaces for several applications to ease the view and understanding of the process taking place. The user guide provided allows students to quickly become familiar with the instruments and control functions available.

Model 9063-H includes the DACI, Model 9063, with the following function sets activated:

- Computer-Based Instrumentation Function, Model 9069-1

- Thyristor Control Function Set, Model 9069-3

- Home Energy Production Control Function Set, Model 9069-4

- HVDC Transmission System Control Function Set, Model 9069-7

- SVC Control Function Set, Model 9069-8

- STATCOM Control Function Set, Model 9069-B

Manual

Description	Manual number
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)

Table of Contents of the Manual(s)

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Personal Computer	579785 (8990-00) [115]
1	AC 24 V Wall Mount Power Supply	579696 (30004-20) [116]

Specifications

Parameter	Value
Insulated Voltage Inputs (4)	
Range (Low / High Scales)	-80 to +80 V / -800 to + 800 V (user-selectable through software)
Impedance (Low / High Scales)	326.6 kΩ / 3.25 MΩ
Bandwidth	DC to 65 kHz (-3 dB)
Accuracy	1% (dc to 10 kHz)
Insulation	800 V
Measurement Category	CAT II (283 V ac/400 V dc versus ground)
Insulated Current Inputs (4)	
Range (Low / High Scales)	-4 to +4 A / -40 to + 40 A (25 A rms)
Impedance (Low / High Scales)	5 mΩ / 50 mΩ
Bandwidth	DC to 65 kHz (-3 dB)
Accuracy	1% (dc to 10 kHz)
Insulation	800 V
Measurement Category	CAT II (283 V ac/400 V dc versus ground)
Analog Inputs (8)	
Voltage Range	-10 to +10 V
Impedance	> 10 MΩ
Bandwidth	DC to 125 kHz
Measured Parameters	User-selectable through software
Parameter-to-Voltage Ratio	User-determined through software
A/D Converter for Insulated and Analog Inputs (16)	
Type	Successive approximation
Resolution	12 bits
Integral Non-Linearity	≤ ±1.5 LSB
Differential Non-Linearity	≤ ±1 LSB
Maximum Sampling Rate	600 ksamples/s (one channel)
FIFO Buffer Size	16 ksamples
Analog Outputs (2)	
Voltage Range (2)	-10 to +10 V
Operational Load Impedance	> 600 Ω
D/A Converter for Analog Outputs (2)	
Type	Resistor string
Resolution	12 bits
Integral Non-Linearity	≤ ±8 LSB
Differential Non-Linearity	-0.5 to +0.7 LSB
Digital Inputs (3)	
Types	Encoder (2), synchronization (1)
Signal Level	0-5 V (TTL compatible)
Maximum Input Frequency	50 kHz
Impedance	5 kΩ
Digital Outputs (9)	
Types	Control (6 on a DB9 connector and 2 on 2 mm banana jacks), synchronization (1 on a DB9 connector)
Signal Level	0-5 V (TTL compatible)
Maximum Output Frequency	20 kHz (software-limited)

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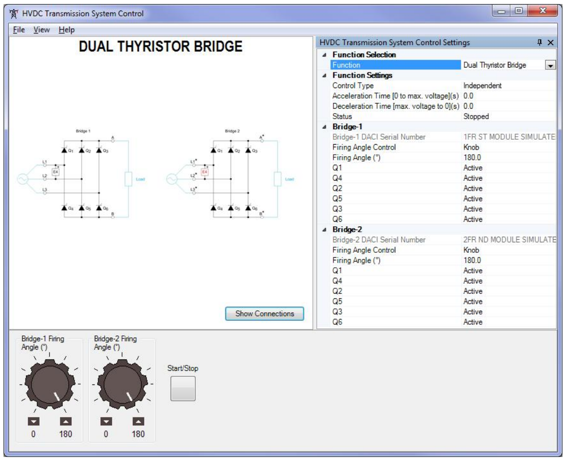
[115] Refer to the Computer Requirements in the System Specifications section of this datasheet if the computer is to be provided by the end-user. Only one computer is required per station. This model is available in multiple voltage- and frequency dependent variants. Contact a Festo representative to obtain the correct part number.

[116] Required if power is not supplied by the Power Supply, Model 8821-2. This model is available in multiple voltage- and frequency dependent variants. Contact a Festo representative to obtain the correct part number.

Parameter	Value
Impedance	200 Ω
Control Functions	
Activated Sets	Computer-Based Instrumentation Function, Model 9069-1
	Thyristor Control Function Set, Model 9069-3
	Home Energy Production Control Function Set, Model 9069-4
	HVDC Transmission System Control Function Set, Model 9069-7
	SVC Control Function Set, Model 9069-8
	STATCOM Control Function Set, Model 9069-B
Computer I/O Interface	USB 2.0 full speed via type-B receptacle
Power Requirements	24 V - 0.4 A - 50/60 Hz
Accessories	
Included Accessories	2 m USB interconnection cable (1)
	24 V power cable (1)
	2 mm banana plug test leads (3)
	DB9 connector control cable (1)
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 410 mm (6.1 x 11.3 x 16.1 in)
Net Weight	3.9 kg (8.6 lb)

High-Voltage DC (HVDC) Transmission System Control Function Set
579790 (9069-70)



HVDC Transmission System Control Settings

Function Selection	
Function	Dual Thyristor Bridge
Function Settings	
Control Type	Independent
Acceleration Time [0 to max. voltage](s)	0.0
Deceleration Time [max. voltage to 0](s)	0.0
Status	Stopped
Bridge-1	
Bridge-1 DACI Serial Number	1FR ST MODULE SIMULATE
Firing Angle Control	Knob
Firing Angle (°)	180.0
Q1	Active
Q4	Active
Q2	Active
Q5	Active
Q3	Active
Q6	Active
Bridge-2	
Bridge-2 DACI Serial Number	2FR ND MODULE SIMULATE
Firing Angle Control	Knob
Firing Angle (°)	180.0
Q1	Active
Q4	Active
Q2	Active
Q5	Active
Q3	Active
Q6	Active

The High-Voltage DC (HVDC) Transmission System Control Function Set enables the following devices required for the study of HVDCs to be implemented using two Data Acquisition and Control Interface, and two Power Thyristors:

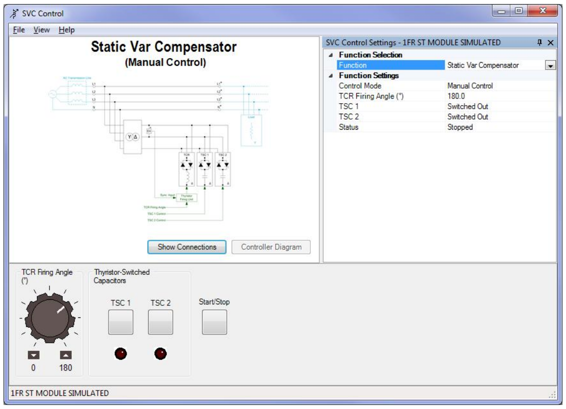
- Dual Thyristor Bridge
- Monopolar HVDC Transmission System
- 12-Pulse Converter

Specifications

Parameter	Value
Control Functions	
Control Functions	Dual Thyristor Bridge
	Monopolar HVDC Transmission System
	12-Pulse Converter
Dual Thyristor Bridge	
Control Type	Independent, common (α,α), or common (α,ß)
Acceleration Time (0 to Max. Voltage)	0-100 s
Deceleration Time (Max. Voltage to 0)	0-100 s
Firing Angle Control (for Each Bridge)	Knob or analog input on the DACI
Firing Angle (for Each Bridge)	0-180°
Monopolar HVDC Transmission System	
Control Type	Independent, linked (rectifier = bridge 1), or linked (rectifier = bridge 2)
Command Input (for Each Bridge)	Knob or analog input on the DACI
Current Command (for Each Bridge)	0-2 A
Inverter Limit (for Each Bridge)	90-180°
Arc-Cosine (for Each Bridge)	On of off
Feedback Filter Cutoff Frequency (for Each Bridge)	10-180 Hz

Parameter	Value
12-Pulse Converter	
Firing Angle	0-180º
Acceleration Time (0 to Max. Voltage)	0-100 s
Deceleration Time (Max. Voltage to 0)	0-100 s

Static Var Compensator (SVC) Control Function Set
581458 (9069-80)


SVC Control
File View Help
Static Var Compensator
(Manual Control)
Show Connections
Controller Diagram
TCR Firing Angle (°)
0
180
Thyristor-Switched Capacitors
TSC 1
TSC 2
Start/Stop
1FR ST MODULE SIMULATED

SVC Control Settings - 1FR ST MODULE SIMULATED

Function Selection	
Function	Static Var Compensator
Function Settings	
Control Mode	Manual Control
TCR Firing Angle (°)	180.0
TSC 1	Switched Out
TSC 2	Switched Out
Status	Stopped

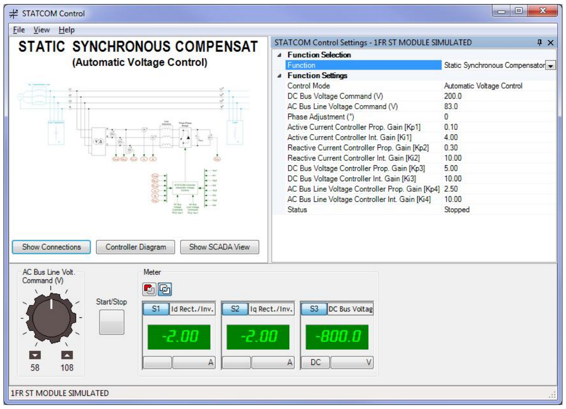
The Static Var Compensator (SVC) Control Function Set enables the following devices required for the study of SVCs to be implemented using the Data Acquisition and Control Interface, and the Power Thyristors:

- Static Var Compensator (Manual Control)
- Static Var Compensator (Automatic Voltage Control)
- Static Var Compensator (Automatic Reactive Power Control)

Specifications

Parameter	Value
Control Modes	
Control Modes	Manual control
	Automatic voltage control
	Automatic reactive power control
Manual Control	
TCR Firing Angle	0-180º
TSC 1 and TSC 2	Switched in or switched out
Automatic Voltage Control	
Line Voltage Command	90-150 V
Automatic Reactive Power Control	
Phase Adjustment	-90º to 90º

Static Synchronous Compensator (STATCOM) Control Function Set
581460 (9069-B0)


STATCOM Control
File View Help
STATIC SYNCHRONOUS COMPENSAT
(Automatic Voltage Control)
Show Connections
Controller Diagram
Show SCADA View
AC Bus Line Volt. Command (V)
58
108
Start/Stop
Meter
S1
Id Rect./Inv.
-2.00
A
S2
Iq Rect./Inv.
-2.00
A
S3
DC Bus Voltag
-800.0
DC
V
1FR ST MODULE SIMULATED

STATCOM Control Settings - 1FR ST MODULE SIMULATED

Function Selection	
Function	Static Synchronous Compensator
Function Settings	
Control Mode	Automatic Voltage Control
DC Bus Voltage Command (V)	200.0
AC Bus Line Voltage Command (V)	83.0
Phase Adjustment (°)	0
Active Current Controller Prop. Gain [Kp1]	0.10
Active Current Controller Int. Gain [Ki1]	4.00
Reactive Current Controller Prop. Gain [Kp2]	0.30
Reactive Current Controller Int. Gain [Ki2]	10.00
DC Bus Voltage Controller Prop. Gain [Kp3]	5.00
DC Bus Voltage Controller Int. Gain [Ki3]	10.00
AC Bus Line Voltage Controller Prop. Gain [Kp4]	2.50
AC Bus Line Voltage Controller Int. Gain [Ki4]	10.00
Status	Stopped

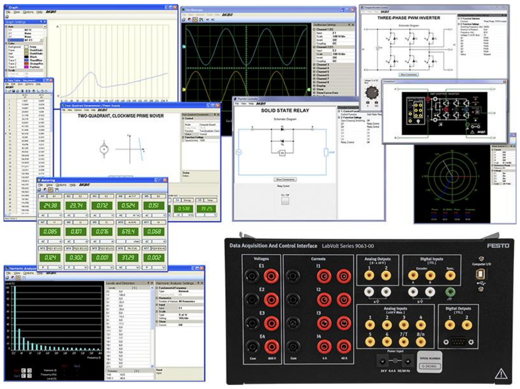
The Static Synchronous Compensator (STATCOM) Control Function Set enables the following devices required for the study of STATCOMs to be implemented using the Data Acquisition and Control Interface, and the IGBT Chopper/ Inverter:

- Static Synchronous Compensator (Automatic Voltage Control)
- Static Synchronous Compensator (Automatic Reactive Power Control)

Specifications

Parameter	Value
Control Modes	
Control Modes	Automatic Voltage Control
	Automatic Reactive Power Control
Automatic Voltage Control	
DC Bus Voltage Command	150-250 V
AC Bus Line Voltage Command	58-108 V
Phase Adjustment	-90° to 90°
Automatic Reactive Power Control	
DC Bus Voltage Command	150-250 V
Phase Adjustment	-90 to 90°

Data Acquisition and Control Interface
579695 (9063-J0)


THREE-PHASE PWM INVERTER
TWO-QUADRANT, CLOCKWISE PRIME MOVER
SOLID STATE RELAY
Data Acquisition And Control Interface LabVolt Series 9063-00
FESTO

The Data Acquisition and Control Interface (DACI) is a versatile USB peripheral used for measuring, observing, analyzing, and controlling electrical and mechanical parameters in electric power systems and power electronics circuits. For these purposes, a set of computer-based instruments as well as a variety of control functions are available for the DACI. These instruments and control functions are accessed through the LVDAC-EMS software. The LVDAC-EMS software, as well as all available upgrades, is free and can be downloaded anytime on the Festo Didactic website.

Together, the DACI and the LVDAC-EMS software allow training in various areas such as electric power technology, ac/dc machines, renewable energy, transmission lines, and power electronics using modern and versatile measuring instruments and control functions. LVDAC-EMS also offers the possibility to use pre-built SCADA interfaces for several applications to ease the view and understanding of the process taking place. The user guide provided allows students to quickly become familiar with the instruments and control functions available.

Model 9063-J includes the DACI, Model 9063, with the following function sets activated:

- Computer-Based Instrumentation Function, Model 9069-1
- Thyristor Control Function Set, Model 9069-3
- HVDC Transmission System Control Function Set, Model 9069-7
- SVC Control Function Set, Model 9069-8
- STATCOM Control Function Set, Model 9069-B

Manual

Description	Manual number
Computer-Based Instruments for EMS (User Guide)	585219 (86718-E0)

Table of Contents of the Manual(s)

Computer-Based Instruments for EMS (User Guide) (585219 (86718-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer

- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Additional Equipment Required to Perform the Exercises (Purchased separately)

Qty	Description	Model number
1	Personal Computer	579785 (8990-00) [117]
1	AC 24 V Wall Mount Power Supply	579696 (30004-20) [118]

Specifications

Parameter	Value
Insulated Voltage Inputs (4)	
Range (Low / High Scales)	-80 to +80 V / -800 to + 800 V (user-selectable through software)
Impedance (Low / High Scales)	326.6 kΩ / 3.25 MΩ
Bandwidth	DC to 65 kHz (-3 dB)
Accuracy	1% (dc to 10 kHz)
Insulation	800 V
Measurement Category	CAT II (283 V ac/400 V dc versus ground)
Insulated Current Inputs (4)	
Range (Low / High Scales)	-4 to +4 A / -40 to + 40 A (25 A rms)
Impedance (Low / High Scales)	5 mΩ / 50 mΩ
Bandwidth	DC to 65 kHz (-3 dB)
Accuracy	1% (dc to 10 kHz)
Insulation	800 V
Measurement Category	CAT II (283 V ac/400 V dc versus ground)
Analog Inputs (8)	
Voltage Range	-10 to +10 V
Impedance	> 10 MΩ
Bandwidth	DC to 125 kHz
Measured Parameters	User-selectable through software
Parameter-to-Voltage Ratio	User-determined through software
A/D Converter for Insulated and Analog Inputs (16)	
Type	Successive approximation
Resolution	12 bits
Integral Non-Linearity	≤ ±1.5 LSB
Differential Non-Linearity	≤ ±1 LSB
Maximum Sampling Rate	600 ksamples/s (one channel)
FIFO Buffer Size	16 ksamples
Analog Outputs (2)	
Voltage Range (2)	-10 to +10 V
Operational Load Impedance	> 600 Ω
D/A Converter for Analog Outputs (2)	
Type	Resistor string
Resolution	12 bits
Integral Non-Linearity	≤ ±8 LSB
Differential Non-Linearity	-0.5 to +0.7 LSB
Digital Inputs (3)	
Types	Encoder (2), synchronization (1)
Signal Level	0-5 V (TTL compatible)
Maximum Input Frequency	50 kHz
Impedance	5 kΩ
Digital Outputs (9)	

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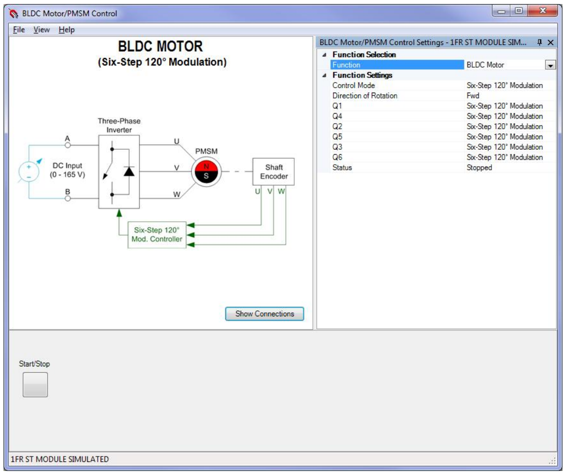
[117] Refer to the Computer Requirements in the System Specifications section of this datasheet if the computer is to be provided by the end-user. Only one computer is required per station. This model is available in multiple voltage- and frequency dependent variants. Contact a Festo representative to obtain the correct part number.

[118] Required if power is not supplied by the Power Supply, Model 8821-2. This model is available in multiple voltage- and frequency dependent variants. Contact a Festo representative to obtain the correct part number.

Parameter	Value
Types	Control (6 on a DB9 connector and 2 on 2 mm banana jacks), synchronization (1 on a DB9 connector)
Signal Level	0-5 V (TTL compatible)
Maximum Output Frequency	20 kHz (software-limited)
Impedance	200 Ω
Control Functions	
Activated Sets	Computer-Based Instrumentation Function, Model 9069-1
	Thyristor Control Function Set, Model 9069-3
	HVDC Transmission System Control Function Set, Model 9069-7
	SVC Control Function Set, Model 9069-8
	STATCOM Control Function Set, Model 9069-B
Computer I/O Interface	USB 2.0 full speed via type-B receptacle
Power Requirements	24 V - 0.4 A - 50/60 Hz
Accessories	
Included Accessories	2 m USB interconnection cable (1)
	24 V power cable (1)
	2 mm banana plug test leads (3)
	DB9 connector control cable (1)
Physical Characteristics	
Dimensions (H x W x D)	154 x 287 x 410 mm (6.1 x 11.3 x 16.1 in)
Net Weight	3.9 kg (8.6 lb)

BLDC Motor/PMSM Control Function Set 581457 (9069-60)



BLDC Motor/PMSM Control Settings - 1FR ST MODULE SIM...

Function Selection
Function: BLDC Motor

Function Settings
Control Mode: Six-Step 120° Modulation
Direction of Rotation: Fwd
Q1: Six-Step 120° Modulation
Q4: Six-Step 120° Modulation
Q2: Six-Step 120° Modulation
Q5: Six-Step 120° Modulation
Q3: Six-Step 120° Modulation
Q6: Six-Step 120° Modulation
Status: Stopped

The BLDC Motor/PMSM Control Function Set enables the following control types for brushless dc (BLDC) motors and permanent-magnet synchronous machines (PMSM) to be implemented using a Data Acquisition and Control Interface, and a IGBT Chopper/Inverter, or using two Data Acquisition and Control Interface, and two IGBT Chopper/Inverter:

- Three-Phase, Six-Step 120° Modulation Inverter

- Brushless DC Motor

- Permanent Magnet Synchronous Motor Drive

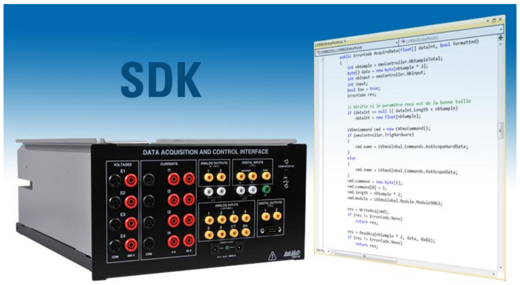
- Wind Turbine with Permanent Magnet Synchronous Generator

Specifications

Parameter	Value
Control Modes	
Control Modes	Three-Phase, Six-Step 120° Modulation Inverter
	Brushless DC Motor
	Permanent Magnet Synchronous Motor Drive
	Wind Turbine with Permanent Magnet Synchronous Generator
Three-Phase, Six-Step 120° Modulation Inverter	
Phase Sequence	Forward (1-2-3) or reverse (1-3-2)
Frequency	0-400 Hz
IGBTs Q1 to Q6	Six-step 120° modulation, on, or off
Brushless DC Motor	
Control Mode	Six-step 120° modulation or low-side six-step PWM
Direction of Rotation	Forward or reverse
Permanent Magnet Synchronous Motor Drive	
Control Mode	Constant V/f ratio or vector control
Switching Frequency	400 Hz to 20 kHz

Parameter	Value
Direction of Rotation	Forward or reverse
Frequency	0-300 Hz
Knee Peak Voltage	0-100% of dc bus voltage/2
Knee Frequency	1-300 Hz
Low-Speed Boost Voltage	0-25% of dc bus voltage/2
Modulation Type	Sinusoidal pulse-width modulation or space vector
Acceleration Time (0 to Knee)	0-100 s
Deceleration Time (Knee to 0)	0-100 s
Wind Turbine with Permanent Magnet Synchronous Generator - First Module (BLDC Motor/PMSM Control)	
Switching Frequency	400 Hz to 20 kHz
Direction of Rotation	Forward or reverse
MPP Tracker	On or off
Vector Control Direct Current Command	0-5 A
Vector Control Quadrature Current Limit	0-3.5 A
Wind Turbine with Permanent Magnet Synchronous Generator - Second Module (PWM Rectifier/Inverter Control)	
DC Bus Voltage Command	150-250 V
PWM Rectifier/Inverter Reactive Current Command	-1.5 A to 1.5 A
PWM Rectifier/Inverter Phase Adjustment	-90° to 90°

Software Development Kit (SDK)
581459 (9069-90)



The DACI SDK (Software Development Kit) offers the possibility to control various inputs and outputs of the Data Acquisition and Control Interface using third-party rapid prototyping software like Mathworks® MATLAB, National Instruments® LabVIEW, Microsoft Visual Studio and other programming tools that support Microsoft® .NET Framework 4.0. The SDK gives users the possibility to build their own advanced functions using the Data Acquisition and Control Interface.

The SDK includes the following:

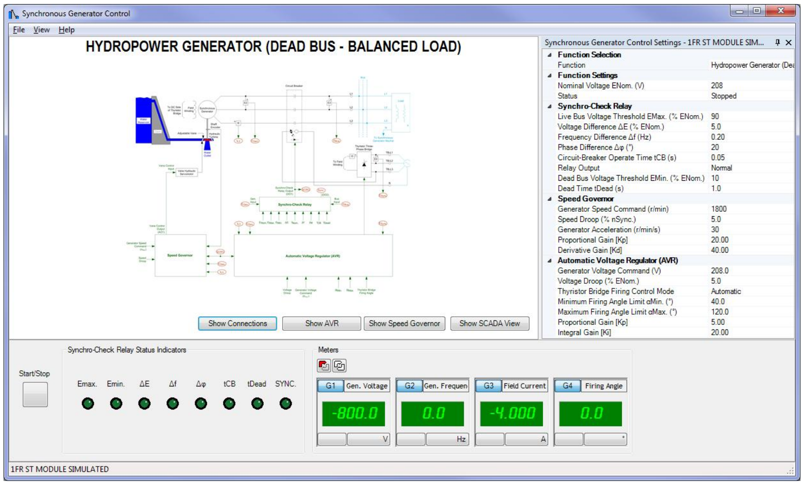
- DLL files for communication with the DACI
- Documentation related to the functions
- MATLAB (2010 or later), LabVIEW (2009 or later) and Visual Studio C# (2012 or later) example programs
- Binaries from the C# example. This application can be used to verify that your PC configuration is compatible with the SDK.

The following functions are available using the SDK:

- Acquisition through the voltage and current inputs
- Acquisition through the encoder inputs
- Acquisition through the analog inputs
- Control of the digital outputs
- Control of the analog outputs

Important Notice: One DACI SDK (Software Development Kit) must be ordered for each Data Acquisition and Control Interface to unlock the SDK features.

Synchronous Generator Control Function Set
579788 (9069-A0)


Synchronous Generator Control
File View Help
HYDROPOWER GENERATOR (DEAD BUS - BALANCED LOAD)
Show Connections
Show AVR
Show Speed Governor
Show SCADA View
Synchro-Check Relay Status Indicators
Start/Stop
Emax. Emin. ΔE Δf Δφ tCB tDead SYNC.
Meters
G1 Gen. Voltage -800.0 V
G2 Gen. Frequen 0.0 Hz
G3 Field Current -4.000 A
G4 Firing Angle 0.0 °
1FR ST MODULE SIMULATED

Synchronous Generator Control Settings - 1FR ST MODULE SIM...

Function Selection	
Function	Hydropower Generator (Dea
Function Settings	
Nominal Voltage ENom. (V)	208
Status	Stopped
Synchro-Check Relay	
Live Bus Voltage Threshold EMax. (% ENom.)	90
Voltage Difference ΔE (% ENom.)	5.0
Frequency Difference Δf (Hz)	0.20
Phase Difference Δφ (°)	20
Circuit-Breaker Operate Time tCB (s)	0.05
Relay Output	Normal
Dead Bus Voltage Threshold EMin. (% ENom.)	10
Dead Time tDead (s)	1.0
Speed Governor	
Generator Speed Command (r/min)	1800
Speed Droop (% nSync.)	5.0
Generator Acceleration (r/min/s)	30
Proportional Gain [Kp]	20.00
Derivative Gain [Kd]	40.00
Automatic Voltage Regulator (AVR)	
Generator Voltage Command (V)	208.0
Voltage Droop (% ENom.)	5.0
Thyristor Bridge Firing Control Mode	Automatic
Minimum Firing Angle Limit αMin. (°)	40.0
Maximum Firing Angle Limit αMax. (°)	120.0
Proportional Gain [Kp]	5.00
Integral Gain [Ki]	20.00

The Synchronous Generator Control Function Set enables the control of synchronous generators using different prime movers (emulated using the Four-Quadrant Dynamometer/Power Supply, and different control types for each prime mover. The function set allows the following prime movers and control types to be implemented using the Data Acquisition and Control Interface, and the Power Thyristors:

- Hydropower Generator (Dead Bus - Balanced Load)

- Hydropower Generator (Infinite Bus)

- Hydropower Generator (Balanced Infinite Bus)

- Hydropower Generator (Generator Paralleling - Balanced Bus)

- Generator (Microgrid)

Specifications

Parameter	Value
Control Functions	
Control Functions	Hydropower generator (dead bus - balanced load)
	Hydropower generator (infinite bus)
	Hydropower generator (balanced infinite bus)
	Hydropower generator (gen. paralleling - balanced bus)
	Generator (Microgrid)
Controller Features	Each function of the Synchronous Generator Control Function Set comprises a synchro-check relay, a speed governor, and an automatic voltage regulator.
Synchro-Check Relay	
Live Bus Voltage Threshold	50-100 V
Voltage Difference	2-40 V
Frequency Difference	0.02-2 Hz
Phase Difference	5-50°
Circuit-Breaker Operate Time	0.05-0.25 s
Relay Output	Normal, high, or low
Dead Bus Voltage Threshold	10-80% of nominal voltage
Dead Time	0.1-20 s
Speed Governor	
Speed Command	0-2000 r/min
Speed Droop	0-10%
Generator Acceleration	10-100 r/min/s
Automatic Voltage Regulator (AVR)	
Generator Voltage Command	0-240 V
Voltage Droop	0-10%
Thyristor Bridge Firing Control Mode	Automatic or manual
Minimum Firing Angle Limit	40-120°
Maximum Firing Angle Limit	120°

AC 24 V Wall Mount Power Supply
579696 (30004-20)

This 24 V AC Power Supply is used specifically to power specific components from our learning systems, such as the Data Acquisition and Control Interface and the protection mechanism of our electrical machines.

Specifications

Parameter	Value
Power Requirements	
Maximum Current	0.75 A
AC Power Network Installation	120 V – 50/60 Hz, must include live, neutral, and ground wires
Power Outputs	
Fixed, Single-Phase AC	24 V – 2,5 A

Hydrogen Cylinder Connection Kit
780548 (52863-00)

The Hydrogen Cylinder Connection Kit allows easy and quick connection of hydrogen cylinders to the quick coupling of a metal hydride canister. A pressure reducer ensures that the system's maximum inlet pressure is not exceeded.

Specifications

Parameter	Value
Hydrogen Cylinder Connection Kit	
Description	One-stage hydrogen pressure regulator
Max. Inlet Pressure	200 bar
Max. Outlet Pressure	17 bar
Connection	CGA, DIN, or BS

Hydrogen Storage Canister
579699 (87948-00)

The Metal Hydride Storage Canister can store enough hydrogen to be used for multiple experiments without requiring a compressed hydrogen cylinder for recharge. The canister is supplied empty and must be refilled from a compressed hydrogen gas canister or hydrogen generator before use.

Specifications

Parameter	Value
Storage Capacity (at a Charge Pressure of 17 bar)	250 Nl
Output	1.7 sl/min
Charge Pressure	10-17 bar
Charge Time	One hour at normal ambient temperature and with active cooling

Optional Equipment Description

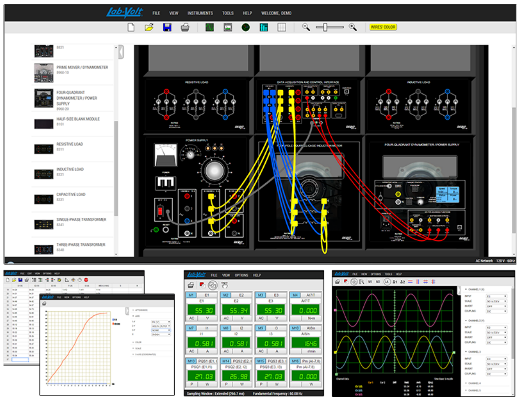
Digital Multimeter (Optional)
579782 (8946-20)

The Digital Multimeter consists of an Extech EX350 Digital Multimeter. It is ideal to perform voltage, current, and resistance measurements in exercises.

Specifications

Parameter	Value
Voltage	
Ranges	0-600 V ac/dc
Current	
Range	0-10 A ac/dc
Resistance	
Range	0-40 MΩ
Physical Characteristics	
Dimensions (H x W x D)	182 x 90 x 45 mm (7.17 x 3.54 x 1.77 in)
Net Weight	354 g (0.78 lb)

Electromechanical Systems Simulation Software (LVSIM®-EMS) - 1 User Online, 1 year (Optional)
586971 (8972-00)



The Electromechanical Systems Simulation Software (LVSIM®-EMS) is a simulation software that covers the same courseware as the following systems:

Computer-Assisted 0.2 kW Electromechanical Training System, Model 8006-1
DC and AC Power Circuits Training System, Model 8010-1
Electromechanical Training System, Model 8010-9
AC Power Transmission Training System, Model 8010-B

All workbooks parts of the systems above are available in the navigation menu of LVSIM-EMS for online consultation. To obtain the printing rights, Campus Licenses for each are available and must be ordered separately.

With LVSIM-EMS, all the standard EMS laboratory equipment is replaced by images of the actual EMS modules that students can manipulate on the computer screen. Students can identify and set up equipment for a given exercise, make the necessary connections between the virtual EMS modules, and verify the connections made without the need for actual EMS equipment.

Sophisticated mathematical models fully simulate the electrical and mechanical characteristics of all the actual EMS modules: power supplies, motors, generators, transformers, electrical and mechanical loads, etc. All modules simulated in the LVSIM-EMS software feature the same front panel information as the actual EMS modules. Short-circuit connections in the virtual equipment setup cause the virtual circuit-breaker protection to trip. This trip condition is clearly indicated on the virtual EMS modules.

Used either as a complement to the actual EMS laboratory equipment, or as a stand-alone product, LVSIM-EMS is a cost-effective tool that enables students to perform the same exercises as in the courseware of the above-mentioned training systems. When used as a stand-alone package, the LVSIM-EMS software allows students to perform hands-on activities related to electrical power and machines, including active, reactive, and apparent power, phasors, ac/dc motors and generators, three-phase circuits, and transformers.

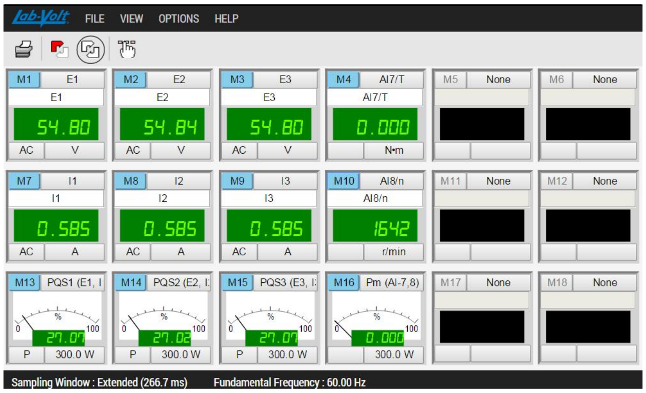
LVSIM-EMS is a web-browser based application **available in three different configurations.** The simulation software can either be installed locally on a Windows® personal computer (local version), on a Windows server (network version), or accessed directly online through the labvolt.com website at lvsim.labvolt.com (online version). Both network and local versions are delivered with perpetual license for the current version. The online version is delivered as a annual license with possibility to expand for more years.

Please visit https://lvsim.labvolt.com and try the online version!

Virtual Instrumentation

LVSIM-EMS comprises a set of conventional and specialized instruments that can be used for measuring, observing, and analyzing electrical and mechanical parameters in electric power systems and power electronic circuits. Each instrument appears as a window on the computer screen. The conventional instruments include ac/dc voltmeters and ammeters, power meters, and an eight-channel oscilloscope. The specialized instruments include a six-channel phasor analyzer, a harmonic analyzer, torque, speed, and mechanical power meters, and user-programmable meters. The software is also provided with data-recording and graph-plotting capabilities. The various instruments are briefly described in the next section of this datasheet.

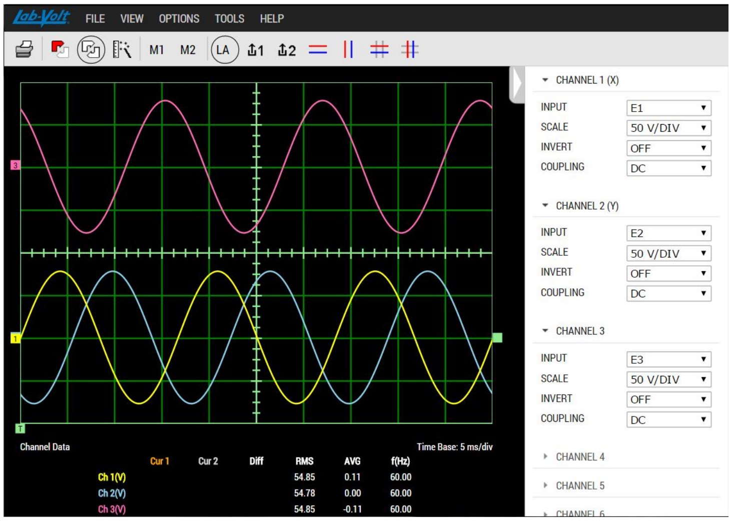
Metering Window



Sampling Window : Extended (266.7 ms) Fundamental Frequency : 60.00 Hz

The Metering window displays up to eighteen meters, which can be configured individually for measuring ac/dc voltage and current, electrical power (active, reactive, and apparent), torque, speed, mechanical power, etc. The voltage and current meters have several modes of operation that allow measurement of the mean (dc) value, RMS value, crest factor, RMS value of a particular harmonic (up to the 15th value), RMS value of the harmonics, and total harmonic distortion (THD). Six of the eighteen meters are user-programmable and give access to a larger variety of functions for measurement of power factor, efficiency, impedance, frequency, energy, phase shift, etc. The layout of the meters in the Metering window is user-customizable.

Oscilloscope



CHANNEL 1 (X)
INPUT: E1
SCALE: 50 V/DIV
INVERT: OFF
COUPLING: DC

CHANNEL 2 (Y)
INPUT: E2
SCALE: 50 V/DIV
INVERT: OFF
COUPLING: DC

CHANNEL 3
INPUT: E3
SCALE: 50 V/DIV
INVERT: OFF
COUPLING: DC

CHANNEL 4

CHANNEL 5

CHANNEL 6

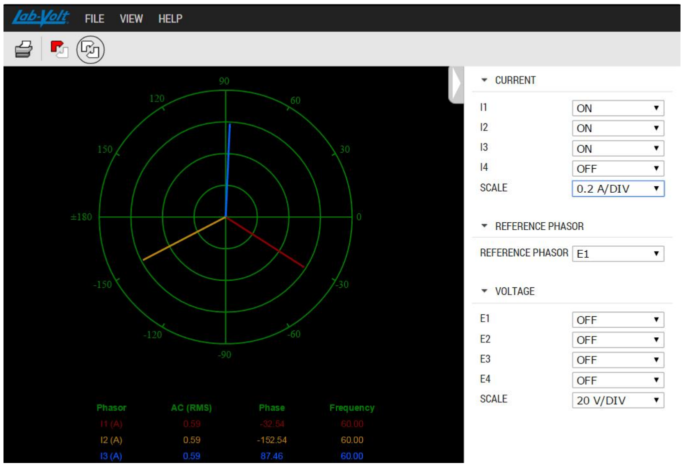
Channel Data

Time Base: 5 ms/div

	Cur 1	Cur 2	Diff	RMS	AVG	f(Hz)
Ch 1(V)				54.85	0.11	60.00
Ch 2(V)				54.78	0.00	60.00
Ch 3(V)				54.85	-0.11	60.00

The Oscilloscope displays up to eight waveforms simultaneously, each of a different color for easy identification. Each channel has independent vertical controls similar to those found on conventional oscilloscopes. An automatic scale-setting function allows the sensitivity of each channel to be set automatically according to the magnitude of the observed parameter. The time base and trigger controls are similar to those found on most oscilloscopes. The RMS value, average value, and frequency of each observed parameters can be displayed in the Oscilloscope window. Two vertical cursors can be activated to perform precise measurements at particular points on the displayed waveforms. The Oscilloscope toolbar includes two memory buttons for saving displayed waveforms.

Phasor Analyzer



CURRENT
I1: ON
I2: ON
I3: ON
I4: OFF
SCALE: 0.2 A/DIV

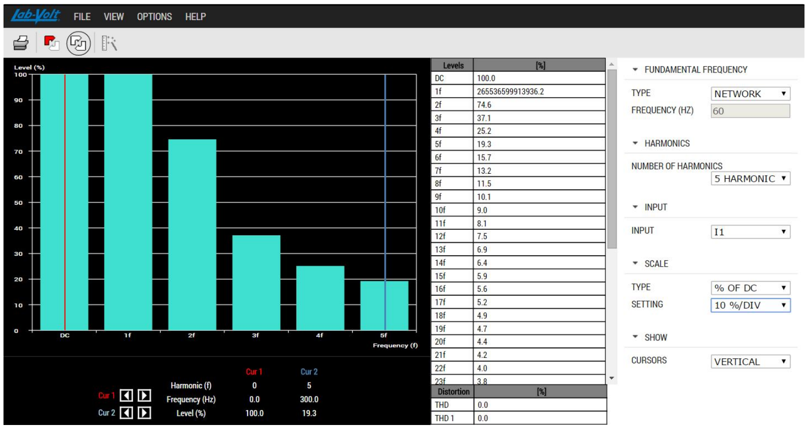
REFERENCE PHASOR
REFERENCE PHASOR: E1

VOLTAGE
E1: OFF
E2: OFF
E3: OFF
E4: OFF
SCALE: 20 V/DIV

Phasor	AC (RMS)	Phase	Frequency
I1 (A)	0.59	-32.54	60.00
I2 (A)	0.59	-152.54	60.00
I3 (A)	0.59	87.46	60.00

The Phasor Analyzer displays the phasors related to the measured voltages and currents. The amplitude and phase angle of each voltage and current is clearly represented by the orientation and length of their corresponding phasors, allowing easy comparison between the displayed parameters. This produces a unique and dynamic display of the voltages and currents in a circuit (especially in three-phase circuits) that cannot be obtained with conventional instruments. The RMS value, phase angle, and frequency of the voltage or current related to each phasor is displayed in the Phasor Analyzer window.

Harmonic Analyzer



Levels	[%]
DC	100.0
1f	265536599913936.2
2f	74.6
3f	37.1
4f	25.2
5f	19.3
6f	15.7
7f	13.2
8f	11.5
9f	10.1
10f	9.0
11f	8.1
12f	7.5
13f	6.9
14f	6.4
15f	5.9
16f	5.6
17f	5.2
18f	4.9
19f	4.7
20f	4.4
21f	4.2
22f	4.0
23f	3.8

Distortion	[%]
THD	0.0
THD 1	0.0

	Cur 1	Cur 2
Harmonic (f)	0	5
Frequency (Hz)	0.0	300.0
Level (%)	100.0	19.3

FUNDAMENTAL FREQUENCY
TYPE: NETWORK
FREQUENCY (HZ): 60

HARMONICS
NUMBER OF HARMONICS: 5 HARMONIC

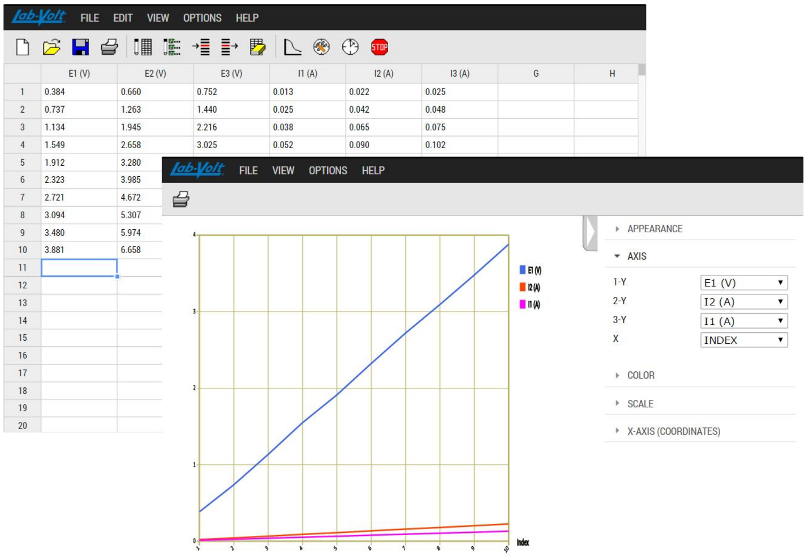
INPUT
INPUT: I1

SCALE
TYPE: % OF DC
SETTING: 10 %/DIV

SHOW
CURSORS: VERTICAL

The Harmonic Analyzer allows observation and analysis of the harmonic components in the measured voltages and currents. The fundamental frequency can be manually set to the ac power network frequency or automatically set to the frequency of the fundamental component of the selected voltage or current. The harmonic components of the selected voltage or current can be displayed using a vertical scale graduated in either absolute or relative values. A group of data displays in the Harmonic Analyzer indicates the values of the dc component of the selected voltage or current, as well as the total harmonic distortion (THD). Vertical and horizontal cursors can be displayed to perform precise measurements at particular points on the display. Since the equipment simulated by LVSIM-EMS produces only dc and sinusoidal ac signals (without harmonics), the Harmonic Analyzer, which is intended for use with devices that produce harmonics, is not often used with LVSIM-EMS.

Data Table and Graph Windows



	E1 (V)	E2 (V)	E3 (V)	I1 (A)	I2 (A)	I3 (A)	G	H
1	0.384	0.660	0.752	0.013	0.022	0.025		
2	0.737	1.263	1.440	0.025	0.042	0.048		
3	1.134	1.945	2.216	0.038	0.065	0.075		
4	1.549	2.658	3.025	0.052	0.090	0.102		
5	1.912	3.280						
6	2.323	3.985						
7	2.721	4.672						
8	3.094	5.307						
9	3.480	5.974						
10	3.881	6.658						
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

1-Y: E1 (V)
2-Y: I2 (A)
3-Y: I1 (A)
X: INDEX

The values indicated by the various meters in the Metering window, as well as values measured by the other instruments, can be recorded in the Data Table window with a click of the mouse. The values recorded in the Data Table can be saved to a file (ASCII-formatted file). The recorded data can also be used to plot graphs by selecting which parameter(s) to plot in the Graph window. This allows lab results to be plotted quickly and easily. More sophisticated graphs can be created by exporting the contents of the Data Table window to any spreadsheet program, such as Microsoft Excel®, directly through the Windows Clipboard.

Software Protection and Licensing

The local and network version provides a perpetual licence and the online access version provides a annual licence (additional years can be purchased when ordering).

The local and network version of LVSIM-EMS are copy-protected by means of a hardlock security device. When LVSIM-EMS detects the security device, students have complete access to all measuring functions of the virtual instruments and other protected features of LVSIM-EMS, as well as to the student manuals included with the simulation software. Note that students are allowed to copy the software onto their personal computer to allow them to prepare laboratories in advance.

Two different security devices are available for LVSIM-EMS: a single-user hardlock key, which can be inserted in the USB port of the user's computer, and a multiple-user hardlock key, which can be inserted in the USB port of the network server or any computer in the same network. Once the hardlock key is active on the network, the other computer will see the available licences. Alternately, the multiple-user hardlock key can be inserted in a USB port inside the server using a circuit board with edge-type connector (provided with the key) that can be installed in a PCI expansion slot of the server.

The multiple-user hardlock key can be installed in servers running under one of the following Microsoft® operating systems: Windows 7, Windows 8, Windows 10, Windows 2008 Server, and Windows 2013 Server. As its name indicates, the multiple-user hardlock key allows several users of a network to run LVSIM-EMS simultaneously. Different versions of LVSIM-EMS are available, each allowing a particular number of users.

Online Edition

The online version of LVSIM-EMS is accessible directly via the internet, and requires no software installation nor any update since the latest version of the software is always available. The online version of LVSIM-EMS also includes a demo mode that allows students to prepare laboratories in advance by familiarizing with the equipment and connections. The demo mode does not require any login.

Computer Requirements

Local and Network Versions:

- One (1) USB 2.0 port for the security dongle, Microsoft Windows 10 operating system recommended (compatible with Windows 7 and 8), basic dual core CPU, Google Chrome web browser installed (for better experience)

Online Version:

- Microsoft Windows 10 operating system recommended (compatible with Windows 7 and 8 but not fully compatible with mobile devices), basic dual core CPU, internet access (bandwidth usage of 50 KB/s maximum), Google Chrome web browser installed (for better experience)

List of Manuals

Description	**Manual number**
Electromechanical Systems Simulation Software (User Guide)	583879 (20858-E0)
Computer-Based Instruments for EMS (User Guide)	584396 (36221-E0)

Table of Contents of the Manual(s)

Electromechanical Systems Simulation Software (User Guide) (583879 (20858-E0))

- 1 Overview of LVSIM-EMS
- 2 Installing the Security Device
- 3 Installing and Running LVSIM-EMS

Computer-Based Instruments for EMS (User Guide) (584396 (36221-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Topic Coverage

- Fundamentals for Electric Power Technology
- Alternating Current
- Capacitors in AC Circuits
- Inductors in AC Circuits
- Power, Phasors, and Impedance in AC Circuits
- Three-Phase Circuits
- Special Transformer Connections
- Single- and three-Phase Transformers
- Fundamentals for Rotating Machines
- DC Motors and Generators
- Special Characteristics of DC Motors
- AC Induction and Synchronous Motors
- Three-Phase Synchronous Generators

Features & Benefits

- Replicates the Electromechanical Training System, enabling students to perform actual experiments using virtual equipment
  - Install, move, and remove EMS modules in and from the workstation
  - Modify module connections at any time and change the color of wires
  - Install a timing belt between two EMS machines
  - Verify module connections using a tool that highlights all wires connected to a same circuit point
  - Perform measurements of voltage, current, power, speed, torque, impedance, resistance, reactance, and frequency and display the values on digital or analog meters
  - Record measurements in a data table and plot graphs using the recorded data
  - Display waveforms on a multi-channel oscilloscope and ac voltages and currents as phasors
- Students prepare for laboratories in advance using virtual equipment, thereby decreasing the time they require to perform the exercises using actual equipment
- Decreases the quantity of actual equipment required per student
- Allows students to practice with EMS equipment operation and connection at home on a personal computer

Specifications

Parameter	Value
Computer Requirements	

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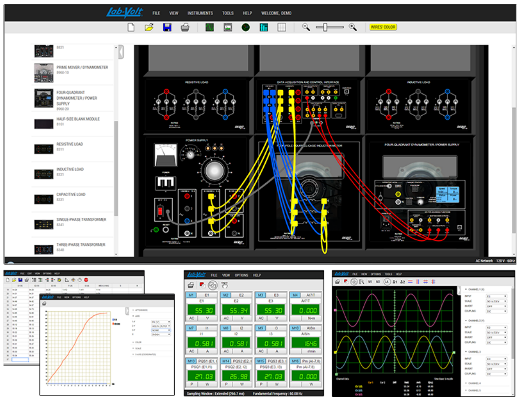
Electromechanical Systems Simulation Software (LVSIM®-EMS) - 5 Users Online, 1 year (Optional) 586974 (8972-A0)



The Electromechanical Systems Simulation Software (LVSIM®-EMS) is a simulation software that covers the same courseware as the following systems:

Computer-Assisted 0.2 kW Electromechanical Training System, Model 8006-1
DC and AC Power Circuits Training System, Model 8010-1
Electromechanical Training System, Model 8010-9
AC Power Transmission Training System, Model 8010-B

All workbooks parts of the systems above are available in the navigation menu of LVSIM-EMS for online consultation. To obtain the printing rights, Campus Licenses for each are available and must be ordered separately.

With LVSIM-EMS, all the standard EMS laboratory equipment is replaced by images of the actual EMS modules that students can manipulate on the computer screen. Students can identify and set up equipment for a given exercise, make the necessary connections between the virtual EMS modules, and verify the connections made without the need for actual EMS equipment.

Sophisticated mathematical models fully simulate the electrical and mechanical characteristics of all the actual EMS modules: power supplies, motors, generators, transformers, electrical and mechanical loads, etc. All modules simulated in the LVSIM-EMS software feature the same front panel information as the actual EMS modules. Short-circuit connections in the virtual equipment setup cause the virtual circuit-breaker protection to trip. This trip condition is clearly indicated on the virtual EMS modules.

Used either as a complement to the actual EMS laboratory equipment, or as a stand-alone product, LVSIM-EMS is a cost-effective tool that enables students to perform the same exercises as in the courseware of the above-mentioned training systems. When used as a stand-alone package, the LVSIM-EMS software allows students to perform hands-on activities related to electrical power and machines, including active, reactive, and apparent power, phasors, ac/dc motors and generators, three-phase circuits, and transformers.

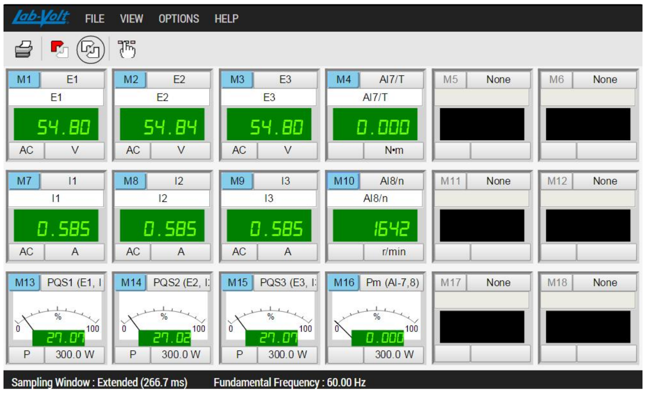
LVSIM-EMS is a web-browser based application **available in three different configurations.** The simulation software can either be installed locally on a Windows® personal computer (local version), on a Windows server (network version), or accessed directly online through the labvolt.com website at lvsim.labvolt.com (online version). Both network and local versions are delivered with perpetual license for the current version. The online version is delivered as a annual license with possibility to expand for more years.

Please visit https://lvsim.labvolt.com and try the online version!

Virtual Instrumentation

LVSIM-EMS comprises a set of conventional and specialized instruments that can be used for measuring, observing, and analyzing electrical and mechanical parameters in electric power systems and power electronic circuits. Each instrument appears as a window on the computer screen. The conventional instruments include ac/dc voltmeters and ammeters, power meters, and an eight-channel oscilloscope. The specialized instruments include a six-channel phasor analyzer, a harmonic analyzer, torque, speed, and mechanical power meters, and user-programmable meters. The software is also provided with data-recording and graph-plotting capabilities. The various instruments are briefly described in the next section of this datasheet.

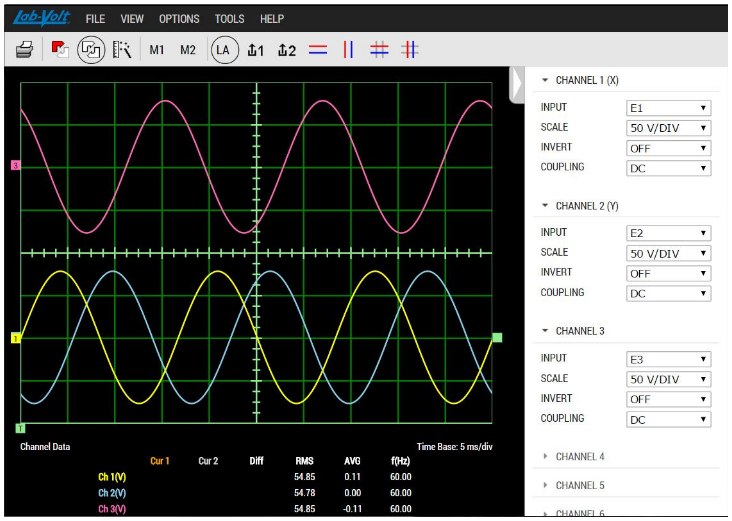
Metering Window


Lab-Volt
FILE
VIEW
OPTIONS
HELP
M1
E1
E1
54.80
AC
V
M2
E2
E2
54.84
AC
V
M3
E3
E3
54.80
AC
V
M4
AI7/T
AI7/T
0.000
N•m
M5
None
M6
None
M7
I1
I1
0.585
AC
A
M8
I2
I2
0.585
AC
A
M9
I3
I3
0.585
AC
A
M10
AI8/n
AI8/n
1642
r/min
M11
None
M12
None
M13
PQS1 (E1, I
%
0
100
27.07
P
300.0 W
M14
PQS2 (E2, I:
%
0
100
27.02
P
300.0 W
M15
PQS3 (E3, I:
%
0
100
27.07
P
300.0 W
M16
Pm (AI-7,8)
%
0
100
0.000
300.0 W
M17
None
M18
None

Sampling Window : Extended (266.7 ms)   Fundamental Frequency : 60.00 Hz

The Metering window displays up to eighteen meters, which can be configured individually for measuring ac/dc voltage and current, electrical power (active, reactive, and apparent), torque, speed, mechanical power, etc. The voltage and current meters have several modes of operation that allow measurement of the mean (dc) value, RMS value, crest factor, RMS value of a particular harmonic (up to the 15th value), RMS value of the harmonics, and total harmonic distortion (THD). Six of the eighteen meters are user-programmable and give access to a larger variety of functions for measurement of power factor, efficiency, impedance, frequency, energy, phase shift, etc. The layout of the meters in the Metering window is user-customizable.

Oscilloscope


Lab-Volt
FILE
VIEW
OPTIONS
TOOLS
HELP
M1
M2
LA
1
2
3
1
T

CHANNEL 1 (X)
INPUT E1
SCALE 50 V/DIV
INVERT OFF
COUPLING DC

CHANNEL 2 (Y)
INPUT E2
SCALE 50 V/DIV
INVERT OFF
COUPLING DC

CHANNEL 3
INPUT E3
SCALE 50 V/DIV
INVERT OFF
COUPLING DC

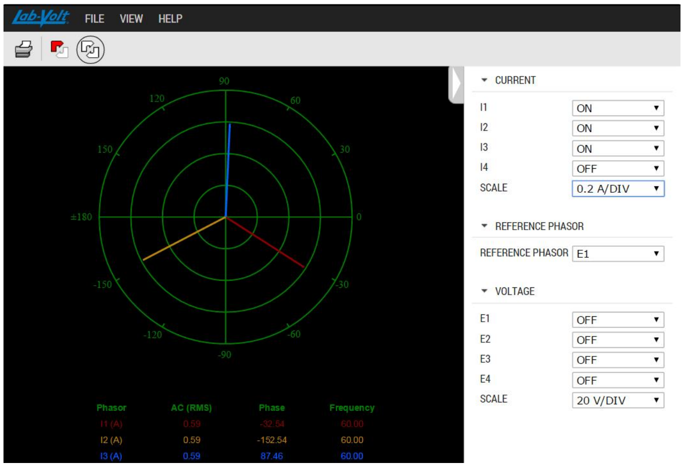
CHANNEL 4
CHANNEL 5
CHANNEL 6

Channel Data   Time Base: 5 ms/div

	Cur 1	Cur 2	Diff	RMS	AVG	f(Hz)
Ch 1(V)				54.85	0.11	60.00
Ch 2(V)				54.78	0.00	60.00
Ch 3(V)				54.85	-0.11	60.00

The Oscilloscope displays up to eight waveforms simultaneously, each of a different color for easy identification. Each channel has independent vertical controls similar to those found on conventional oscilloscopes. An automatic scale-setting function allows the sensitivity of each channel to be set automatically according to the magnitude of the observed parameter. The time base and trigger controls are similar to those found on most oscilloscopes. The RMS value, average value, and frequency of each observed parameters can be displayed in the Oscilloscope window. Two vertical cursors can be activated to perform precise measurements at particular points on the displayed waveforms. The Oscilloscope toolbar includes two memory buttons for saving displayed waveforms.

Phasor Analyzer



CURRENT
I1: ON
I2: ON
I3: ON
I4: OFF
SCALE: 0.2 A/DIV

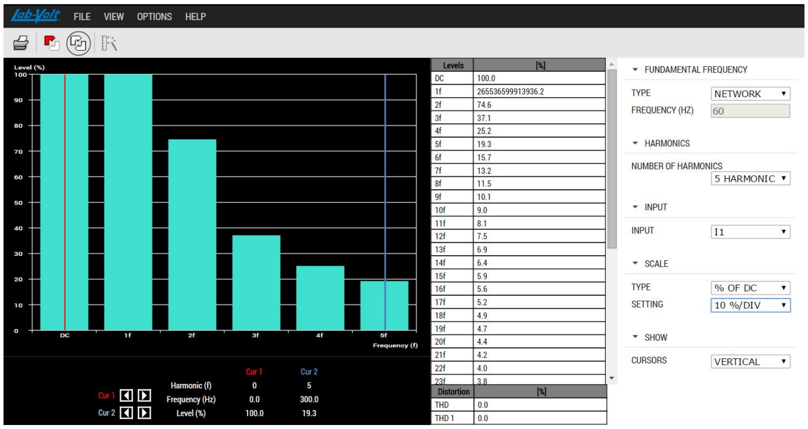
REFERENCE PHASOR
REFERENCE PHASOR: E1

VOLTAGE
E1: OFF
E2: OFF
E3: OFF
E4: OFF
SCALE: 20 V/DIV

Phasor	AC (RMS)	Phase	Frequency
I1 (A)	0.59	-32.54	60.00
I2 (A)	0.59	-152.54	60.00
I3 (A)	0.59	87.46	60.00

The Phasor Analyzer displays the phasors related to the measured voltages and currents. The amplitude and phase angle of each voltage and current is clearly represented by the orientation and length of their corresponding phasors, allowing easy comparison between the displayed parameters. This produces a unique and dynamic display of the voltages and currents in a circuit (especially in three-phase circuits) that cannot be obtained with conventional instruments. The RMS value, phase angle, and frequency of the voltage or current related to each phasor is displayed in the Phasor Analyzer window.

Harmonic Analyzer



	Cur 1	Cur 2
Harmonic (f)	0	5
Frequency (Hz)	0.0	300.0
Level (%)	100.0	19.3

Levels	[%]
DC	100.0
1f	265536599913936.2
2f	74.6
3f	37.1
4f	25.2
5f	19.3
6f	15.7
7f	13.2
8f	11.5
9f	10.1
10f	9.0
11f	8.1
12f	7.5
13f	6.9
14f	6.4
15f	5.9
16f	5.6
17f	5.2
18f	4.9
19f	4.7
20f	4.4
21f	4.2
22f	4.0
23f	3.8

Distortion	[%]
THD	0.0
THD 1	0.0

FUNDAMENTAL FREQUENCY
TYPE: NETWORK
FREQUENCY (HZ): 60

HARMONICS
NUMBER OF HARMONICS: 5 HARMONIC

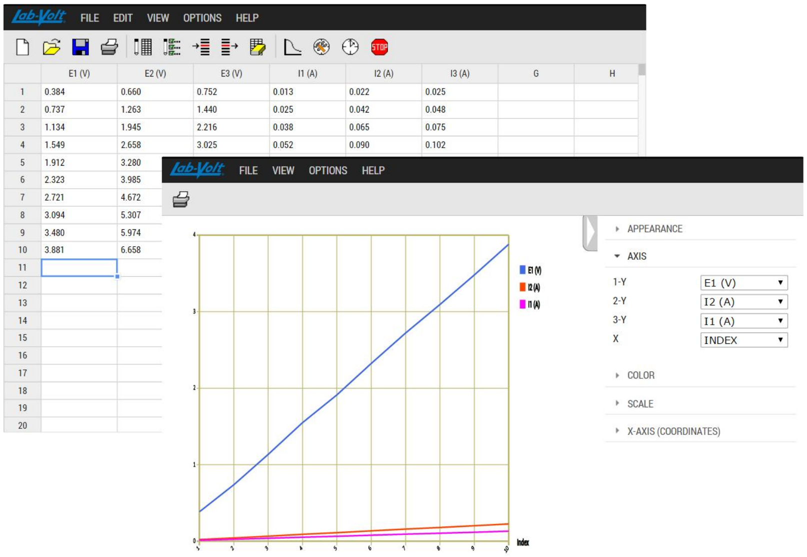
INPUT
INPUT: I1

SCALE
TYPE: % OF DC
SETTING: 10 %/DIV

SHOW
CURSORS: VERTICAL

The Harmonic Analyzer allows observation and analysis of the harmonic components in the measured voltages and currents. The fundamental frequency can be manually set to the ac power network frequency or automatically set to the frequency of the fundamental component of the selected voltage or current. The harmonic components of the selected voltage or current can be displayed using a vertical scale graduated in either absolute or relative values. A group of data displays in the Harmonic Analyzer indicates the values of the dc component of the selected voltage or current, as well as the total harmonic distortion (THD). Vertical and horizontal cursors can be displayed to perform precise measurements at particular points on the display. Since the equipment simulated by LVSIM-EMS produces only dc and sinusoidal ac signals (without harmonics), the Harmonic Analyzer, which is intended for use with devices that produce harmonics, is not often used with LVSIM-EMS.

Data Table and Graph Windows



	E1 (V)	E2 (V)	E3 (V)	I1 (A)	I2 (A)	I3 (A)	G	H
1	0.384	0.660	0.752	0.013	0.022	0.025		
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11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

1-Y E1 (V)
2-Y I2 (A)
3-Y I1 (A)
X INDEX

The values indicated by the various meters in the Metering window, as well as values measured by the other instruments, can be recorded in the Data Table window with a click of the mouse. The values recorded in the Data Table can be saved to a file (ASCII-formatted file). The recorded data can also be used to plot graphs by selecting which parameter(s) to plot in the Graph window. This allows lab results to be plotted quickly and easily. More sophisticated graphs can be created by exporting the contents of the Data Table window to any spreadsheet program, such as Microsoft Excel®, directly through the Windows Clipboard.

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Computer Requirements

Local and Network Versions:

- One (1) USB 2.0 port for the security dongle, Microsoft Windows 10 operating system recommended (compatible with Windows 7 and 8), basic dual core CPU, Google Chrome web browser installed (for better experience)

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List of Manuals

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Table of Contents of the Manual(s)

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Topic Coverage

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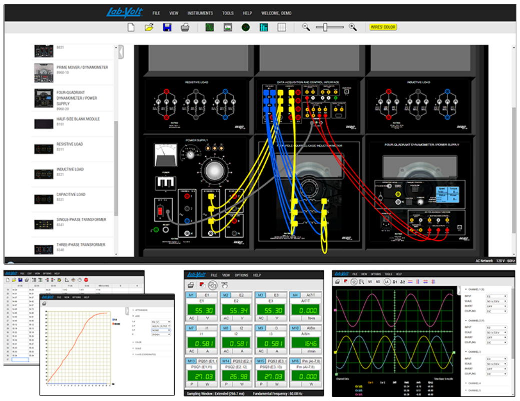
Electromechanical Systems Simulation Software (LVSIM®-EMS) - 10 Users Online, 1 year (Optional)

586977 (8972-B0)



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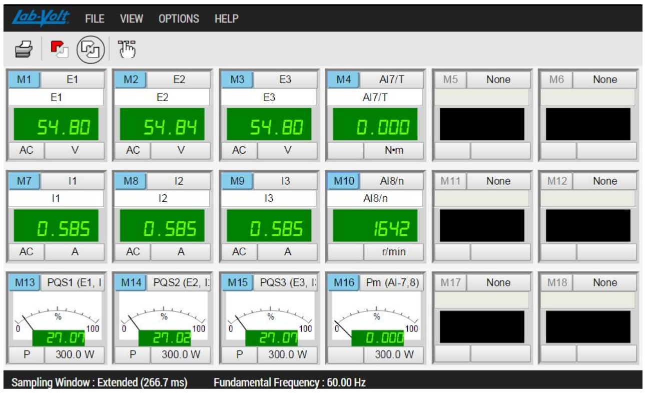
Please visit https://lvsim.labvolt.com and try the online version!

Virtual Instrumentation

LVSIM-EMS comprises a set of conventional and specialized instruments that can be used for measuring, observing, and analyzing electrical and mechanical parameters in electric power systems and power electronic circuits. Each instrument appears as a window on the computer screen. The conventional instruments include ac/dc voltmeters and ammeters, power meters, and an eight-channel oscilloscope. The specialized instruments include a six-channel phasor analyzer, a harmonic analyzer, torque, speed, and mechanical power meters, and user-programmable meters. The software is also provided with data-recording and graph-plotting capabilities. The various instruments are briefly described in the next section of this datasheet.

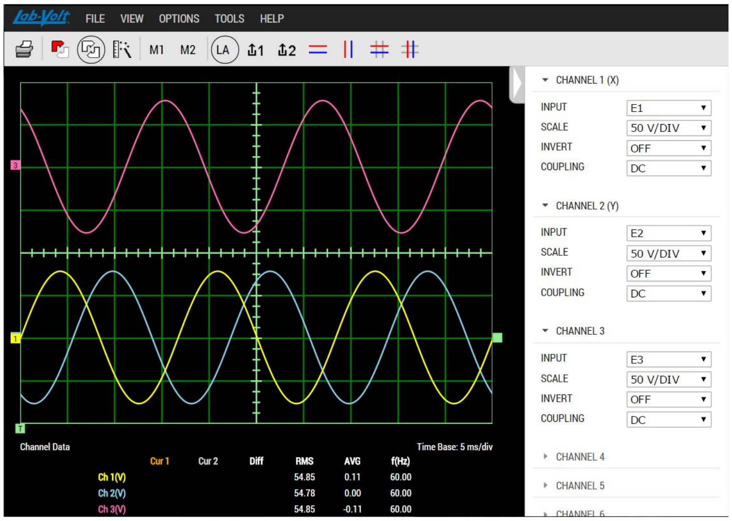
Metering Window



Sampling Window : Extended (266.7 ms)   Fundamental Frequency : 60.00 Hz

The Metering window displays up to eighteen meters, which can be configured individually for measuring ac/dc voltage and current, electrical power (active, reactive, and apparent), torque, speed, mechanical power, etc. The voltage and current meters have several modes of operation that allow measurement of the mean (dc) value, RMS value, crest factor, RMS value of a particular harmonic (up to the 15th value), RMS value of the harmonics, and total harmonic distortion (THD). Six of the eighteen meters are user-programmable and give access to a larger variety of functions for measurement of power factor, efficiency, impedance, frequency, energy, phase shift, etc. The layout of the meters in the Metering window is user-customizable.

Oscilloscope



CHANNEL 1 (X)
INPUT E1
SCALE 50 V/DIV
INVERT OFF
COUPLING DC

CHANNEL 2 (Y)
INPUT E2
SCALE 50 V/DIV
INVERT OFF
COUPLING DC

CHANNEL 3
INPUT E3
SCALE 50 V/DIV
INVERT OFF
COUPLING DC

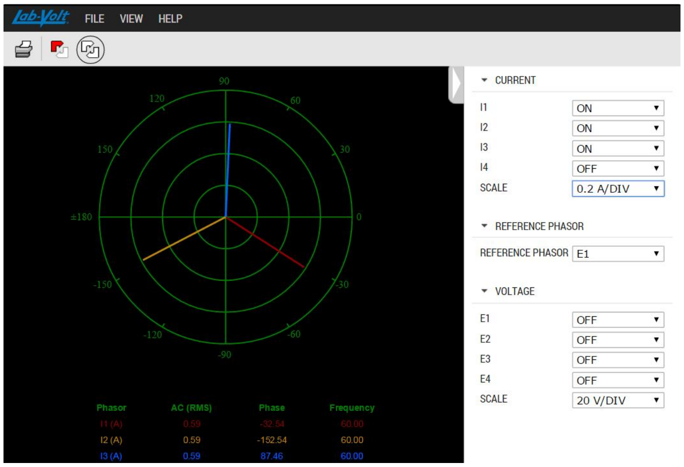
CHANNEL 4
CHANNEL 5
CHANNEL 6

Channel Data
Time Base: 5 ms/div

	Cur 1	Cur 2	Diff	RMS	AVG	f(Hz)
Ch 1(V)				54.85	0.11	60.00
Ch 2(V)				54.78	0.00	60.00
Ch 3(V)				54.85	-0.11	60.00

The Oscilloscope displays up to eight waveforms simultaneously, each of a different color for easy identification. Each channel has independent vertical controls similar to those found on conventional oscilloscopes. An automatic scale-setting function allows the sensitivity of each channel to be set automatically according to the magnitude of the observed parameter. The time base and trigger controls are similar to those found on most oscilloscopes. The RMS value, average value, and frequency of each observed parameters can be displayed in the Oscilloscope window. Two vertical cursors can be activated to perform precise measurements at particular points on the displayed waveforms. The Oscilloscope toolbar includes two memory buttons for saving displayed waveforms.

Phasor Analyzer



CURRENT
I1 ON
I2 ON
I3 ON
I4 OFF
SCALE 0.2 A/DIV

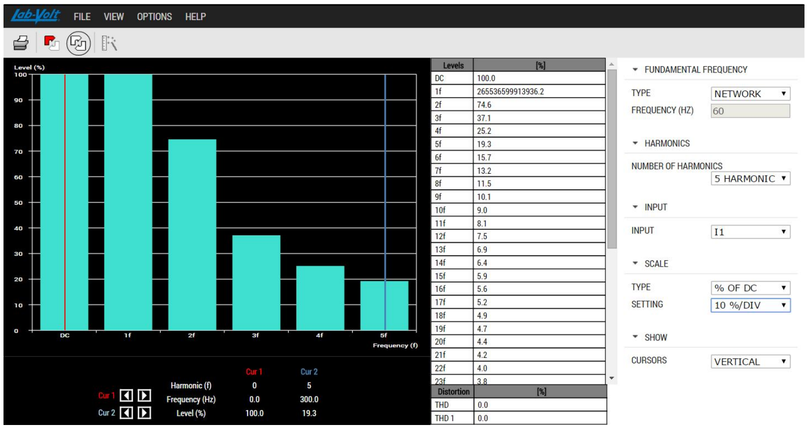
REFERENCE PHASOR
REFERENCE PHASOR E1

VOLTAGE
E1 OFF
E2 OFF
E3 OFF
E4 OFF
SCALE 20 V/DIV

Phasor	AC (RMS)	Phase	Frequency
I1 (A)	0.59	-32.54	60.00
I2 (A)	0.59	-152.54	60.00
I3 (A)	0.59	87.46	60.00

The Phasor Analyzer displays the phasors related to the measured voltages and currents. The amplitude and phase angle of each voltage and current is clearly represented by the orientation and length of their corresponding phasors, allowing easy comparison between the displayed parameters. This produces a unique and dynamic display of the voltages and currents in a circuit (especially in three-phase circuits) that cannot be obtained with conventional instruments. The RMS value, phase angle, and frequency of the voltage or current related to each phasor is displayed in the Phasor Analyzer window.

Harmonic Analyzer



	Cur 1	Cur 2
Harmonic (f)	0	5
Frequency (Hz)	0.0	300.0
Level (%)	100.0	19.3

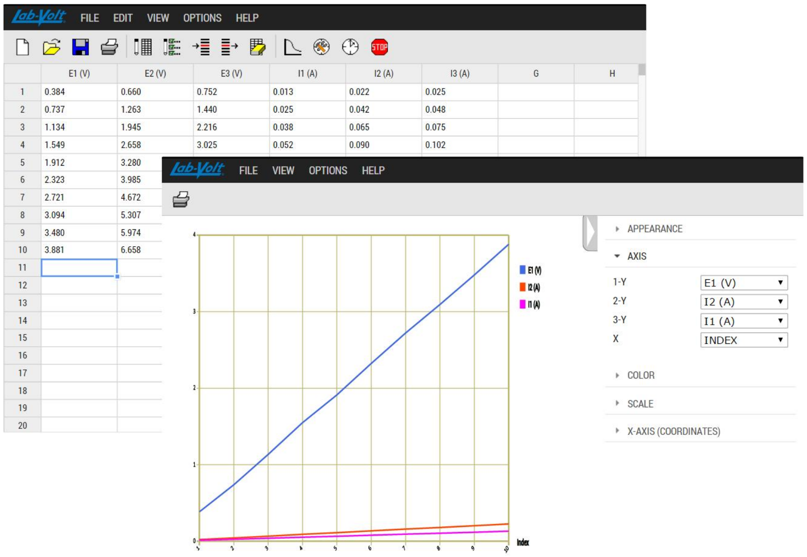
Levels	[%]
DC	100.0
1f	265536599913936.2
2f	74.6
3f	37.1
4f	25.2
5f	19.3
6f	15.7
7f	13.2
8f	11.5
9f	10.1
10f	9.0
11f	8.1
12f	7.5
13f	6.9
14f	6.4
15f	5.9
16f	5.6
17f	5.2
18f	4.9
19f	4.7
20f	4.4
21f	4.2
22f	4.0
23f	3.8

Distortion	[%]
THD	0.0
THD 1	0.0

FUNDAMENTAL FREQUENCY
TYPE: NETWORK
FREQUENCY (HZ): 60
HARMONICS
NUMBER OF HARMONICS: 5 HARMONIC
INPUT
INPUT: I1
SCALE
TYPE: % OF DC
SETTING: 10 %/DIV
SHOW
CURSORS: VERTICAL

The Harmonic Analyzer allows observation and analysis of the harmonic components in the measured voltages and currents. The fundamental frequency can be manually set to the ac power network frequency or automatically set to the frequency of the fundamental component of the selected voltage or current. The harmonic components of the selected voltage or current can be displayed using a vertical scale graduated in either absolute or relative values. A group of data displays in the Harmonic Analyzer indicates the values of the dc component of the selected voltage or current, as well as the total harmonic distortion (THD). Vertical and horizontal cursors can be displayed to perform precise measurements at particular points on the display. Since the equipment simulated by LVSIM-EMS produces only dc and sinusoidal ac signals (without harmonics), the Harmonic Analyzer, which is intended for use with devices that produce harmonics, is not often used with LVSIM-EMS.

Data Table and Graph Windows



	E1 (V)	E2 (V)	E3 (V)	I1 (A)	I2 (A)	I3 (A)	G	H
1	0.384	0.660	0.752	0.013	0.022	0.025		
2	0.737	1.263	1.440	0.025	0.042	0.048		
3	1.134	1.945	2.216	0.038	0.065	0.075		
4	1.549	2.658	3.025	0.052	0.090	0.102		
5	1.912	3.280						
6	2.323	3.985						
7	2.721	4.672						
8	3.094	5.307						
9	3.480	5.974						
10	3.881	6.658						
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

1-Y: E1 (V)
2-Y: I2 (A)
3-Y: I1 (A)
X: INDEX

The values indicated by the various meters in the Metering window, as well as values measured by the other instruments, can be recorded in the Data Table window with a click of the mouse. The values recorded in the Data Table can be saved to a file (ASCII-formatted file). The recorded data can also be used to plot graphs by selecting which parameter(s) to plot in the Graph window. This allows lab results to be plotted quickly and easily. More sophisticated graphs can be created by exporting the contents of the Data Table window to any spreadsheet program, such as Microsoft Excel®, directly through the Windows Clipboard.

Software Protection and Licensing

The local and network version provides a perpetual licence and the online access version provides a annual licence (additional years can be purchased when ordering).

The local and network version of LVSIM-EMS are copy-protected by means of a hardlock security device. When LVSIM-EMS detects the security device, students have complete access to all measuring functions of the virtual instruments and other protected features of LVSIM-EMS, as well as to the student manuals included with the simulation software. Note that students are allowed to copy the software onto their personal computer to allow them to prepare laboratories in advance.

Two different security devices are available for LVSIM-EMS: a single-user hardlock key, which can be inserted in the USB port of the user's computer, and a multiple-user hardlock key, which can be inserted in the USB port of the network server or any computer in the same network. Once the hardlock key is active on the network, the other computer will see the available licences. Alternately, the multiple-user hardlock key can be inserted in a USB port inside the server using a circuit board with edge-type connector (provided with the key) that can be installed in a PCI expansion slot of the server.

The multiple-user hardlock key can be installed in servers running under one of the following Microsoft® operating systems: Windows 7, Windows 8, Windows 10, Windows 2008 Server, and Windows 2013 Server. As its name indicates, the multiple-user hardlock key allows several users of a network to run LVSIM-EMS simultaneously. Different versions of LVSIM-EMS are available, each allowing a particular number of users.

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The online version of LVSIM-EMS is accessible directly via the internet, and requires no software installation nor any update since the latest version of the software is always available. The online version of LVSIM-EMS also includes a demo mode that allows students to prepare laboratories in advance by familiarizing with the equipment and connections. The demo mode does not require any login.

Computer Requirements

Local and Network Versions:

- One (1) USB 2.0 port for the security dongle, Microsoft Windows 10 operating system recommended (compatible with Windows 7 and 8), basic dual core CPU, Google Chrome web browser installed (for better experience)

Online Version:

- Microsoft Windows 10 operating system recommended (compatible with Windows 7 and 8 but not fully compatible with mobile devices), basic dual core CPU, internet access (bandwidth usage of 50 KB/s maximum), Google Chrome web browser installed (for better experience)

List of Manuals

Description	Manual number
Electromechanical Systems Simulation Software (User Guide)	583879 (20858-E0)
Computer-Based Instruments for EMS (User Guide)	584396 (36221-E0)

Table of Contents of the Manual(s)

Electromechanical Systems Simulation Software (User Guide) (583879 (20858-E0))

- 1 Overview of LVSIM-EMS
- 2 Installing the Security Device
- 3 Installing and Running LVSIM-EMS

Computer-Based Instruments for EMS (User Guide) (584396 (36221-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Topic Coverage

- Fundamentals for Electric Power Technology
- Alternating Current
- Capacitors in AC Circuits
- Inductors in AC Circuits
- Power, Phasors, and Impedance in AC Circuits
- Three-Phase Circuits
- Special Transformer Connections
- Single- and three-Phase Transformers
- Fundamentals for Rotating Machines
- DC Motors and Generators
- Special Characteristics of DC Motors
- AC Induction and Synchronous Motors
- Three-Phase Synchronous Generators

Features & Benefits

- Replicates the Electromechanical Training System, enabling students to perform actual experiments using virtual equipment
  - Install, move, and remove EMS modules in and from the workstation
  - Modify module connections at any time and change the color of wires
  - Install a timing belt between two EMS machines
  - Verify module connections using a tool that highlights all wires connected to a same circuit point
  - Perform measurements of voltage, current, power, speed, torque, impedance, resistance, reactance, and frequency and display the values on digital or analog meters
  - Record measurements in a data table and plot graphs using the recorded data
  - Display waveforms on a multi-channel oscilloscope and ac voltages and currents as phasors
- Students prepare for laboratories in advance using virtual equipment, thereby decreasing the time they require to perform the exercises using actual equipment
- Decreases the quantity of actual equipment required per student
- Allows students to practice with EMS equipment operation and connection at home on a personal computer

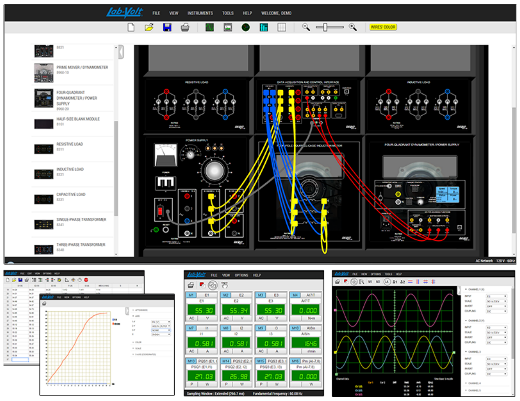
Specifications

Parameter	Value
Computer Requirements	

Parameter	Value
Local and Network versions	One (1) USB 2.0 port for the security dongle, Microsoft Windows 10 operating system recommended (compatible with Windows 7 and 8), basic dual core CPU, Google Chrome web browser installed (for better experience)
Online version	Microsoft Windows 10 operating system recommended (compatible with Windows 7 and 8 but not fully compatible with mobile devices), basic dual core CPU, internet access (bandwidth usage of 50 KB/s maximum), Google Chrome web browser installed (for better experience)

Electromechanical Systems Simulation Software (LVSIM®-EMS) - 15 Users Online, 1 year (Optional)

586980 (8972-C0)



The Electromechanical Systems Simulation Software (LVSIM®-EMS) is a simulation software that covers the same courseware as the following systems:

Computer-Assisted 0.2 kW Electromechanical Training System, Model 8006-1
DC and AC Power Circuits Training System, Model 8010-1
Electromechanical Training System, Model 8010-9
AC Power Transmission Training System, Model 8010-B

All workbooks parts of the systems above are available in the navigation menu of LVSIM-EMS for online consultation. To obtain the printing rights, Campus Licenses for each are available and must be ordered separately.

With LVSIM-EMS, all the standard EMS laboratory equipment is replaced by images of the actual EMS modules that students can manipulate on the computer screen. Students can identify and set up equipment for a given exercise, make the necessary connections between the virtual EMS modules, and verify the connections made without the need for actual EMS equipment.

Sophisticated mathematical models fully simulate the electrical and mechanical characteristics of all the actual EMS modules: power supplies, motors, generators, transformers, electrical and mechanical loads, etc. All modules simulated in the LVSIM-EMS software feature the same front panel information as the actual EMS modules. Short-circuit connections in the virtual equipment setup cause the virtual circuit-breaker protection to trip. This trip condition is clearly indicated on the virtual EMS modules.

Used either as a complement to the actual EMS laboratory equipment, or as a stand-alone product, LVSIM-EMS is a cost-effective tool that enables students to perform the same exercises as in the courseware of the above-mentioned training systems. When used as a stand-alone package, the LVSIM-EMS software allows students to perform hands-on activities related to electrical power and machines, including active, reactive, and apparent power, phasors, ac/dc motors and generators, three-phase circuits, and transformers.

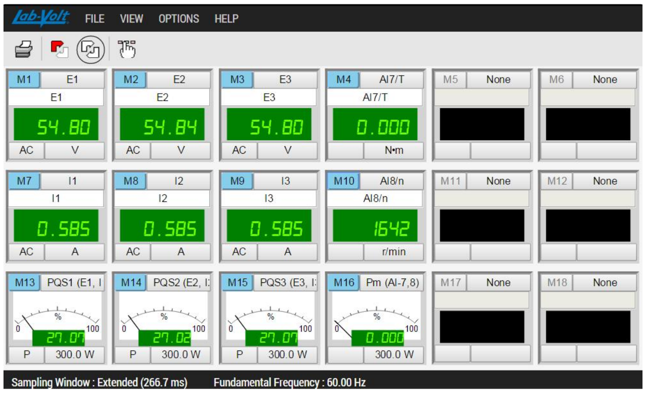
LVSIM-EMS is a web-browser based application **available in three different configurations.** The simulation software can either be installed locally on a Windows® personal computer (local version), on a Windows server (network version), or accessed directly online through the labvolt.com website at lvsim.labvolt.com (online version). Both network and local versions are delivered with perpetual license for the current version. The online version is delivered as a annual license with possibility to expand for more years.

Please visit https://lvsim.labvolt.com and try the online version!

Virtual Instrumentation

LVSIM-EMS comprises a set of conventional and specialized instruments that can be used for measuring, observing, and analyzing electrical and mechanical parameters in electric power systems and power electronic circuits. Each instrument appears as a window on the computer screen. The conventional instruments include ac/dc voltmeters and ammeters, power meters, and an eight-channel oscilloscope. The specialized instruments include a six-channel phasor analyzer, a harmonic analyzer, torque, speed, and mechanical power meters, and user-programmable meters. The software is also provided with data-recording and graph-plotting capabilities. The various instruments are briefly described in the next section of this datasheet.

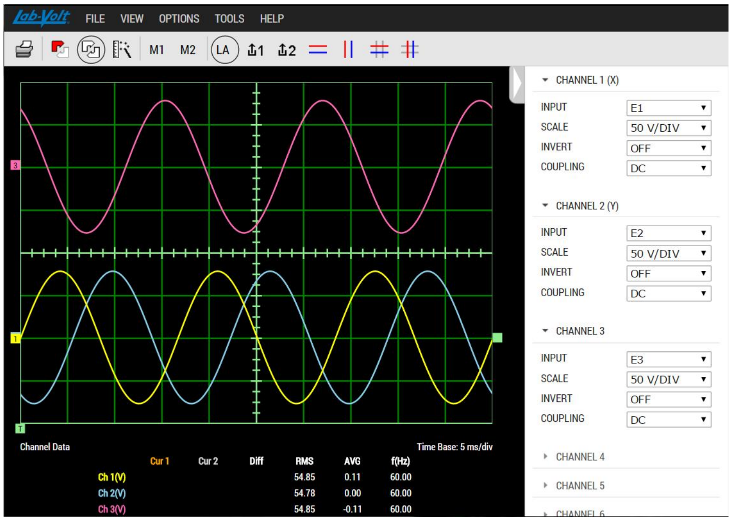
Metering Window


Lab-Volt
FILE
VIEW
OPTIONS
HELP
M1 E1 E1 54.80 AC V
M2 E2 E2 54.84 AC V
M3 E3 E3 54.80 AC V
M4 AI7/T AI7/T 0.000 N·m
M5 None
M6 None
M7 I1 I1 0.585 AC A
M8 I2 I2 0.585 AC A
M9 I3 I3 0.585 AC A
M10 AI8/n AI8/n 1642 r/min
M11 None
M12 None
M13 PQS1 (E1, I 27.07 P 300.0 W
M14 PQS2 (E2, I 27.02 P 300.0 W
M15 PQS3 (E3, I 27.07 P 300.0 W
M16 Pm (AI-7,8) 0.000 300.0 W
M17 None
M18 None

Sampling Window : Extended (266.7 ms)
Fundamental Frequency : 60.00 Hz

The Metering window displays up to eighteen meters, which can be configured individually for measuring ac/dc voltage and current, electrical power (active, reactive, and apparent), torque, speed, mechanical power, etc. The voltage and current meters have several modes of operation that allow measurement of the mean (dc) value, RMS value, crest factor, RMS value of a particular harmonic (up to the 15th value), RMS value of the harmonics, and total harmonic distortion (THD). Six of the eighteen meters are user-programmable and give access to a larger variety of functions for measurement of power factor, efficiency, impedance, frequency, energy, phase shift, etc. The layout of the meters in the Metering window is user-customizable.

Oscilloscope


Lab-Volt
FILE
VIEW
OPTIONS
TOOLS
HELP
M1
M2
LA
1
2
3
T

CHANNEL 1 (X)
INPUT E1
SCALE 50 V/DIV
INVERT OFF
COUPLING DC

CHANNEL 2 (Y)
INPUT E2
SCALE 50 V/DIV
INVERT OFF
COUPLING DC

CHANNEL 3
INPUT E3
SCALE 50 V/DIV
INVERT OFF
COUPLING DC

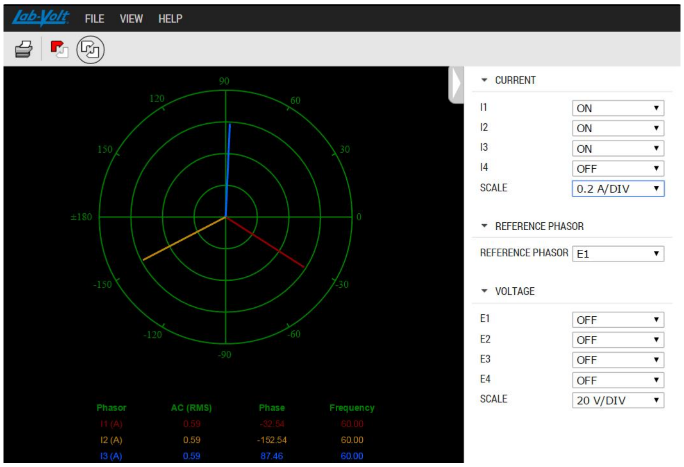
CHANNEL 4
CHANNEL 5
CHANNEL 6

Channel Data
Time Base: 5 ms/div

	Cur 1	Cur 2	Diff	RMS	AVG	f(Hz)
Ch 1(V)				54.85	0.11	60.00
Ch 2(V)				54.78	0.00	60.00
Ch 3(V)				54.85	-0.11	60.00

The Oscilloscope displays up to eight waveforms simultaneously, each of a different color for easy identification. Each channel has independent vertical controls similar to those found on conventional oscilloscopes. An automatic scale-setting function allows the sensitivity of each channel to be set automatically according to the magnitude of the observed parameter. The time base and trigger controls are similar to those found on most oscilloscopes. The RMS value, average value, and frequency of each observed parameters can be displayed in the Oscilloscope window. Two vertical cursors can be activated to perform precise measurements at particular points on the displayed waveforms. The Oscilloscope toolbar includes two memory buttons for saving displayed waveforms.

Phasor Analyzer



CURRENT

I1: ON
I2: ON
I3: ON
I4: OFF
SCALE: 0.2 A/DIV

REFERENCE PHASOR

REFERENCE PHASOR: E1

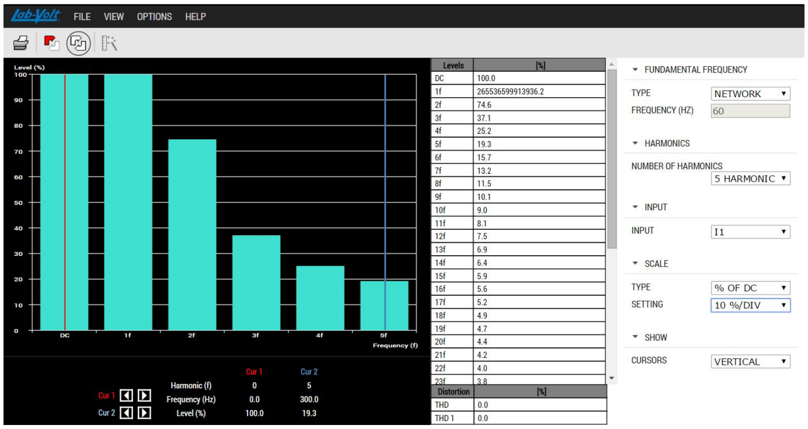
VOLTAGE

E1: OFF
E2: OFF
E3: OFF
E4: OFF
SCALE: 20 V/DIV

Phasor	AC (RMS)	Phase	Frequency
I1 (A)	0.59	-32.54	60.00
I2 (A)	0.59	-152.54	60.00
I3 (A)	0.59	87.46	60.00

The Phasor Analyzer displays the phasors related to the measured voltages and currents. The amplitude and phase angle of each voltage and current is clearly represented by the orientation and length of their corresponding phasors, allowing easy comparison between the displayed parameters. This produces a unique and dynamic display of the voltages and currents in a circuit (especially in three-phase circuits) that cannot be obtained with conventional instruments. The RMS value, phase angle, and frequency of the voltage or current related to each phasor is displayed in the Phasor Analyzer window.

Harmonic Analyzer



	Cur 1	Cur 2
Harmonic (f)	0	5
Frequency (Hz)	0.0	300.0
Level (%)	100.0	19.3

Levels	[%]
DC	100.0
1f	265536599913936.2
2f	74.6
3f	37.1
4f	25.2
5f	19.3
6f	15.7
7f	13.2
8f	11.5
9f	10.1
10f	9.0
11f	8.1
12f	7.5
13f	6.9
14f	6.4
15f	5.9
16f	5.6
17f	5.2
18f	4.9
19f	4.7
20f	4.4
21f	4.2
22f	4.0
23f	3.8

Distortion	[%]
THD	0.0
THD 1	0.0

FUNDAMENTAL FREQUENCY

TYPE: NETWORK
FREQUENCY (HZ): 60

HARMONICS

NUMBER OF HARMONICS: 5 HARMONIC

INPUT

INPUT: I1

SCALE

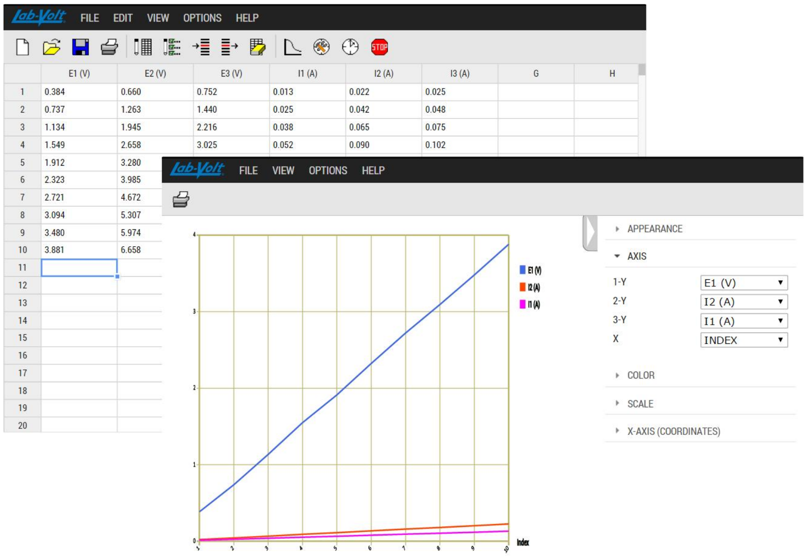
TYPE: % OF DC
SETTING: 10 %/DIV

SHOW

CURSORS: VERTICAL

The Harmonic Analyzer allows observation and analysis of the harmonic components in the measured voltages and currents. The fundamental frequency can be manually set to the ac power network frequency or automatically set to the frequency of the fundamental component of the selected voltage or current. The harmonic components of the selected voltage or current can be displayed using a vertical scale graduated in either absolute or relative values. A group of data displays in the Harmonic Analyzer indicates the values of the dc component of the selected voltage or current, as well as the total harmonic distortion (THD). Vertical and horizontal cursors can be displayed to perform precise measurements at particular points on the display. Since the equipment simulated by LVSIM-EMS produces only dc and sinusoidal ac signals (without harmonics), the Harmonic Analyzer, which is intended for use with devices that produce harmonics, is not often used with LVSIM-EMS.

Data Table and Graph Windows



	E1 (V)	E2 (V)	E3 (V)	I1 (A)	I2 (A)	I3 (A)	G	H
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2	0.737	1.263	1.440	0.025	0.042	0.048		
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5	1.912	3.280						
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9	3.480	5.974						
10	3.881	6.658						
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

1-Y E1 (V)
2-Y I2 (A)
3-Y I1 (A)
X INDEX

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Computer-Based Instruments for EMS (User Guide)	584396 (36221-E0)

Table of Contents of the Manual(s)

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- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Topic Coverage

- Fundamentals for Electric Power Technology
- Alternating Current
- Capacitors in AC Circuits
- Inductors in AC Circuits
- Power, Phasors, and Impedance in AC Circuits
- Three-Phase Circuits
- Special Transformer Connections
- Single- and three-Phase Transformers
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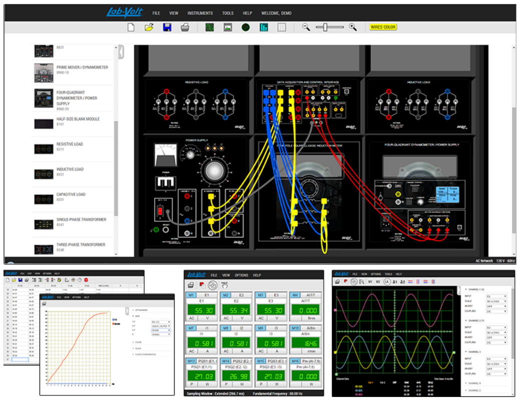
- Replicates the Electromechanical Training System, enabling students to perform actual experiments using virtual equipment
    - Install, move, and remove EMS modules in and from the workstation
    - Modify module connections at any time and change the color of wires
    - Install a timing belt between two EMS machines
    - Verify module connections using a tool that highlights all wires connected to a same circuit point
    - Perform measurements of voltage, current, power, speed, torque, impedance, resistance, reactance, and frequency and display the values on digital or analog meters
    - Record measurements in a data table and plot graphs using the recorded data
    - Display waveforms on a multi-channel oscilloscope and ac voltages and currents as phasors
- Students prepare for laboratories in advance using virtual equipment, thereby decreasing the time they require to perform the exercises using actual equipment
- Decreases the quantity of actual equipment required per student
- Allows students to practice with EMS equipment operation and connection at home on a personal computer

Specifications

Parameter	Value
Computer Requirements	
Local and Network versions	One (1) USB 2.0 port for the security dongle, Microsoft Windows 10 operating system recommended (compatible with Windows 7 and 8), basic dual core CPU, Google Chrome web browser installed (for better experience)
Online version	Microsoft Windows 10 operating system recommended (compatible with Windows 7 and 8 but not fully compatible with mobile devices), basic dual core CPU, internet access (bandwidth usage of 50 KB/s maximum), Google Chrome web browser installed (for better experience)

Electromechanical Systems Simulation Software (LVSIM®-EMS) - 20 Users Online, 1 year (Optional)

586983 (8972-D0)



The Electromechanical Systems Simulation Software (LVSIM®-EMS) is a simulation software that covers the same courseware as the following systems:

Computer-Assisted 0.2 kW Electromechanical Training System, Model 8006-1
DC and AC Power Circuits Training System, Model 8010-1
Electromechanical Training System, Model 8010-9
AC Power Transmission Training System, Model 8010-B

All workbooks parts of the systems above are available in the navigation menu of LVSIM-EMS for online consultation. To obtain the printing rights, Campus Licenses for each are available and must be ordered separately.

With LVSIM-EMS, all the standard EMS laboratory equipment is replaced by images of the actual EMS modules that students can manipulate on the computer screen. Students can identify and set up equipment for a given exercise, make the necessary connections between the virtual EMS modules, and verify the connections made without the need for actual EMS equipment.

Sophisticated mathematical models fully simulate the electrical and mechanical characteristics of all the actual EMS modules: power supplies, motors, generators, transformers, electrical and mechanical loads, etc. All

modules simulated in the LVSIM-EMS software feature the same front panel information as the actual EMS modules. Short-circuit connections in the virtual equipment setup cause the virtual circuit-breaker protection to trip. This trip condition is clearly indicated on the virtual EMS modules.

Used either as a complement to the actual EMS laboratory equipment, or as a stand-alone product, LVSIM-EMS is a cost-effective tool that enables students to perform the same exercises as in the courseware of the above-mentioned training systems. When used as a stand-alone package, the LVSIM-EMS software allows students to perform hands-on activities related to electrical power and machines, including active, reactive, and apparent power, phasors, ac/dc motors and generators, three-phase circuits, and transformers.

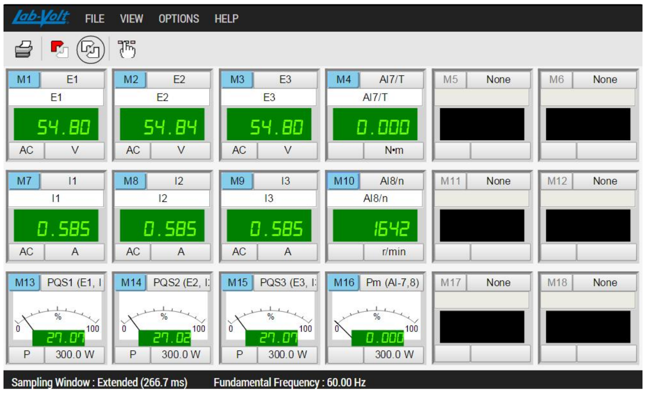
LVSIM-EMS is a web-browser based application **available in three different configurations.** The simulation software can either be installed locally on a Windows® personal computer (local version), on a Windows server (network version), or accessed directly online through the labvolt.com website at lvsim.labvolt.com (online version). Both network and local versions are delivered with perpetual license for the current version. The online version is delivered as a annual license with possibility to expand for more years.

Please visit https://lvsim.labvolt.com and try the online version!

Virtual Instrumentation

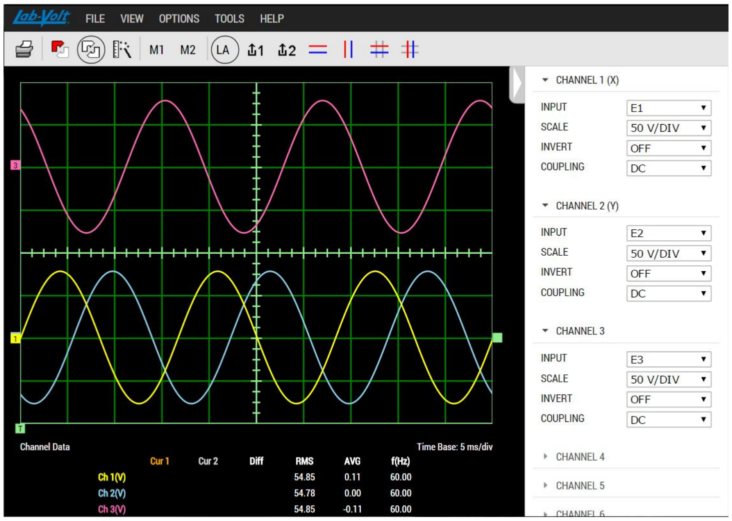
LVSIM-EMS comprises a set of conventional and specialized instruments that can be used for measuring, observing, and analyzing electrical and mechanical parameters in electric power systems and power electronic circuits. Each instrument appears as a window on the computer screen. The conventional instruments include ac/dc voltmeters and ammeters, power meters, and an eight-channel oscilloscope. The specialized instruments include a six-channel phasor analyzer, a harmonic analyzer, torque, speed, and mechanical power meters, and user-programmable meters. The software is also provided with data-recording and graph-plotting capabilities. The various instruments are briefly described in the next section of this datasheet.

Metering Window


Lab-Volt
FILE
VIEW
OPTIONS
HELP
M1 E1 54.80 AC V
M2 E2 54.84 AC V
M3 E3 54.80 AC V
M4 AI7/T 0.000 N·m
M5 None
M6 None
M7 I1 0.585 AC A
M8 I2 0.585 AC A
M9 I3 0.585 AC A
M10 AI8/n 1642 r/min
M11 None
M12 None
M13 PQS1 (E1, I 27.07 P 300.0 W
M14 PQS2 (E2, I2 27.02 P 300.0 W
M15 PQS3 (E3, I3 27.07 P 300.0 W
M16 Pm (AI-7,8) 0.000 300.0 W
M17 None
M18 None
Sampling Window : Extended (266.7 ms)
Fundamental Frequency : 60.00 Hz

The Metering window displays up to eighteen meters, which can be configured individually for measuring ac/dc voltage and current, electrical power (active, reactive, and apparent), torque, speed, mechanical power, etc. The voltage and current meters have several modes of operation that allow measurement of the mean (dc) value, RMS value, crest factor, RMS value of a particular harmonic (up to the 15th value), RMS value of the harmonics, and total harmonic distortion (THD). Six of the eighteen meters are user-programmable and give access to a larger variety of functions for measurement of power factor, efficiency, impedance, frequency, energy, phase shift, etc. The layout of the meters in the Metering window is user-customizable.

Oscilloscope



CHANNEL 1 (X)
INPUT: E1
SCALE: 50 V/DIV
INVERT: OFF
COUPLING: DC

CHANNEL 2 (Y)
INPUT: E2
SCALE: 50 V/DIV
INVERT: OFF
COUPLING: DC

CHANNEL 3
INPUT: E3
SCALE: 50 V/DIV
INVERT: OFF
COUPLING: DC

CHANNEL 4
CHANNEL 5
CHANNEL 6

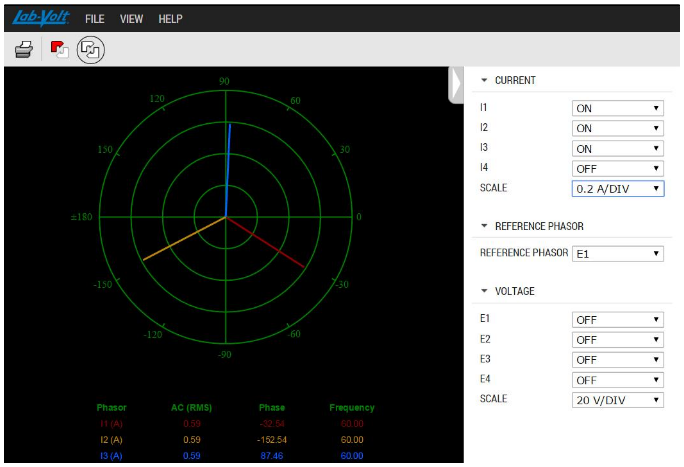
Channel Data

Time Base: 5 ms/div

	Cur 1	Cur 2	Diff	RMS	AVG	f(Hz)
Ch 1(V)				54.85	0.11	60.00
Ch 2(V)				54.78	0.00	60.00
Ch 3(V)				54.85	-0.11	60.00

The Oscilloscope displays up to eight waveforms simultaneously, each of a different color for easy identification. Each channel has independent vertical controls similar to those found on conventional oscilloscopes. An automatic scale-setting function allows the sensitivity of each channel to be set automatically according to the magnitude of the observed parameter. The time base and trigger controls are similar to those found on most oscilloscopes. The RMS value, average value, and frequency of each observed parameters can be displayed in the Oscilloscope window. Two vertical cursors can be activated to perform precise measurements at particular points on the displayed waveforms. The Oscilloscope toolbar includes two memory buttons for saving displayed waveforms.

Phasor Analyzer



CURRENT
I1: ON
I2: ON
I3: ON
I4: OFF
SCALE: 0.2 A/DIV

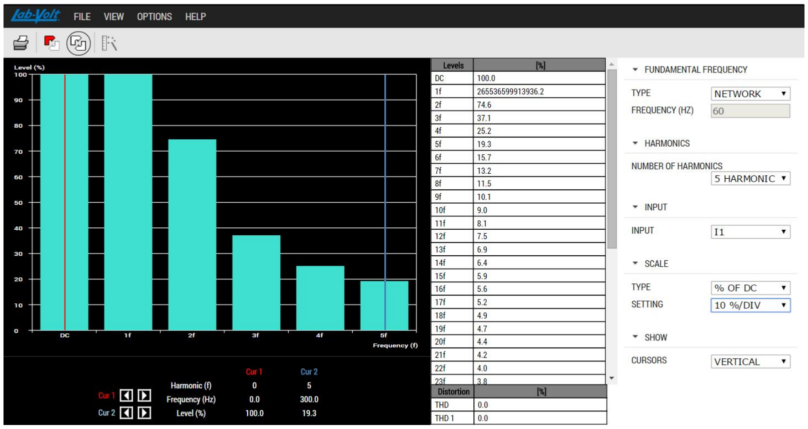
REFERENCE PHASOR
REFERENCE PHASOR: E1

VOLTAGE
E1: OFF
E2: OFF
E3: OFF
E4: OFF
SCALE: 20 V/DIV

Phasor	AC (RMS)	Phase	Frequency
I1 (A)	0.59	-32.54	60.00
I2 (A)	0.59	-152.54	60.00
I3 (A)	0.59	87.46	60.00

The Phasor Analyzer displays the phasors related to the measured voltages and currents. The amplitude and phase angle of each voltage and current is clearly represented by the orientation and length of their corresponding phasors, allowing easy comparison between the displayed parameters. This produces a unique and dynamic display of the voltages and currents in a circuit (especially in three-phase circuits) that cannot be obtained with conventional instruments. The RMS value, phase angle, and frequency of the voltage or current related to each phasor is displayed in the Phasor Analyzer window.

Harmonic Analyzer


FILE
VIEW
OPTIONS
HELP
Level (%)
100
90
80
70
60
50
40
30
20
10
0
DC
1f
2f
3f
4f
5f
Frequency (f)
FUNDAMENTAL FREQUENCY
HARMONICS
INPUT
SCALE
SHOW

Levels	[%]
DC	100.0
1f	265536599913936.2
2f	74.6
3f	37.1
4f	25.2
5f	19.3
6f	15.7
7f	13.2
8f	11.5
9f	10.1
10f	9.0
11f	8.1
12f	7.5
13f	6.9
14f	6.4
15f	5.9
16f	5.6
17f	5.2
18f	4.9
19f	4.7
20f	4.4
21f	4.2
22f	4.0
23f	3.8

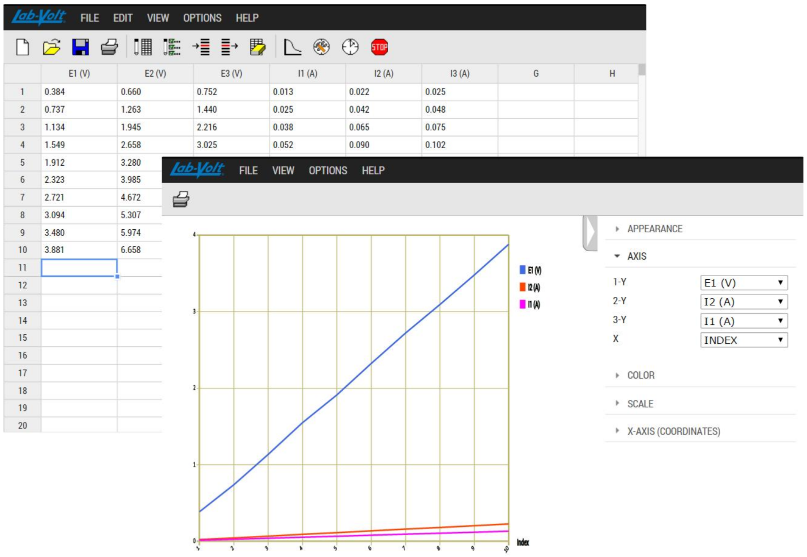
Distortion	[%]
THD	0.0
THD 1	0.0

	Cur 1	Cur 2
Harmonic (f)	0	5
Frequency (Hz)	0.0	300.0
Level (%)	100.0	19.3

TYPE: NETWORK
FREQUENCY (HZ): 60
NUMBER OF HARMONICS: 5 HARMONIC
INPUT: I1
TYPE: % OF DC
SETTING: 10 %/DIV
CURSORS: VERTICAL

The Harmonic Analyzer allows observation and analysis of the harmonic components in the measured voltages and currents. The fundamental frequency can be manually set to the ac power network frequency or automatically set to the frequency of the fundamental component of the selected voltage or current. The harmonic components of the selected voltage or current can be displayed using a vertical scale graduated in either absolute or relative values. A group of data displays in the Harmonic Analyzer indicates the values of the dc component of the selected voltage or current, as well as the total harmonic distortion (THD). Vertical and horizontal cursors can be displayed to perform precise measurements at particular points on the display. Since the equipment simulated by LVSIM-EMS produces only dc and sinusoidal ac signals (without harmonics), the Harmonic Analyzer, which is intended for use with devices that produce harmonics, is not often used with LVSIM-EMS.

Data Table and Graph Windows


FILE
EDIT
VIEW
OPTIONS
HELP
STOP
FILE
VIEW
OPTIONS
HELP
APPEARANCE
AXIS
COLOR
SCALE
X-AXIS (COORDINATES)
E1 (V)
I2 (A)
I1 (A)
4
3
2
1
0
1
2
3
4
5
6
7
8
9
10
Index

	E1 (V)	E2 (V)	E3 (V)	I1 (A)	I2 (A)	I3 (A)	G	H
1	0.384	0.660	0.752	0.013	0.022	0.025		
2	0.737	1.263	1.440	0.025	0.042	0.048		
3	1.134	1.945	2.216	0.038	0.065	0.075		
4	1.549	2.658	3.025	0.052	0.090	0.102		
5	1.912	3.280						
6	2.323	3.985						
7	2.721	4.672						
8	3.094	5.307						
9	3.480	5.974						
10	3.881	6.658						
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

1-Y: E1 (V)
2-Y: I2 (A)
3-Y: I1 (A)
X: INDEX

The values indicated by the various meters in the Metering window, as well as values measured by the other instruments, can be recorded in the Data Table window with a click of the mouse. The values recorded in the Data Table can be saved to a file (ASCII-formatted file). The recorded data can also be used to plot graphs by selecting which parameter(s) to plot in the Graph window. This allows lab results to be plotted quickly and easily. More sophisticated graphs can be created by exporting the contents of the Data Table window to any spreadsheet program, such as Microsoft Excel®, directly through the Windows Clipboard.

Software Protection and Licensing

The local and network version provides a perpetual licence and the online access version provides a annual licence (additional years can be purchased when ordering).

The local and network version of LVSIM-EMS are copy-protected by means of a hardlock security device. When LVSIM-EMS detects the security device, students have complete access to all measuring functions of the virtual instruments and other protected features of LVSIM-EMS, as well as to the student manuals included with the simulation software. Note that students are allowed to copy the software onto their personal computer to allow them to prepare laboratories in advance.

Two different security devices are available for LVSIM-EMS: a single-user hardlock key, which can be inserted in the USB port of the user's computer, and a multiple-user hardlock key, which can be inserted in the USB port of the network server or any computer in the same network. Once the hardlock key is active on the network, the other computer will see the available licences. Alternately, the multiple-user hardlock key can be inserted in a USB port inside the server using a circuit board with edge-type connector (provided with the key) that can be installed in a PCI expansion slot of the server.

The multiple-user hardlock key can be installed in servers running under one of the following Microsoft® operating systems: Windows 7, Windows 8, Windows 10, Windows 2008 Server, and Windows 2013 Server. As its name indicates, the multiple-user hardlock key allows several users of a network to run LVSIM-EMS simultaneously. Different versions of LVSIM-EMS are available, each allowing a particular number of users.

Online Edition

The online version of LVSIM-EMS is accessible directly via the internet, and requires no software installation nor any update since the latest version of the software is always available. The online version of LVSIM-EMS also includes a demo mode that allows students to prepare laboratories in advance by familiarizing with the equipment and connections. The demo mode does not require any login.

Computer Requirements

Local and Network Versions:

- One (1) USB 2.0 port for the security dongle, Microsoft Windows 10 operating system recommended (compatible with Windows 7 and 8), basic dual core CPU, Google Chrome web browser installed (for better experience)

Online Version:

- Microsoft Windows 10 operating system recommended (compatible with Windows 7 and 8 but not fully compatible with mobile devices), basic dual core CPU, internet access (bandwidth usage of 50 KB/s maximum), Google Chrome web browser installed (for better experience)

List of Manuals

Description	Manual number
Electromechanical Systems Simulation Software (User Guide)	583879 (20858-E0)
Computer-Based Instruments for EMS (User Guide)	584396 (36221-E0)

Table of Contents of the Manual(s)

Electromechanical Systems Simulation Software (User Guide) (583879 (20858-E0))

- 1 Overview of LVSIM-EMS
- 2 Installing the Security Device
- 3 Installing and Running LVSIM-EMS

Computer-Based Instruments for EMS (User Guide) (584396 (36221-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Topic Coverage

- Fundamentals for Electric Power Technology
- Alternating Current
- Capacitors in AC Circuits
- Inductors in AC Circuits
- Power, Phasors, and Impedance in AC Circuits
- Three-Phase Circuits
- Special Transformer Connections
- Single- and three-Phase Transformers
- Fundamentals for Rotating Machines
- DC Motors and Generators
- Special Characteristics of DC Motors
- AC Induction and Synchronous Motors
- Three-Phase Synchronous Generators

Features & Benefits

- Replicates the Electromechanical Training System, enabling students to perform actual experiments using virtual equipment
    - Install, move, and remove EMS modules in and from the workstation
    - Modify module connections at any time and change the color of wires
    - Install a timing belt between two EMS machines
    - Verify module connections using a tool that highlights all wires connected to a same circuit point
    - Perform measurements of voltage, current, power, speed, torque, impedance, resistance, reactance, and frequency and display the values on digital or analog meters
    - Record measurements in a data table and plot graphs using the recorded data
    - Display waveforms on a multi-channel oscilloscope and ac voltages and currents as phasors
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Parameter	Value
Computer Requirements	

Parameter	Value
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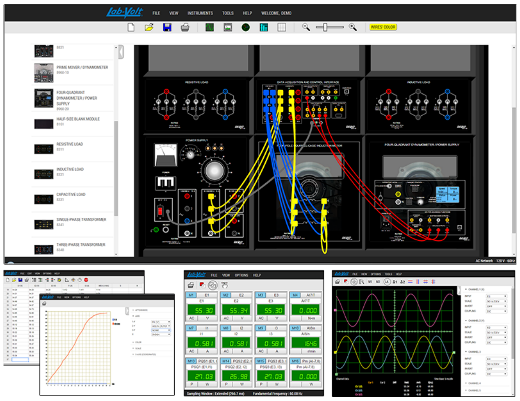
Electromechanical Systems Simulation Software (LVSIM®-EMS) - 25 Users Online, 1 year (Optional)

586986 (8972-E0)



The Electromechanical Systems Simulation Software (LVSIM®-EMS) is a simulation software that covers the same courseware as the following systems:

Computer-Assisted 0.2 kW Electromechanical Training System, Model 8006-1
DC and AC Power Circuits Training System, Model 8010-1
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Used either as a complement to the actual EMS laboratory equipment, or as a stand-alone product, LVSIM-EMS is a cost-effective tool that enables students to perform the same exercises as in the courseware of the above-mentioned training systems. When used as a stand-alone package, the LVSIM-EMS software allows students to perform hands-on activities related to electrical power and machines, including active, reactive, and apparent power, phasors, ac/dc motors and generators, three-phase circuits, and transformers.

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Please visit https://lvsim.labvolt.com and try the online version!

Virtual Instrumentation

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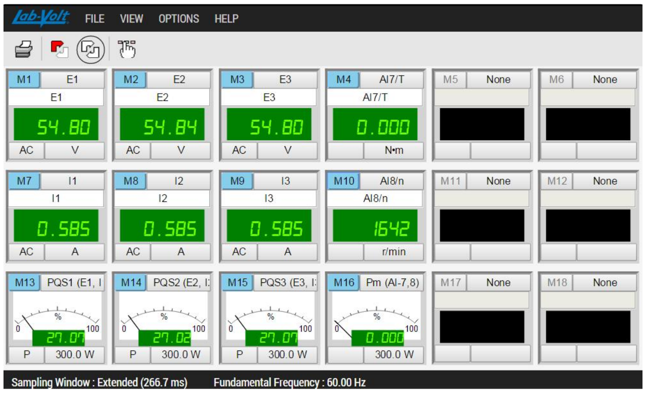
Metering Window

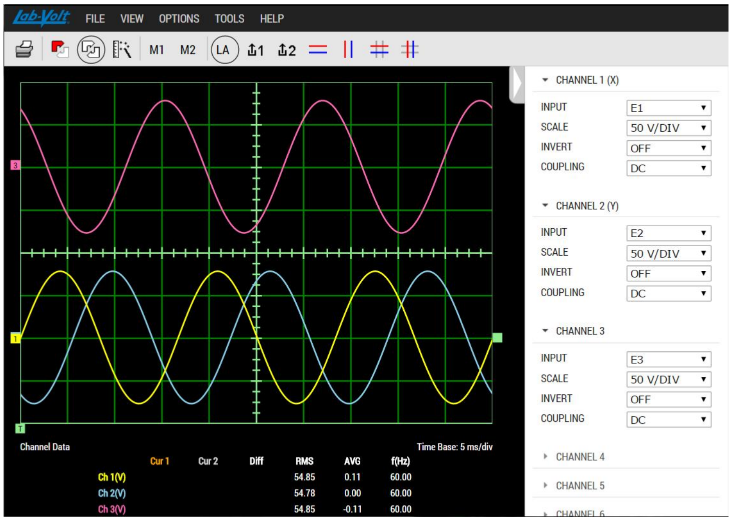

Lab-Volt
FILE
VIEW
OPTIONS
HELP
M1 E1 E1 54.80 AC V
M2 E2 E2 54.84 AC V
M3 E3 E3 54.80 AC V
M4 AI7/T AI7/T 0.000 N·m
M5 None
M6 None
M7 I1 I1 0.585 AC A
M8 I2 I2 0.585 AC A
M9 I3 I3 0.585 AC A
M10 AI8/n AI8/n 1642 r/min
M11 None
M12 None
M13 PQS1 (E1, I 27.07 P 300.0 W
M14 PQS2 (E2, I2 27.02 P 300.0 W
M15 PQS3 (E3, I3 27.07 P 300.0 W
M16 Pm (AI-7,8) 0.000 300.0 W
M17 None
M18 None

Sampling Window : Extended (266.7 ms)

Fundamental Frequency : 60.00 Hz

The Metering window displays up to eighteen meters, which can be configured individually for measuring ac/dc voltage and current, electrical power (active, reactive, and apparent), torque, speed, mechanical power, etc. The voltage and current meters have several modes of operation that allow measurement of the mean (dc) value, RMS value, crest factor, RMS value of a particular harmonic (up to the 15th value), RMS value of the harmonics, and total harmonic distortion (THD). Six of the eighteen meters are user-programmable and give access to a larger variety of functions for measurement of power factor, efficiency, impedance, frequency, energy, phase shift, etc. The layout of the meters in the Metering window is user-customizable.

Oscilloscope


Lab-Volt
FILE
VIEW
OPTIONS
TOOLS
HELP
M1
M2
LA
1
2
3
T

CHANNEL 1 (X)
INPUT E1
SCALE 50 V/DIV
INVERT OFF
COUPLING DC

CHANNEL 2 (Y)
INPUT E2
SCALE 50 V/DIV
INVERT OFF
COUPLING DC

CHANNEL 3
INPUT E3
SCALE 50 V/DIV
INVERT OFF
COUPLING DC

CHANNEL 4
CHANNEL 5
CHANNEL 6

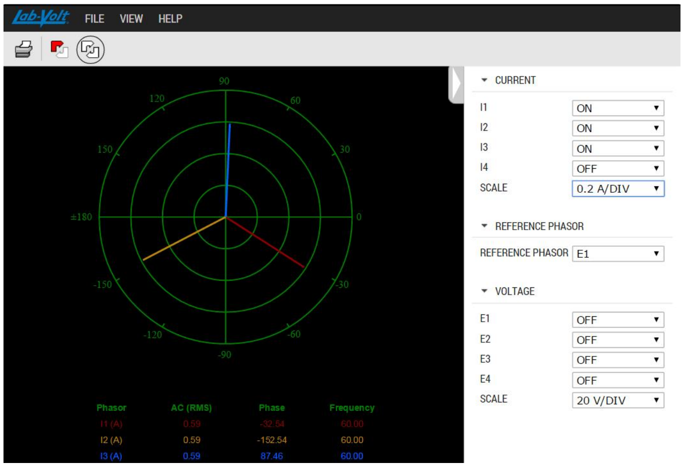
Channel Data

Time Base: 5 ms/div

	Cur 1	Cur 2	Diff	RMS	AVG	f(Hz)
Ch 1(V)				54.85	0.11	60.00
Ch 2(V)				54.78	0.00	60.00
Ch 3(V)				54.85	-0.11	60.00

The Oscilloscope displays up to eight waveforms simultaneously, each of a different color for easy identification. Each channel has independent vertical controls similar to those found on conventional oscilloscopes. An automatic scale-setting function allows the sensitivity of each channel to be set automatically according to the magnitude of the observed parameter. The time base and trigger controls are similar to those found on most oscilloscopes. The RMS value, average value, and frequency of each observed parameters can be displayed in the Oscilloscope window. Two vertical cursors can be activated to perform precise measurements at particular points on the displayed waveforms. The Oscilloscope toolbar includes two memory buttons for saving displayed waveforms.

Phasor Analyzer



CURRENT

I1: ON
I2: ON
I3: ON
I4: OFF
SCALE: 0.2 A/DIV

REFERENCE PHASOR

REFERENCE PHASOR: E1

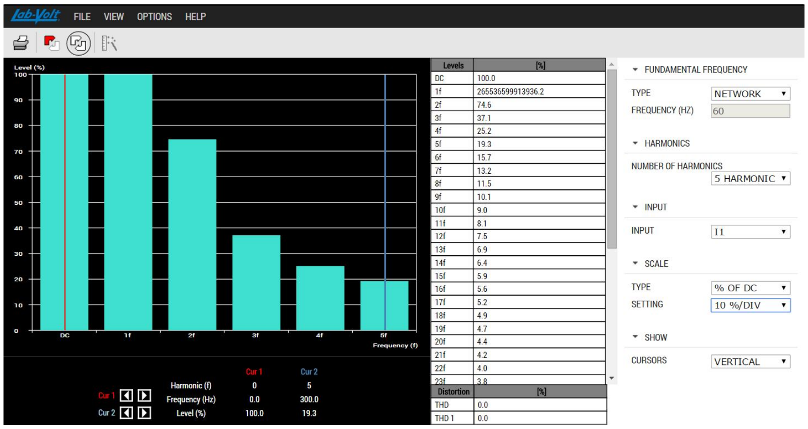
VOLTAGE

E1: OFF
E2: OFF
E3: OFF
E4: OFF
SCALE: 20 V/DIV

Phasor	AC (RMS)	Phase	Frequency
I1 (A)	0.59	-32.54	60.00
I2 (A)	0.59	-152.54	60.00
I3 (A)	0.59	87.46	60.00

The Phasor Analyzer displays the phasors related to the measured voltages and currents. The amplitude and phase angle of each voltage and current is clearly represented by the orientation and length of their corresponding phasors, allowing easy comparison between the displayed parameters. This produces a unique and dynamic display of the voltages and currents in a circuit (especially in three-phase circuits) that cannot be obtained with conventional instruments. The RMS value, phase angle, and frequency of the voltage or current related to each phasor is displayed in the Phasor Analyzer window.

Harmonic Analyzer



Levels	[%]
DC	100.0
1f	265536599913936.2
2f	74.6
3f	37.1
4f	25.2
5f	19.3
6f	15.7
7f	13.2
8f	11.5
9f	10.1
10f	9.0
11f	8.1
12f	7.5
13f	6.9
14f	6.4
15f	5.9
16f	5.6
17f	5.2
18f	4.9
19f	4.7
20f	4.4
21f	4.2
22f	4.0
23f	3.8

Distortion	[%]
THD	0.0
THD 1	0.0

	Cur 1	Cur 2
Harmonic (f)	0	5
Frequency (Hz)	0.0	300.0
Level (%)	100.0	19.3

FUNDAMENTAL FREQUENCY

TYPE: NETWORK
FREQUENCY (HZ): 60

HARMONICS

NUMBER OF HARMONICS: 5 HARMONIC

INPUT

INPUT: I1

SCALE

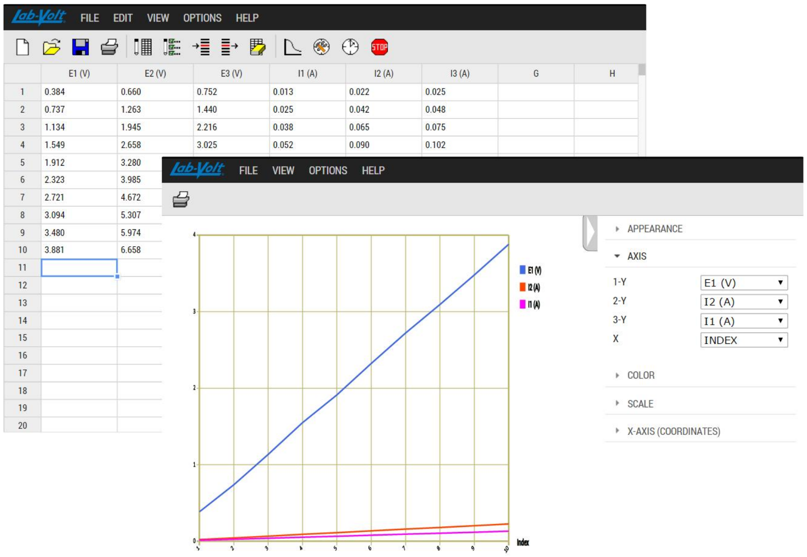
TYPE: % OF DC
SETTING: 10 %/DIV

SHOW

CURSORS: VERTICAL

The Harmonic Analyzer allows observation and analysis of the harmonic components in the measured voltages and currents. The fundamental frequency can be manually set to the ac power network frequency or automatically set to the frequency of the fundamental component of the selected voltage or current. The harmonic components of the selected voltage or current can be displayed using a vertical scale graduated in either absolute or relative values. A group of data displays in the Harmonic Analyzer indicates the values of the dc component of the selected voltage or current, as well as the total harmonic distortion (THD). Vertical and horizontal cursors can be displayed to perform precise measurements at particular points on the display. Since the equipment simulated by LVSIM-EMS produces only dc and sinusoidal ac signals (without harmonics), the Harmonic Analyzer, which is intended for use with devices that produce harmonics, is not often used with LVSIM-EMS.

Data Table and Graph Windows



	E1 (V)	E2 (V)	E3 (V)	I1 (A)	I2 (A)	I3 (A)	G	H
1	0.384	0.660	0.752	0.013	0.022	0.025		
2	0.737	1.263	1.440	0.025	0.042	0.048		
3	1.134	1.945	2.216	0.038	0.065	0.075		
4	1.549	2.658	3.025	0.052	0.090	0.102		
5	1.912	3.280						
6	2.323	3.985						
7	2.721	4.672						
8	3.094	5.307						
9	3.480	5.974						
10	3.881	6.658						
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

1-Y E1 (V)
2-Y I2 (A)
3-Y I1 (A)
X INDEX

The values indicated by the various meters in the Metering window, as well as values measured by the other instruments, can be recorded in the Data Table window with a click of the mouse. The values recorded in the Data Table can be saved to a file (ASCII-formatted file). The recorded data can also be used to plot graphs by selecting which parameter(s) to plot in the Graph window. This allows lab results to be plotted quickly and easily. More sophisticated graphs can be created by exporting the contents of the Data Table window to any spreadsheet program, such as Microsoft Excel®, directly through the Windows Clipboard.

Software Protection and Licensing

The local and network version provides a perpetual licence and the online access version provides a annual licence (additional years can be purchased when ordering).

The local and network version of LVSIM-EMS are copy-protected by means of a hardlock security device. When LVSIM-EMS detects the security device, students have complete access to all measuring functions of the virtual instruments and other protected features of LVSIM-EMS, as well as to the student manuals included with the simulation software. Note that students are allowed to copy the software onto their personal computer to allow them to prepare laboratories in advance.

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The multiple-user hardlock key can be installed in servers running under one of the following Microsoft® operating systems: Windows 7, Windows 8, Windows 10, Windows 2008 Server, and Windows 2013 Server. As its name indicates, the multiple-user hardlock key allows several users of a network to run LVSIM-EMS simultaneously. Different versions of LVSIM-EMS are available, each allowing a particular number of users.

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Computer Requirements

Local and Network Versions:

- One (1) USB 2.0 port for the security dongle, Microsoft Windows 10 operating system recommended (compatible with Windows 7 and 8), basic dual core CPU, Google Chrome web browser installed (for better experience)

Online Version:

- Microsoft Windows 10 operating system recommended (compatible with Windows 7 and 8 but not fully compatible with mobile devices), basic dual core CPU, internet access (bandwidth usage of 50 KB/s maximum), Google Chrome web browser installed (for better experience)

List of Manuals

Description	Manual number
Electromechanical Systems Simulation Software (User Guide)	583879 (20858-E0)
Computer-Based Instruments for EMS (User Guide)	584396 (36221-E0)

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- 3 Installing and Running LVSIM-EMS

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- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Topic Coverage

- Fundamentals for Electric Power Technology
- Alternating Current
- Capacitors in AC Circuits
- Inductors in AC Circuits
- Power, Phasors, and Impedance in AC Circuits
- Three-Phase Circuits
- Special Transformer Connections
- Single- and three-Phase Transformers
- Fundamentals for Rotating Machines
- DC Motors and Generators
- Special Characteristics of DC Motors
- AC Induction and Synchronous Motors
- Three-Phase Synchronous Generators

Features & Benefits

- Replicates the Electromechanical Training System, enabling students to perform actual experiments using virtual equipment
    - Install, move, and remove EMS modules in and from the workstation
    - Modify module connections at any time and change the color of wires
    - Install a timing belt between two EMS machines
    - Verify module connections using a tool that highlights all wires connected to a same circuit point
    - Perform measurements of voltage, current, power, speed, torque, impedance, resistance, reactance, and frequency and display the values on digital or analog meters
    - Record measurements in a data table and plot graphs using the recorded data
    - Display waveforms on a multi-channel oscilloscope and ac voltages and currents as phasors
- Students prepare for laboratories in advance using virtual equipment, thereby decreasing the time they require to perform the exercises using actual equipment
- Decreases the quantity of actual equipment required per student
- Allows students to practice with EMS equipment operation and connection at home on a personal computer

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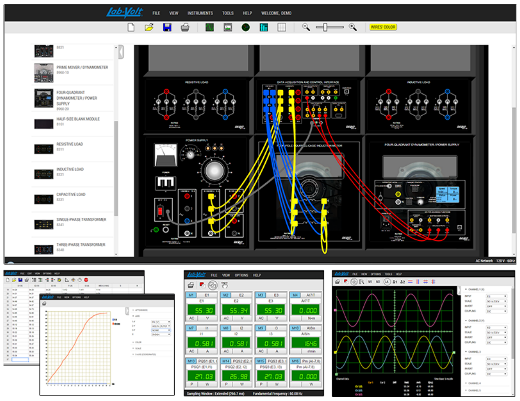
Electromechanical Systems Simulation Software (LVSIM®-EMS) - 30 Users Online, 1 year (Optional)

586989 (8972-F0)



The Electromechanical Systems Simulation Software (LVSIM®-EMS) is a simulation software that covers the same courseware as the following systems:

Computer-Assisted 0.2 kW Electromechanical Training System, Model 8006-1
DC and AC Power Circuits Training System, Model 8010-1
Electromechanical Training System, Model 8010-9
AC Power Transmission Training System, Model 8010-B

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With LVSIM-EMS, all the standard EMS laboratory equipment is replaced by images of the actual EMS modules that students can manipulate on the computer screen. Students can identify and set up equipment for a given exercise, make the necessary connections between the virtual EMS modules, and verify the connections made without the need for actual EMS equipment.

Sophisticated mathematical models fully simulate the electrical and mechanical characteristics of all the actual EMS modules: power supplies, motors, generators, transformers, electrical and mechanical loads, etc. All

modules simulated in the LVSIM-EMS software feature the same front panel information as the actual EMS modules. Short-circuit connections in the virtual equipment setup cause the virtual circuit-breaker protection to trip. This trip condition is clearly indicated on the virtual EMS modules.

Used either as a complement to the actual EMS laboratory equipment, or as a stand-alone product, LVSIM-EMS is a cost-effective tool that enables students to perform the same exercises as in the courseware of the above-mentioned training systems. When used as a stand-alone package, the LVSIM-EMS software allows students to perform hands-on activities related to electrical power and machines, including active, reactive, and apparent power, phasors, ac/dc motors and generators, three-phase circuits, and transformers.

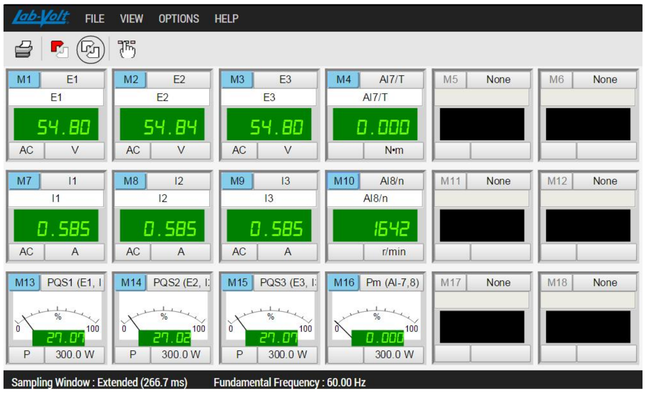
LVSIM-EMS is a web-browser based application **available in three different configurations.** The simulation software can either be installed locally on a Windows® personal computer (local version), on a Windows server (network version), or accessed directly online through the labvolt.com website at lvsim.labvolt.com (online version). Both network and local versions are delivered with perpetual license for the current version. The online version is delivered as a annual license with possibility to expand for more years.

Please visit https://lvsim.labvolt.com and try the online version!

Virtual Instrumentation

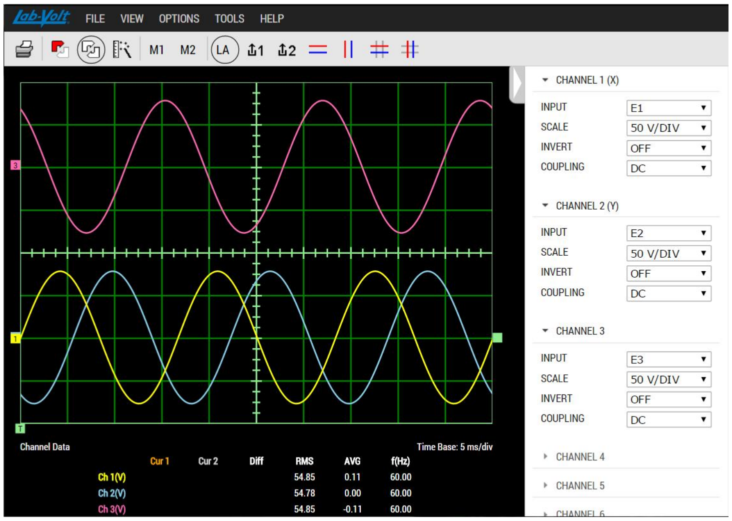
LVSIM-EMS comprises a set of conventional and specialized instruments that can be used for measuring, observing, and analyzing electrical and mechanical parameters in electric power systems and power electronic circuits. Each instrument appears as a window on the computer screen. The conventional instruments include ac/dc voltmeters and ammeters, power meters, and an eight-channel oscilloscope. The specialized instruments include a six-channel phasor analyzer, a harmonic analyzer, torque, speed, and mechanical power meters, and user-programmable meters. The software is also provided with data-recording and graph-plotting capabilities. The various instruments are briefly described in the next section of this datasheet.

Metering Window


Lab-Volt
FILE
VIEW
OPTIONS
HELP
M1 E1 54.80 AC V
M2 E2 54.84 AC V
M3 E3 54.80 AC V
M4 AI7/T 0.000 N·m
M5 None
M6 None
M7 I1 0.585 AC A
M8 I2 0.585 AC A
M9 I3 0.585 AC A
M10 AI8/n 1642 r/min
M11 None
M12 None
M13 PQS1 (E1, I 27.07 P 300.0 W
M14 PQS2 (E2, I 27.02 P 300.0 W
M15 PQS3 (E3, I 27.07 P 300.0 W
M16 Pm (AI-7,8) 0.000 300.0 W
M17 None
M18 None
Sampling Window : Extended (266.7 ms)
Fundamental Frequency : 60.00 Hz

The Metering window displays up to eighteen meters, which can be configured individually for measuring ac/dc voltage and current, electrical power (active, reactive, and apparent), torque, speed, mechanical power, etc. The voltage and current meters have several modes of operation that allow measurement of the mean (dc) value, RMS value, crest factor, RMS value of a particular harmonic (up to the 15th value), RMS value of the harmonics, and total harmonic distortion (THD). Six of the eighteen meters are user-programmable and give access to a larger variety of functions for measurement of power factor, efficiency, impedance, frequency, energy, phase shift, etc. The layout of the meters in the Metering window is user-customizable.

Oscilloscope



CHANNEL 1 (X)

INPUT	E1
SCALE	50 V/DIV
INVERT	OFF
COUPLING	DC

CHANNEL 2 (Y)

INPUT	E2
SCALE	50 V/DIV
INVERT	OFF
COUPLING	DC

CHANNEL 3

INPUT	E3
SCALE	50 V/DIV
INVERT	OFF
COUPLING	DC

CHANNEL 4

CHANNEL 5

CHANNEL 6

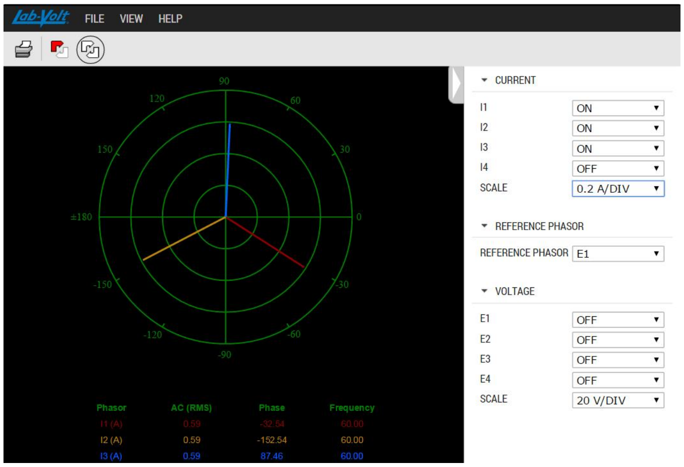
Channel Data

Time Base: 5 ms/div

	Cur 1	Cur 2	Diff	RMS	AVG	f(Hz)
Ch 1(V)				54.85	0.11	60.00
Ch 2(V)				54.78	0.00	60.00
Ch 3(V)				54.85	-0.11	60.00

The Oscilloscope displays up to eight waveforms simultaneously, each of a different color for easy identification. Each channel has independent vertical controls similar to those found on conventional oscilloscopes. An automatic scale-setting function allows the sensitivity of each channel to be set automatically according to the magnitude of the observed parameter. The time base and trigger controls are similar to those found on most oscilloscopes. The RMS value, average value, and frequency of each observed parameters can be displayed in the Oscilloscope window. Two vertical cursors can be activated to perform precise measurements at particular points on the displayed waveforms. The Oscilloscope toolbar includes two memory buttons for saving displayed waveforms.

Phasor Analyzer



CURRENT

I1	ON
I2	ON
I3	ON
I4	OFF
SCALE	0.2 A/DIV

REFERENCE PHASOR

REFERENCE PHASOR	E1

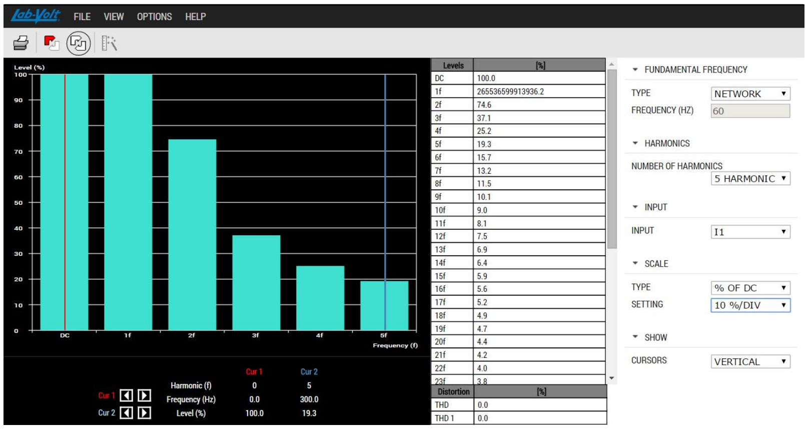
VOLTAGE

E1	OFF
E2	OFF
E3	OFF
E4	OFF
SCALE	20 V/DIV

Phasor	AC (RMS)	Phase	Frequency
I1 (A)	0.59	-32.54	60.00
I2 (A)	0.59	-152.54	60.00
I3 (A)	0.59	87.46	60.00

The Phasor Analyzer displays the phasors related to the measured voltages and currents. The amplitude and phase angle of each voltage and current is clearly represented by the orientation and length of their corresponding phasors, allowing easy comparison between the displayed parameters. This produces a unique and dynamic display of the voltages and currents in a circuit (especially in three-phase circuits) that cannot be obtained with conventional instruments. The RMS value, phase angle, and frequency of the voltage or current related to each phasor is displayed in the Phasor Analyzer window.

Harmonic Analyzer



Levels	[%]
DC	100.0
1f	265536599913936.2
2f	74.6
3f	37.1
4f	25.2
5f	19.3
6f	15.7
7f	13.2
8f	11.5
9f	10.1
10f	9.0
11f	8.1
12f	7.5
13f	6.9
14f	6.4
15f	5.9
16f	5.6
17f	5.2
18f	4.9
19f	4.7
20f	4.4
21f	4.2
22f	4.0
23f	3.8

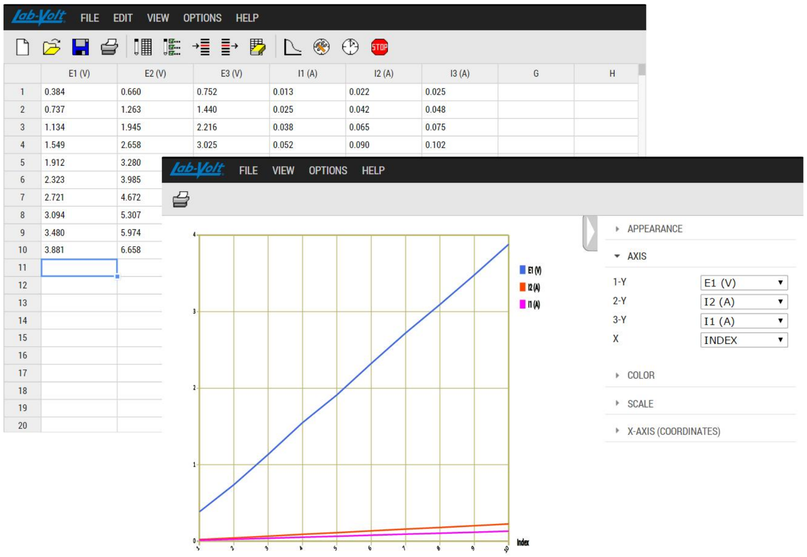
Distortion	[%]
THD	0.0
THD 1	0.0

	Cur 1	Cur 2
Harmonic (f)	0	5
Frequency (Hz)	0.0	300.0
Level (%)	100.0	19.3

FUNDAMENTAL FREQUENCY
TYPE: NETWORK
FREQUENCY (HZ): 60
HARMONICS
NUMBER OF HARMONICS: 5 HARMONIC
INPUT
INPUT: I1
SCALE
TYPE: % OF DC
SETTING: 10 %/DIV
SHOW
CURSORS: VERTICAL

The Harmonic Analyzer allows observation and analysis of the harmonic components in the measured voltages and currents. The fundamental frequency can be manually set to the ac power network frequency or automatically set to the frequency of the fundamental component of the selected voltage or current. The harmonic components of the selected voltage or current can be displayed using a vertical scale graduated in either absolute or relative values. A group of data displays in the Harmonic Analyzer indicates the values of the dc component of the selected voltage or current, as well as the total harmonic distortion (THD). Vertical and horizontal cursors can be displayed to perform precise measurements at particular points on the display. Since the equipment simulated by LVSIM-EMS produces only dc and sinusoidal ac signals (without harmonics), the Harmonic Analyzer, which is intended for use with devices that produce harmonics, is not often used with LVSIM-EMS.

Data Table and Graph Windows



	E1 (V)	E2 (V)	E3 (V)	I1 (A)	I2 (A)	I3 (A)	G	H
1	0.384	0.660	0.752	0.013	0.022	0.025		
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11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

1-Y: E1 (V)
2-Y: I2 (A)
3-Y: I1 (A)
X: INDEX

The values indicated by the various meters in the Metering window, as well as values measured by the other instruments, can be recorded in the Data Table window with a click of the mouse. The values recorded in the Data Table can be saved to a file (ASCII-formatted file). The recorded data can also be used to plot graphs by selecting which parameter(s) to plot in the Graph window. This allows lab results to be plotted quickly and easily. More sophisticated graphs can be created by exporting the contents of the Data Table window to any spreadsheet program, such as Microsoft Excel®, directly through the Windows Clipboard.

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List of Manuals

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Topic Coverage

- Fundamentals for Electric Power Technology
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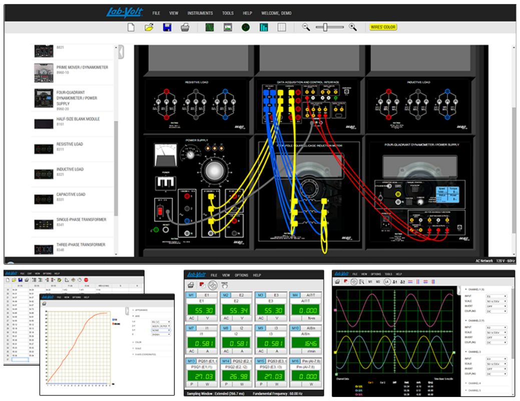
Electromechanical Systems Simulation Software (LVSIM®-EMS) - 35 Users Online, 1 year (Optional)

586992 (8972-G0)



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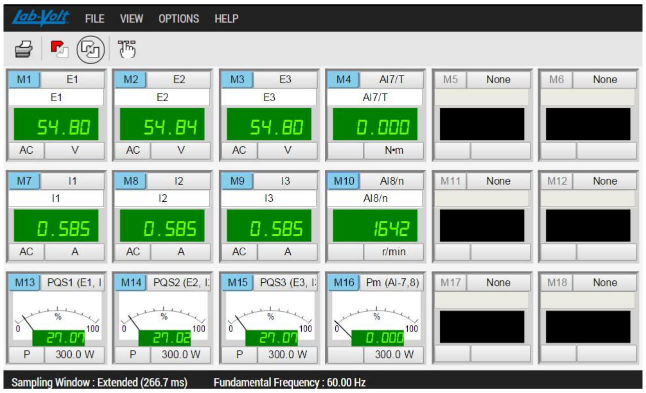
Metering Window

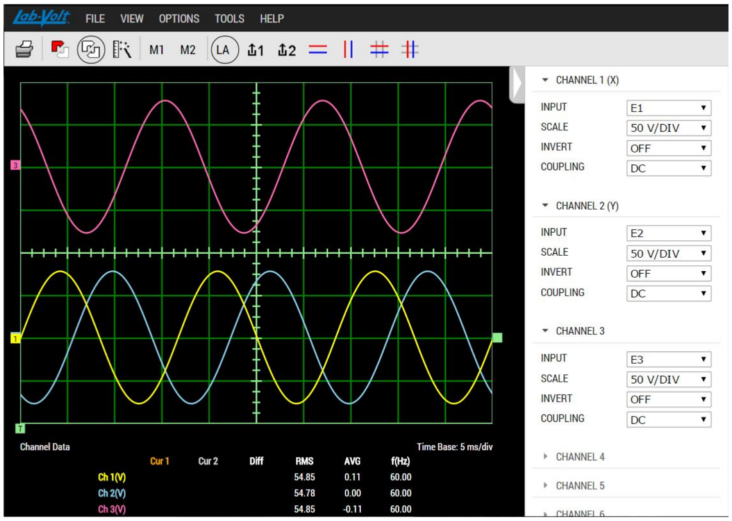


M1 E1: 54.80 AC V
M2 E2: 54.84 AC V
M3 E3: 54.80 AC V
M4 AI7/T: 0.000 N•m
M5 None
M6 None
M7 I1: 0.585 AC A
M8 I2: 0.585 AC A
M9 I3: 0.585 AC A
M10 AI8/n: 1642 r/min
M11 None
M12 None
M13 PQS1 (E1, I: 27.07 % P 300.0 W
M14 PQS2 (E2, I: 27.02 % P 300.0 W
M15 PQS3 (E3, I: 27.07 % P 300.0 W
M16 Pm (AI-7,8): 0.000 % 300.0 W
M17 None
M18 None

Sampling Window : Extended (266.7 ms)   Fundamental Frequency : 60.00 Hz

The Metering window displays up to eighteen meters, which can be configured individually for measuring ac/dc voltage and current, electrical power (active, reactive, and apparent), torque, speed, mechanical power, etc. The voltage and current meters have several modes of operation that allow measurement of the mean (dc) value, RMS value, crest factor, RMS value of a particular harmonic (up to the 15th value), RMS value of the harmonics, and total harmonic distortion (THD). Six of the eighteen meters are user-programmable and give access to a larger variety of functions for measurement of power factor, efficiency, impedance, frequency, energy, phase shift, etc. The layout of the meters in the Metering window is user-customizable.

Oscilloscope



CHANNEL 1 (X)
INPUT E1
SCALE 50 V/DIV
INVERT OFF
COUPLING DC

CHANNEL 2 (Y)
INPUT E2
SCALE 50 V/DIV
INVERT OFF
COUPLING DC

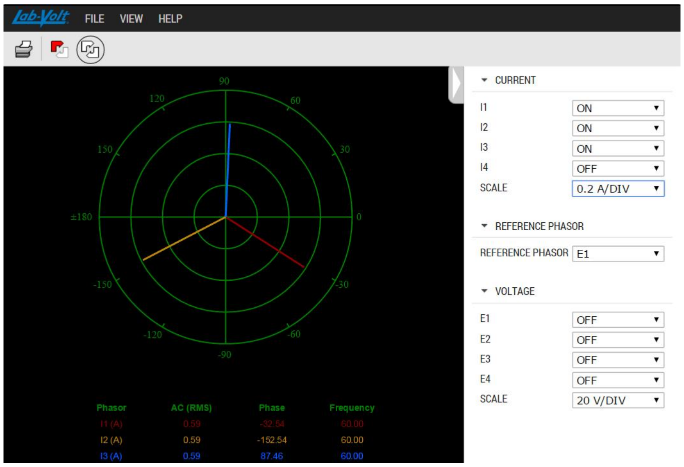
CHANNEL 3
INPUT E3
SCALE 50 V/DIV
INVERT OFF
COUPLING DC

Channel Data   Time Base: 5 ms/div

	Cur 1	Cur 2	Diff	RMS	AVG	f(Hz)
Ch 1(V)				54.85	0.11	60.00
Ch 2(V)				54.78	0.00	60.00
Ch 3(V)				54.85	-0.11	60.00

The Oscilloscope displays up to eight waveforms simultaneously, each of a different color for easy identification. Each channel has independent vertical controls similar to those found on conventional oscilloscopes. An automatic scale-setting function allows the sensitivity of each channel to be set automatically according to the magnitude of the observed parameter. The time base and trigger controls are similar to those found on most oscilloscopes. The RMS value, average value, and frequency of each observed parameters can be displayed in the Oscilloscope window. Two vertical cursors can be activated to perform precise measurements at particular points on the displayed waveforms. The Oscilloscope toolbar includes two memory buttons for saving displayed waveforms.

Phasor Analyzer



Phasor	AC (RMS)	Phase	Frequency
I1 (A)	0.59	-32.54	60.00
I2 (A)	0.59	-152.54	60.00
I3 (A)	0.59	87.46	60.00

CURRENT

I1	ON
I2	ON
I3	ON
I4	OFF
SCALE	0.2 A/DIV

REFERENCE PHASOR

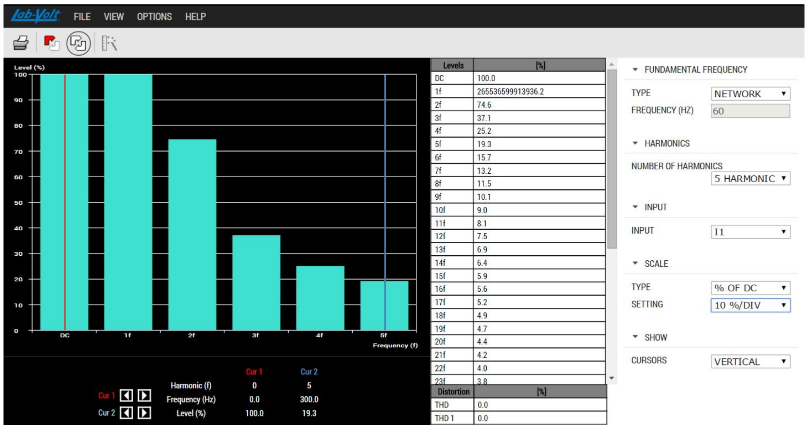
REFERENCE PHASOR	E1

VOLTAGE

E1	OFF
E2	OFF
E3	OFF
E4	OFF
SCALE	20 V/DIV

The Phasor Analyzer displays the phasors related to the measured voltages and currents. The amplitude and phase angle of each voltage and current is clearly represented by the orientation and length of their corresponding phasors, allowing easy comparison between the displayed parameters. This produces a unique and dynamic display of the voltages and currents in a circuit (especially in three-phase circuits) that cannot be obtained with conventional instruments. The RMS value, phase angle, and frequency of the voltage or current related to each phasor is displayed in the Phasor Analyzer window.

Harmonic Analyzer



	Cur 1	Cur 2
Harmonic (f)	0	5
Frequency (Hz)	0.0	300.0
Level (%)	100.0	19.3

Levels	[%]
DC	100.0
1f	265536599913936.2
2f	74.6
3f	37.1
4f	25.2
5f	19.3
6f	15.7
7f	13.2
8f	11.5
9f	10.1
10f	9.0
11f	8.1
12f	7.5
13f	6.9
14f	6.4
15f	5.9
16f	5.6
17f	5.2
18f	4.9
19f	4.7
20f	4.4
21f	4.2
22f	4.0
23f	3.8

Distortion	[%]
THD	0.0
THD 1	0.0

FUNDAMENTAL FREQUENCY

TYPE	NETWORK
FREQUENCY (HZ)	60

HARMONICS

NUMBER OF HARMONICS	5 HARMONIC

INPUT

INPUT	I1

SCALE

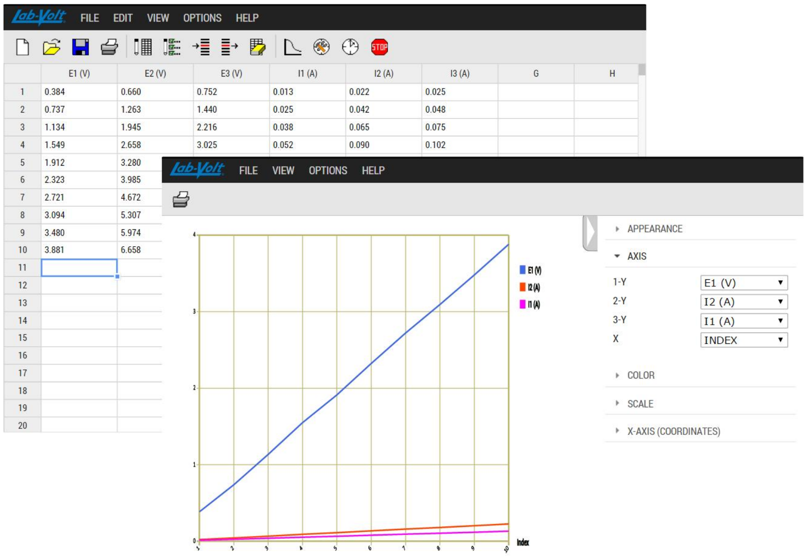
TYPE	% OF DC
SETTING	10 %/DIV

SHOW

CURSORS	VERTICAL

The Harmonic Analyzer allows observation and analysis of the harmonic components in the measured voltages and currents. The fundamental frequency can be manually set to the ac power network frequency or automatically set to the frequency of the fundamental component of the selected voltage or current. The harmonic components of the selected voltage or current can be displayed using a vertical scale graduated in either absolute or relative values. A group of data displays in the Harmonic Analyzer indicates the values of the dc component of the selected voltage or current, as well as the total harmonic distortion (THD). Vertical and horizontal cursors can be displayed to perform precise measurements at particular points on the display. Since the equipment simulated by LVSIM-EMS produces only dc and sinusoidal ac signals (without harmonics), the Harmonic Analyzer, which is intended for use with devices that produce harmonics, is not often used with LVSIM-EMS.

Data Table and Graph Windows



	E1 (V)	E2 (V)	E3 (V)	I1 (A)	I2 (A)	I3 (A)	G	H
1	0.384	0.660	0.752	0.013	0.022	0.025		
2	0.737	1.263	1.440	0.025	0.042	0.048		
3	1.134	1.945	2.216	0.038	0.065	0.075		
4	1.549	2.658	3.025	0.052	0.090	0.102		
5	1.912	3.280						
6	2.323	3.985						
7	2.721	4.672						
8	3.094	5.307						
9	3.480	5.974						
10	3.881	6.658						
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

1-Y: E1 (V)
2-Y: I2 (A)
3-Y: I1 (A)
X: INDEX

The values indicated by the various meters in the Metering window, as well as values measured by the other instruments, can be recorded in the Data Table window with a click of the mouse. The values recorded in the Data Table can be saved to a file (ASCII-formatted file). The recorded data can also be used to plot graphs by selecting which parameter(s) to plot in the Graph window. This allows lab results to be plotted quickly and easily. More sophisticated graphs can be created by exporting the contents of the Data Table window to any spreadsheet program, such as Microsoft Excel®, directly through the Windows Clipboard.

Software Protection and Licensing

The local and network version provides a perpetual licence and the online access version provides a annual licence (additional years can be purchased when ordering).

The local and network version of LVSIM-EMS are copy-protected by means of a hardlock security device. When LVSIM-EMS detects the security device, students have complete access to all measuring functions of the virtual instruments and other protected features of LVSIM-EMS, as well as to the student manuals included with the simulation software. Note that students are allowed to copy the software onto their personal computer to allow them to prepare laboratories in advance.

Two different security devices are available for LVSIM-EMS: a single-user hardlock key, which can be inserted in the USB port of the user's computer, and a multiple-user hardlock key, which can be inserted in the USB port of the network server or any computer in the same network. Once the hardlock key is active on the network, the other computer will see the available licences. Alternately, the multiple-user hardlock key can be inserted in a USB port inside the server using a circuit board with edge-type connector (provided with the key) that can be installed in a PCI expansion slot of the server.

The multiple-user hardlock key can be installed in servers running under one of the following Microsoft® operating systems: Windows 7, Windows 8, Windows 10, Windows 2008 Server, and Windows 2013 Server. As its name indicates, the multiple-user hardlock key allows several users of a network to run LVSIM-EMS simultaneously. Different versions of LVSIM-EMS are available, each allowing a particular number of users.

Online Edition

The online version of LVSIM-EMS is accessible directly via the internet, and requires no software installation nor any update since the latest version of the software is always available. The online version of LVSIM-EMS also includes a demo mode that allows students to prepare laboratories in advance by familiarizing with the equipment and connections. The demo mode does not require any login.

Computer Requirements

Local and Network Versions:

- One (1) USB 2.0 port for the security dongle, Microsoft Windows 10 operating system recommended (compatible with Windows 7 and 8), basic dual core CPU, Google Chrome web browser installed (for better experience)

Online Version:

- Microsoft Windows 10 operating system recommended (compatible with Windows 7 and 8 but not fully compatible with mobile devices), basic dual core CPU, internet access (bandwidth usage of 50 KB/s maximum), Google Chrome web browser installed (for better experience)

List of Manuals

Description	Manual number
Electromechanical Systems Simulation Software (User Guide)	583879 (20858-E0)
Computer-Based Instruments for EMS (User Guide)	584396 (36221-E0)

Table of Contents of the Manual(s)

Electromechanical Systems Simulation Software (User Guide) (583879 (20858-E0))

- 1 Overview of LVSIM-EMS
- 2 Installing the Security Device
- 3 Installing and Running LVSIM-EMS

Computer-Based Instruments for EMS (User Guide) (584396 (36221-E0))

- 1 Familiarization with the Metering Window and the Data Table
- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Topic Coverage

- Fundamentals for Electric Power Technology
- Alternating Current
- Capacitors in AC Circuits
- Inductors in AC Circuits
- Power, Phasors, and Impedance in AC Circuits
- Three-Phase Circuits
- Special Transformer Connections
- Single- and three-Phase Transformers
- Fundamentals for Rotating Machines
- DC Motors and Generators
- Special Characteristics of DC Motors
- AC Induction and Synchronous Motors
- Three-Phase Synchronous Generators

Features & Benefits

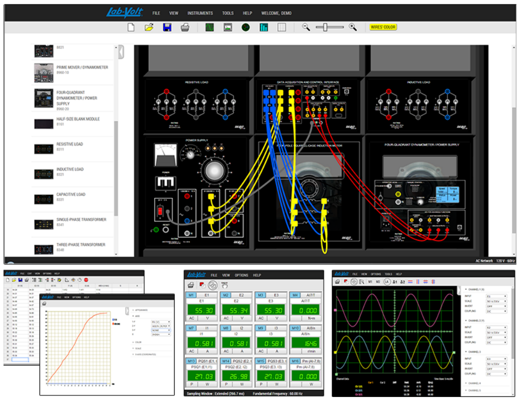
- Replicates the Electromechanical Training System, enabling students to perform actual experiments using virtual equipment
    - Install, move, and remove EMS modules in and from the workstation
    - Modify module connections at any time and change the color of wires
    - Install a timing belt between two EMS machines
    - Verify module connections using a tool that highlights all wires connected to a same circuit point
    - Perform measurements of voltage, current, power, speed, torque, impedance, resistance, reactance, and frequency and display the values on digital or analog meters
    - Record measurements in a data table and plot graphs using the recorded data
    - Display waveforms on a multi-channel oscilloscope and ac voltages and currents as phasors
- Students prepare for laboratories in advance using virtual equipment, thereby decreasing the time they require to perform the exercises using actual equipment
- Decreases the quantity of actual equipment required per student
- Allows students to practice with EMS equipment operation and connection at home on a personal computer

Specifications

Parameter	Value
Computer Requirements	
Local and Network versions	One (1) USB 2.0 port for the security dongle, Microsoft Windows 10 operating system recommended (compatible with Windows 7 and 8), basic dual core CPU, Google Chrome web browser installed (for better experience)
Online version	Microsoft Windows 10 operating system recommended (compatible with Windows 7 and 8 but not fully compatible with mobile devices), basic dual core CPU, internet access (bandwidth usage of 50 KB/s maximum), Google Chrome web browser installed (for better experience)

Electromechanical Systems Simulation Software (LVSIM®-EMS) - 40 Users Online, 1 year (Optional)

586995 (8972-H0)



The Electromechanical Systems Simulation Software (LVSIM®-EMS) is a simulation software that covers the same courseware as the following systems:

Computer-Assisted 0.2 kW Electromechanical Training System, Model 8006-1
DC and AC Power Circuits Training System, Model 8010-1
Electromechanical Training System, Model 8010-9
AC Power Transmission Training System, Model 8010-B

All workbooks parts of the systems above are available in the navigation menu of LVSIM-EMS for online consultation. To obtain the printing rights, Campus Licenses for each are available and must be ordered separately.

With LVSIM-EMS, all the standard EMS laboratory equipment is replaced by images of the actual EMS modules that students can manipulate on the computer screen. Students can identify and set up equipment for a given exercise, make the necessary connections between the virtual EMS modules, and verify the connections made without the need for actual EMS equipment.

Sophisticated mathematical models fully simulate the electrical and mechanical characteristics of all the actual EMS modules: power supplies, motors, generators, transformers, electrical and mechanical loads, etc. All

modules simulated in the LVSIM-EMS software feature the same front panel information as the actual EMS modules. Short-circuit connections in the virtual equipment setup cause the virtual circuit-breaker protection to trip. This trip condition is clearly indicated on the virtual EMS modules.

Used either as a complement to the actual EMS laboratory equipment, or as a stand-alone product, LVSIM-EMS is a cost-effective tool that enables students to perform the same exercises as in the courseware of the above-mentioned training systems. When used as a stand-alone package, the LVSIM-EMS software allows students to perform hands-on activities related to electrical power and machines, including active, reactive, and apparent power, phasors, ac/dc motors and generators, three-phase circuits, and transformers.

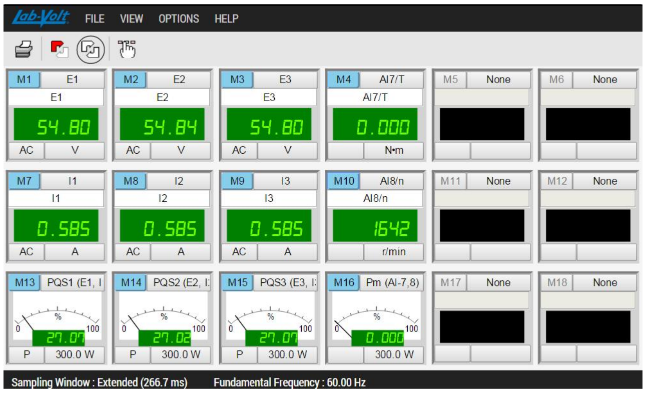
LVSIM-EMS is a web-browser based application **available in three different configurations.** The simulation software can either be installed locally on a Windows® personal computer (local version), on a Windows server (network version), or accessed directly online through the labvolt.com website at lvsim.labvolt.com (online version). Both network and local versions are delivered with perpetual license for the current version. The online version is delivered as a annual license with possibility to expand for more years.

Please visit https://lvsim.labvolt.com and try the online version!

Virtual Instrumentation

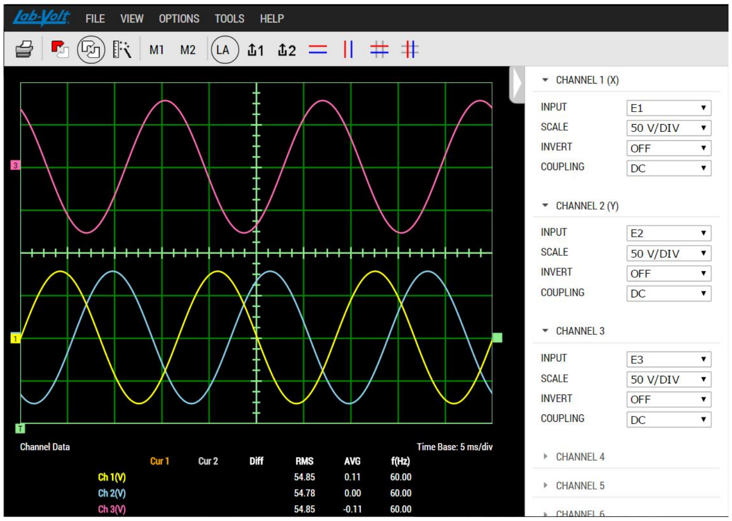
LVSIM-EMS comprises a set of conventional and specialized instruments that can be used for measuring, observing, and analyzing electrical and mechanical parameters in electric power systems and power electronic circuits. Each instrument appears as a window on the computer screen. The conventional instruments include ac/dc voltmeters and ammeters, power meters, and an eight-channel oscilloscope. The specialized instruments include a six-channel phasor analyzer, a harmonic analyzer, torque, speed, and mechanical power meters, and user-programmable meters. The software is also provided with data-recording and graph-plotting capabilities. The various instruments are briefly described in the next section of this datasheet.

Metering Window


Lab-Volt
FILE
VIEW
OPTIONS
HELP
M1 E1
54.80
AC V
M2 E2
54.84
AC V
M3 E3
54.80
AC V
M4 AI7/T
0.000
N•m
M5 None
M6 None
M7 I1
0.585
AC A
M8 I2
0.585
AC A
M9 I3
0.585
AC A
M10 AI8/n
1642
r/min
M11 None
M12 None
M13 PQS1 (E1, I
27.07
P 300.0 W
M14 PQS2 (E2, I
27.02
P 300.0 W
M15 PQS3 (E3, I
27.07
P 300.0 W
M16 Pm (AI-7,8)
0.000
300.0 W
M17 None
M18 None
Sampling Window : Extended (266.7 ms)
Fundamental Frequency : 60.00 Hz

The Metering window displays up to eighteen meters, which can be configured individually for measuring ac/dc voltage and current, electrical power (active, reactive, and apparent), torque, speed, mechanical power, etc. The voltage and current meters have several modes of operation that allow measurement of the mean (dc) value, RMS value, crest factor, RMS value of a particular harmonic (up to the 15th value), RMS value of the harmonics, and total harmonic distortion (THD). Six of the eighteen meters are user-programmable and give access to a larger variety of functions for measurement of power factor, efficiency, impedance, frequency, energy, phase shift, etc. The layout of the meters in the Metering window is user-customizable.

Oscilloscope



CHANNEL 1 (X)

INPUT	E1
SCALE	50 V/DIV
INVERT	OFF
COUPLING	DC

CHANNEL 2 (Y)

INPUT	E2
SCALE	50 V/DIV
INVERT	OFF
COUPLING	DC

CHANNEL 3

INPUT	E3
SCALE	50 V/DIV
INVERT	OFF
COUPLING	DC

CHANNEL 4

CHANNEL 5

CHANNEL 6

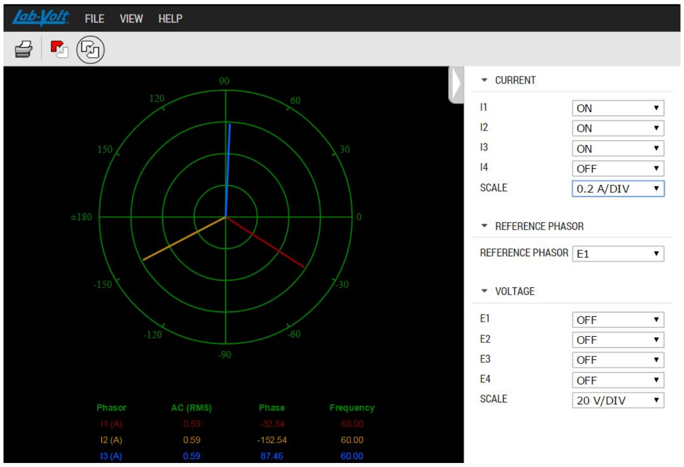
Channel Data

Time Base: 5 ms/div

	Cur 1	Cur 2	Diff	RMS	AVG	f(Hz)
Ch 1(V)				54.85	0.11	60.00
Ch 2(V)				54.78	0.00	60.00
Ch 3(V)				54.85	-0.11	60.00

The Oscilloscope displays up to eight waveforms simultaneously, each of a different color for easy identification. Each channel has independent vertical controls similar to those found on conventional oscilloscopes. An automatic scale-setting function allows the sensitivity of each channel to be set automatically according to the magnitude of the observed parameter. The time base and trigger controls are similar to those found on most oscilloscopes. The RMS value, average value, and frequency of each observed parameters can be displayed in the Oscilloscope window. Two vertical cursors can be activated to perform precise measurements at particular points on the displayed waveforms. The Oscilloscope toolbar includes two memory buttons for saving displayed waveforms.

Phasor Analyzer



CURRENT

I1	ON
I2	ON
I3	ON
I4	OFF
SCALE	0.2 A/DIV

REFERENCE PHASOR

REFERENCE PHASOR	E1

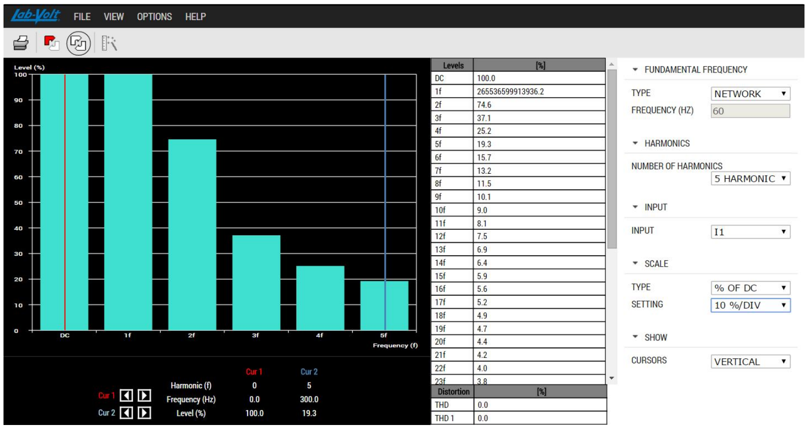
VOLTAGE

E1	OFF
E2	OFF
E3	OFF
E4	OFF
SCALE	20 V/DIV

Phasor	AC (RMS)	Phase	Frequency
I1 (A)	0.59	-32.54	60.00
I2 (A)	0.59	-152.54	60.00
I3 (A)	0.59	87.46	60.00

The Phasor Analyzer displays the phasors related to the measured voltages and currents. The amplitude and phase angle of each voltage and current is clearly represented by the orientation and length of their corresponding phasors, allowing easy comparison between the displayed parameters. This produces a unique and dynamic display of the voltages and currents in a circuit (especially in three-phase circuits) that cannot be obtained with conventional instruments. The RMS value, phase angle, and frequency of the voltage or current related to each phasor is displayed in the Phasor Analyzer window.

Harmonic Analyzer



	Cur 1	Cur 2
Harmonic (f)	0	5
Frequency (Hz)	0.0	300.0
Level (%)	100.0	19.3

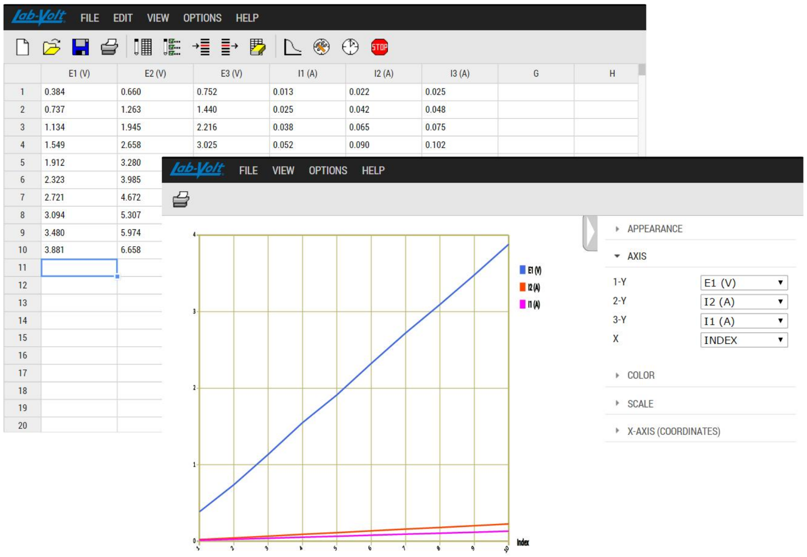
Levels	[%]
DC	100.0
1f	265536599913936.2
2f	74.6
3f	37.1
4f	25.2
5f	19.3
6f	15.7
7f	13.2
8f	11.5
9f	10.1
10f	9.0
11f	8.1
12f	7.5
13f	6.9
14f	6.4
15f	5.9
16f	5.6
17f	5.2
18f	4.9
19f	4.7
20f	4.4
21f	4.2
22f	4.0
23f	3.8

Distortion	[%]
THD	0.0
THD 1	0.0

FUNDAMENTAL FREQUENCY
TYPE: NETWORK
FREQUENCY (HZ): 60
HARMONICS
NUMBER OF HARMONICS: 5 HARMONIC
INPUT
INPUT: I1
SCALE
TYPE: % OF DC
SETTING: 10 %/DIV
SHOW
CURSORS: VERTICAL

The Harmonic Analyzer allows observation and analysis of the harmonic components in the measured voltages and currents. The fundamental frequency can be manually set to the ac power network frequency or automatically set to the frequency of the fundamental component of the selected voltage or current. The harmonic components of the selected voltage or current can be displayed using a vertical scale graduated in either absolute or relative values. A group of data displays in the Harmonic Analyzer indicates the values of the dc component of the selected voltage or current, as well as the total harmonic distortion (THD). Vertical and horizontal cursors can be displayed to perform precise measurements at particular points on the display. Since the equipment simulated by LVSIM-EMS produces only dc and sinusoidal ac signals (without harmonics), the Harmonic Analyzer, which is intended for use with devices that produce harmonics, is not often used with LVSIM-EMS.

Data Table and Graph Windows



	E1 (V)	E2 (V)	E3 (V)	I1 (A)	I2 (A)	I3 (A)	G	H
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2	0.737	1.263	1.440	0.025	0.042	0.048		
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7	2.721	4.672						
8	3.094	5.307						
9	3.480	5.974						
10	3.881	6.658						

AXIS
1-Y: E1 (V)
2-Y: I2 (A)
3-Y: I1 (A)
X: INDEX

The values indicated by the various meters in the Metering window, as well as values measured by the other instruments, can be recorded in the Data Table window with a click of the mouse. The values recorded in the Data Table can be saved to a file (ASCII-formatted file). The recorded data can also be used to plot graphs by selecting which parameter(s) to plot in the Graph window. This allows lab results to be plotted quickly and easily. More sophisticated graphs can be created by exporting the contents of the Data Table window to any spreadsheet program, such as Microsoft Excel®, directly through the Windows Clipboard.

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The multiple-user hardlock key can be installed in servers running under one of the following Microsoft® operating systems: Windows 7, Windows 8, Windows 10, Windows 2008 Server, and Windows 2013 Server. As its name indicates, the multiple-user hardlock key allows several users of a network to run LVSIM-EMS simultaneously. Different versions of LVSIM-EMS are available, each allowing a particular number of users.

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Computer Requirements

Local and Network Versions:

- One (1) USB 2.0 port for the security dongle, Microsoft Windows 10 operating system recommended (compatible with Windows 7 and 8), basic dual core CPU, Google Chrome web browser installed (for better experience)

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List of Manuals

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Computer-Based Instruments for EMS (User Guide)	584396 (36221-E0)

Table of Contents of the Manual(s)

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- 2 Familiarization with the Oscilloscope
- 3 Familiarization with the Phasor Analyzer
- 4 Familiarization with the Harmonic Analyzer
- 5 Measuring Three-Phase Power Using the Metering Window

Topic Coverage

- Fundamentals for Electric Power Technology
- Alternating Current
- Capacitors in AC Circuits
- Inductors in AC Circuits
- Power, Phasors, and Impedance in AC Circuits
- Three-Phase Circuits
- Special Transformer Connections
- Single- and three-Phase Transformers
- Fundamentals for Rotating Machines
- DC Motors and Generators
- Special Characteristics of DC Motors
- AC Induction and Synchronous Motors
- Three-Phase Synchronous Generators

Features & Benefits

- Replicates the Electromechanical Training System, enabling students to perform actual experiments using virtual equipment
  - Install, move, and remove EMS modules in and from the workstation
  - Modify module connections at any time and change the color of wires
  - Install a timing belt between two EMS machines
  - Verify module connections using a tool that highlights all wires connected to a same circuit point
  - Perform measurements of voltage, current, power, speed, torque, impedance, resistance, reactance, and frequency and display the values on digital or analog meters
  - Record measurements in a data table and plot graphs using the recorded data
  - Display waveforms on a multi-channel oscilloscope and ac voltages and currents as phasors
- Students prepare for laboratories in advance using virtual equipment, thereby decreasing the time they require to perform the exercises using actual equipment
- Decreases the quantity of actual equipment required per student
- Allows students to practice with EMS equipment operation and connection at home on a personal computer

Specifications

Parameter	Value
Computer Requirements	

Parameter	Value
Local and Network versions	One (1) USB 2.0 port for the security dongle, Microsoft Windows 10 operating system recommended (compatible with Windows 7 and 8), basic dual core CPU, Google Chrome web browser installed (for better experience)
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SCADA for LVDAC-EMS (Optional)
8094377 (8973-00)

Education in electrical engineering at Festo Didactic is largely based on our unique electric power technology training platform, which combines hardware, software, and courseware to allow study of electrical energy.

At the heart of the systems are the data acquisition and control interface (DACI) and the four-quadrant dynamometer/power supply. When used in combination with LVDAC-EMS software program, students have access to a complete set of computer-based instruments to measure, observe, analyze, and control electrical and mechanical parameters of a workstation on their computers.

Our state-of-the-art training platform has just been enhanced through the integration of a new SCADA-EMS feature, a software program designed to run in combination with LVDAC-EMS. SCADA-EMS transforms LVDAC-EMS and the workstation's computer into a local workstation that can be monitored and controlled over a local network from a supervisory computer. Using the OPC Server protocol, SCADA-EMS enables users to design their own interface by calling the different applications running on the local workstations.

SCADA-EMS enhances LVDAC-EMS by adding several new features. You will be able to:

- Collect data from local workstations.

- Observe and control one or more stations from one or more supervisory stations.

- Remotely control several applications in your lab.

- Use a workstation in a different room to make real demonstrations over the network in your classroom without having to bring your workstation to class.

- Introduce students to the fundamentals of SCADA in a smart grid context.

- Recreate a complete grid with several different applications running.

The SCADA-EMS software program can be downloaded from our website. This locked version can be unlocked by a USB dongle. A dongle unlocks five workstations; order as many dongles as required.

Before ordering the dongles, please install:

- LVDAC-EMS (version 3.19 or later) on all your workstation computers.

- SCADA-EMS (1.01 or later) on the workstation computers you want to use to build up your SCADA application.

Contact your sales representative about order details and options.

LVDAC-EMS

The LVDAC-EMS software is a freeware which can be downloaded anytime from the Festo Didactic website (www.labvolt.com). The LVDAC-EMS software is a user-friendly tool that facilitates the use of the various functions which can be implemented with USB peripherals such as the Data Acquisition and Control Interface (DACI), LabVolt Series 9063, and the Four-Quadrant Dynamometer / Power Supply, LabVolt Series 8960.

The LVDAC-EMS software also includes a firmware update for the DACI. When a DACI is connected to a newer version of LVDAC-EMS, the user can easily update the module using a simple update wizard.

LVDAC-EMS Functions

The functions that are currently available for the DACI, Model 9063, are described below. All functions can be activated in any DACI by purchasing a license for that specific function and then performing the upgrade procedure on the DACI. New functions will be added to this datasheet as they become available.

Instrumentation Functions

The instrumentation functions of LVDAC-EMS replace a multitude of actual data acquisition devices (e.g., voltmeters, ammeters, oscilloscopes, synchroscopes) with a series of computer-based instruments that display the data measured by the DACI.

Features & Benefits

- Monitor and control several workstations from one (or more) supervisory computer(s)
- Use OPC server protocol to communicate between the different workstations
- Include your own pictures and schematics
- Introduce SCADA in existing EMS laboratories

Pyranometer (Optional)
579784 (8989-00)

FESTO
PYRANOMETER
Output
+
–
Rating: Refer to label on pyranometer

The Pyranometer is a high-quality instrument for measuring solar irradiance. The thermopile sensor construction measures the solar energy that is received from the total solar spectrum and the whole hemisphere (180° field of view). The output signal of the Pyranometer is a voltage proportional to the measured solar irradiance, expressed in Watts/m². The Pyranometer is a useful instrument when measuring the performance of solar panels versus insolation.

Specifications

Parameter	Value
Spectral Range	310 to 2800 nm
Sensitivity	5 to 20 uV/W/m²
Response Time	<18 s
Maximum Solar Irradiance	2000 W/m²
Field of View	180°
Operating Temperature Range	-40°C to +80°C (-40°F to +176°F)
Physical Characteristics	

Parameter	Value
Dimensions (H x W x D)	85 x 130 x 100 mm (3.4 x 5.1 x 3.9 in)
Net Weight	1.1 kg (2.4 lb)

Heavy-Duty Tripod (Optional)
583216 (40208-10)

The Heavy-Duty Tripod is a compact, heavy-duty unit that is perfectly suited to hold the Solar Panel, Model 8806, when performing outdoor exercises.

Specifications

Parameter	Value
Load Capacity	5 kg (11 lb)
Physical Characteristics	
Closed Length	53.5 cm (21.1 in)
Minimum Height	8.0 cm (3.1 in)
Maximum Height	146 cm (57.5 in)
Net Weight	1.8 kg (4 lb)

Step 7 professional and WinCC Advanced, 6 users (perpetual) + 20 Students (1 year), Educational (Optional)
8164650 (81646-50)

Trainer Package V17 STEP 7 Professional, Safety, WinCC Advanced and Unified Engineering

- STEP 7 Professional, Safety, WinCC Advanced and Unified Engineering, RT and Options, CFC, DCC, SiVArc, Test Suite, SIRIUS, Multiuser, Teamcenter Gateway, Cloud Connector; Target, ODK, PRODIAG, OPC UA, PLCSIM Advanced, Startdrive Advanced

- 6 x software license unlimited

- 20 x trial license for 365 days

- Software on DVD or Download

- License key on USB flash drive

- 9 languages: de,en,zh included, fr,es,it,ru,ja,ko as download

- Executable in Windows 10

- For configuring of SIMATIC S7- 1500/1200/300/400/WinAC, SIMATIC Panels

Technical changes are possible.

Special license rules apply for schools and educational institutes in the commercial sector.

Step 7 professional and WinCC Advanced, 20 Students (1 year), Educational (Optional)

8164652 (81646-52)

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- STEP 7 Professional, Safety, WinCC Advanced and Unified Engineering, RT and options, CFC, Test Suite, Multiuser, PLCSIM Advanced, Target, ODK
- 20 x trial license for 365 days
- Software on DVD or Download
- License key on USB flash drive
- 9 languages: de,en,zh included, fr,es,it,ru,ja,ko as download
- Executable in Windows 10
- For configuring of SIMATIC S7- 1500/1200/300/400/WinAC, SIMATIC Panels

Technical changes are possible.

Special license rules apply for schools and educational institutes in the commercial sector.

Reflecting the commitment of Festo Didactic to high quality standards in product, design, development, production, installation, and service, our manufacturing and distribution facility has received the ISO 9001 certification.

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