

Smart Grid Technologies Training System 579325 (8010-C0)

FESTO

LabVolt Series

Datasheet

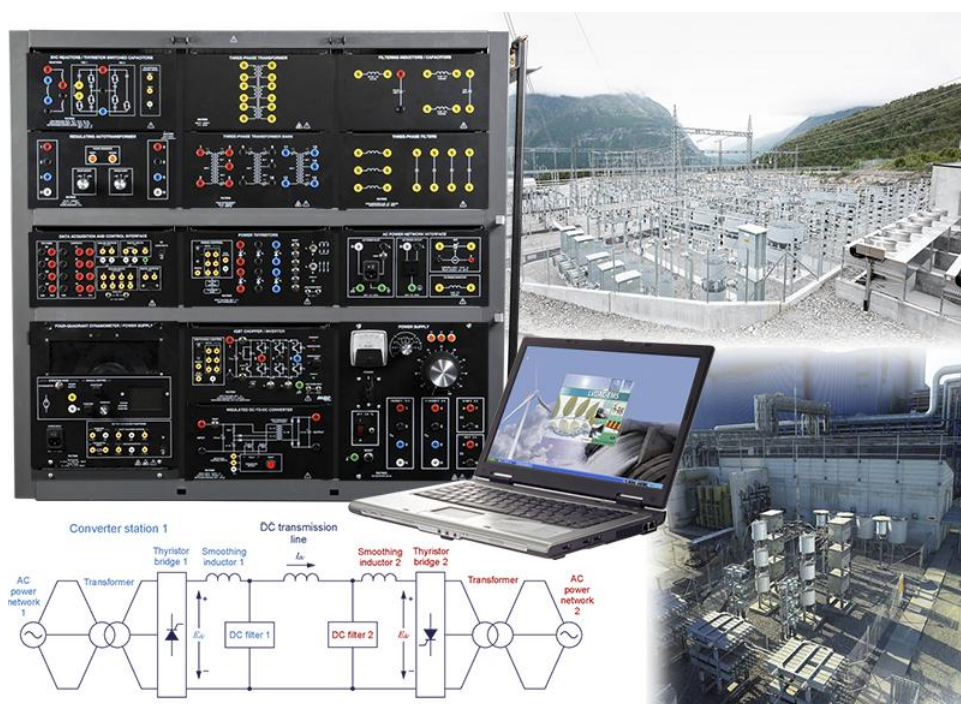


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General Description

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:

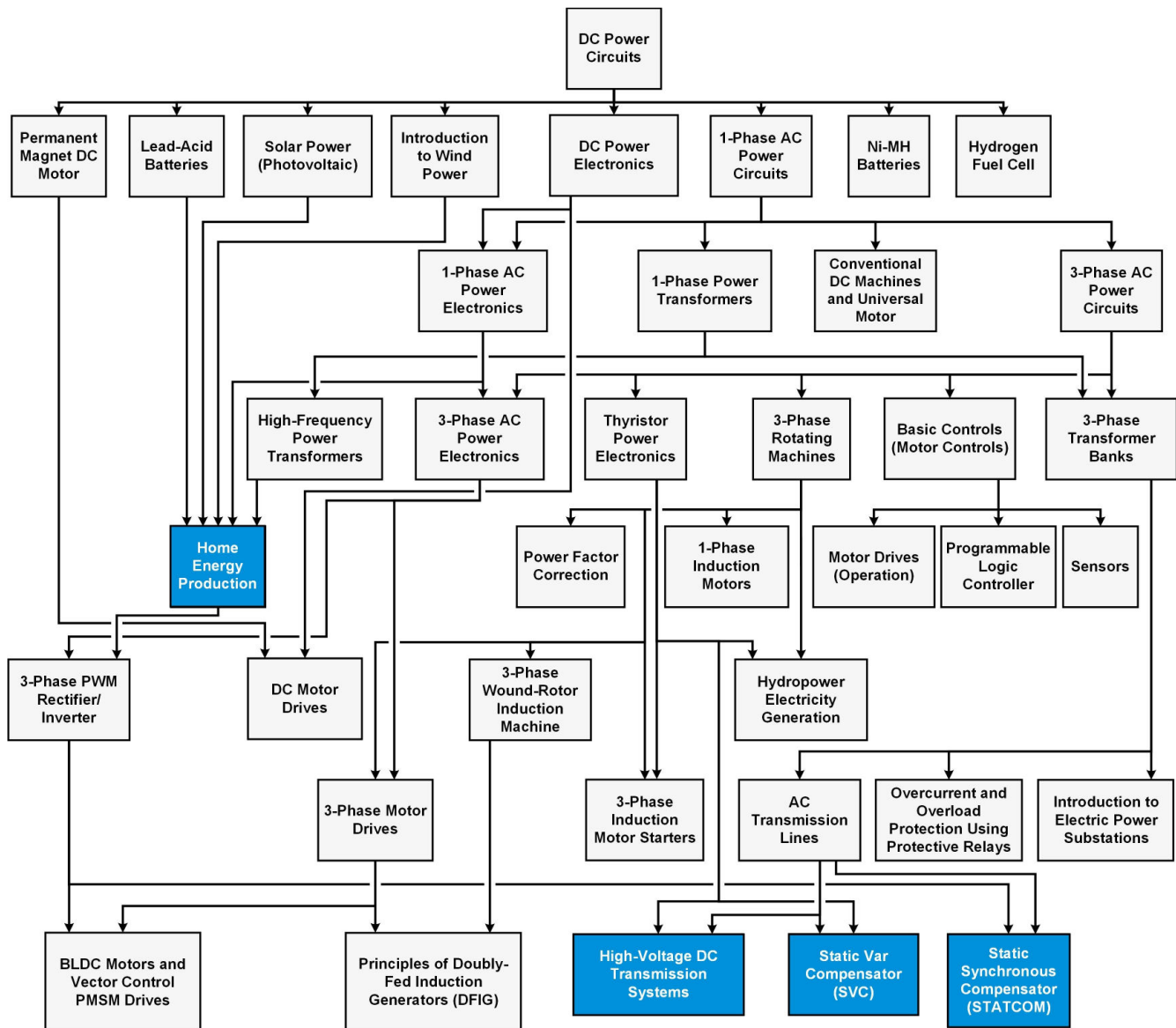
- Static Var Compensator (SVC)
- Static Synchronous Compensator (STATCOM)
- High-Voltage DC (HVDC) Transmission Systems

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.

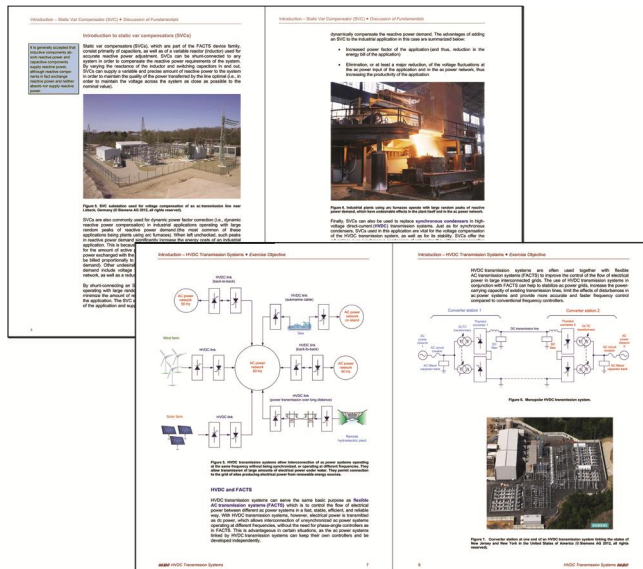
The Electric Power Technology Training Program is highly modular in both courseware and hardware. Because of this, courses and equipment from the program are available as required, either individually or in the context of a specific training system. The program covers several different subjects in the 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.



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	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	Power Supply _____	579603 (8821-20)

Qty	Description	Model number
1	Insulated DC-to-DC Converter _____	579618 (8835-00)
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 _____	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 (Student Manual) _____	579385 (86361-00)
Home Energy Production (Instructor Guide) _____	579387 (86361-10)
Static Var Compensator (SVC) (Student Manual) _____	579431 (86370-00)
Static Var Compensator (SVC) (Instructor Guide) _____	579432 (86370-10)
Static Synchronous Compensator (STATCOM) (Student Manual) _____	579433 (86371-00)
Static Synchronous Compensator (STATCOM) (Instructor Guide) _____	579434 (86371-10)
HVDC Transmission Systems (Student Manual) _____	579460 (86380-00)
HVDC Transmission Systems (Instructor Guide) _____	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 (Student Manual) (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) (Student Manual) (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) (Student Manual) (579433 (86371-00))

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

HVDC Transmission Systems (Student Manual) (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

Qty	Description	Model number
1	Digital Multimeter _____	579782 (8946-20)
1	Personal Computer _____	579785 (8990-00) ¹

Optional Equipment

Qty	Description	Model number
1	Mobile Workstation _____	579755 (8110-20) ²
1	Storage Shelves _____	579756 (8150-10)
1	Full-Size Blank EMS Module _____	579757 (8160-00)
1	Half-Size Blank EMS Module _____	579758 (8161-00)
1	Wind Turbine Generator/Controller _____	579487 (8216-00) ³
1	Timing Belt _____	579637 (8942-00) ⁴
1	Multimeters Module _____	586888 (8946-A0) ⁵
1	Turbine Emulator Function Set _____	579783 (8968-30) ⁶
1	Smart Grid Technologies Training System (Manuals on CD-ROM) _____	579724 (86361-A0)

Optional Manual(s)

Qty	Description	Model number
1	AC Transmission Lines (Student Manual) _____	580204 (20521-00)
1	AC Transmission Lines (Instructor Guide) _____	580205 (20521-10)

¹ 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.

² Can replace the Workstation, Model 8134.

³ Optional equipment in the course Home Energy Production, Model 86361.

⁴ Optional equipment in the course Home Energy Production, Model 86361.

⁵ Can replace the Digital Multimeter, Model 8946-2.

⁶ Optional equipment in the course Home Energy Production, Model 86361.

Qty	Description	Model number
1	Three-Phase AC Power Circuits (Student Manual)	579374 (86360-00) ⁷
1	Three-Phase AC Power Circuits (Instructor Guide)	579378 (86360-10)
1	Three-Phase Transformer Banks (Student Manual)	579448 (86379-00) ⁸
1	Three-Phase Transformer Banks (Instructor Guide)	579451 (86379-10)

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 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)

Equipment Description

Workstation 579484 (8134-20)



The Workstation is a fully assembled workstation that serves the same purpose as the Mobile Workstation, Model 8110-2, 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, Model 89117-1, to make a Mobile Workstation, Model 8110-2, or on a Mobile Base, Model 88863, to make a mobile workstation without storage cabinet. In that case, it is possible to mount and lock a second

Workstation, Model 8134-2, 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

⁷ Bonus course that can be performed using the equipment included in this training system.

⁸ Bonus course that can be performed using the equipment included in this training system.

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.



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.



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

Optional Equipment

Qty	Description	Model number
1	Industrial Controls Single-Rail Workstation	581243 (3105-A0) ⁹
1	Industrial Controls Double-Rail Workstation	585964 (3105-B0) ¹⁰
1	Dust Cover for Workstations	587004 (8991-00)
1	Mobile Base	587518 (88863-00)
1	Mobile Storage Cabinet	587519 (89117-10)

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)

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.

⁹ This add-on workstation allows modules from the Industrial Controls Training Systems, Models 8036, to be installed in the EMS workstation. Refer to the 8036 datasheet for more information.

¹⁰ This add-on workstation allows modules from the Industrial Controls Training Systems, Models 8036, to be installed in the EMS workstation. Refer to the 8036 datasheet for more information.

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 load 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	$\pm 5\%$
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)



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 load 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	$\pm 5\%$
Load at Nominal Voltage (Each Bank)	
Reactive Power	12-84 var

Parameter	Value
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)



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 μ F - 450 V
High Frequency Filter	
Inductance (2)	2 mH - 5 A - 0-20 kHz
Capacitor (Metallized Polypropylene)	5 μ F - 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)



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	

Parameter	Value
Number	3
Ratings	2 mH – 5 A – 0-20 kHz
Capacitors	
Number	4
Type	Metallized polypropylene
Ratings	5 μ F – 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)



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)



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

Parameter	Value
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)



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 load on a circuit.

Specifications

Parameter	Value
Capacitors	
Quantity	Three identical banks of three capacitors
Capacitance Values (Each Bank)	2.2/4.4/8.8 μ F
Reactance Values (Each Bank)	300/600/1200 Ω
Nominal Voltage	120 V – 60 Hz
Maximum Voltage	230 V
Capacitance Value Accuracy	\pm 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)



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 overcurrents. Fuse status lamps on the module front panel turn on when the resettable fuses open.

Specifications

Parameter	Value
Rating (Each Transformer)	

Parameter	Value
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 $\pm 15^\circ$. 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)



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 transformer, 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

AC Power Network Interface
579581 (8622-00)



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 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 overcurrents 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 k Ω
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

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.

Power connections provided with the module



Wall connectors provided with the module.

Each model comprises a three-phase wall connector with the corresponding three-phase power cable. These components allow the model's connection to the local ac power network. The provided connector type depends on the exact part number of the ordered Power Supply and the countries for which the model is

designed, as shown in the picture.

From left to right: 120/208 V (P/N 579603), 220/380 V (P/N 579606), and 240/415 V (P/N 579609).

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
Fixed DC	120 V – 2 A
Low Power AC	24 V – 3 A - 60 Hz
Included Accessories	
	3 m (10 ft) ac power cord (1)
	NEMA L21-20 wall connector with wall plate (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.

Insulated DC-to-DC Converter 579618 (8835-00)



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)



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 μ F
Protections	
DC Bus Overvoltage	440 V
DC Bus Circuit Breaker	6 A
IGBT Electronic Overcurrent	12 A
IGBT Overheat	About 70°C
Dumping Circuit	
Voltage Threshold	330 V
Resistor	100 Ω , 100 W
Switching Control Signals	
Level	0/5 V
Frequency Range	0-20 kHz
Minimum Dead Time	700 ns
Power Requirements	24 V, 0.16 A, 50/60 Hz
Accessories	
Accessories	24 V power cable (1)
	2 mm banana plug test leads (2)
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	5.67 kg (12.5 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)

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.

Specifications

Parameter	Value
4 mm Safety Banana Plug Leads Characteristics	
Cross Section	1 mm ² (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 mm ² (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 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. The set also includes three-phase leads, which are made of three color-coded leads bundled together along their length to simplify the connection of three-phase circuits.

Specifications

Parameter	Value
4 mm Safety Banana Plug Leads Characteristics	
Cross Section	1 mm ² (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
Blue, 90 cm (36 in)	4

Parameter	Value
Three-Phase 4 mm Safety Banana Plug Leads Characteristics	
Cross Section	1 mm ² (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

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.

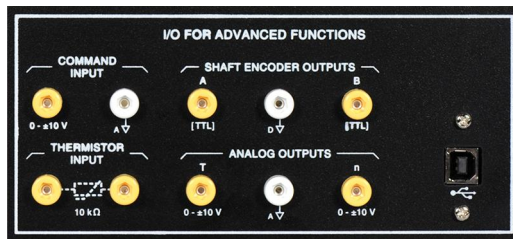
In the Power Supply mode, the four-quadrant power supply operates as a four-quadrant power supply that can act as a dc voltage source, dc current source, ac power source, etc., depending on the control function selected by the user. Two 4 mm safety banana jacks on the front panel provide access to the four-quadrant power supply terminals.



Controls, power supply terminals, and display on the front panel. 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.

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



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 8960-2, 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 8960-2, 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.

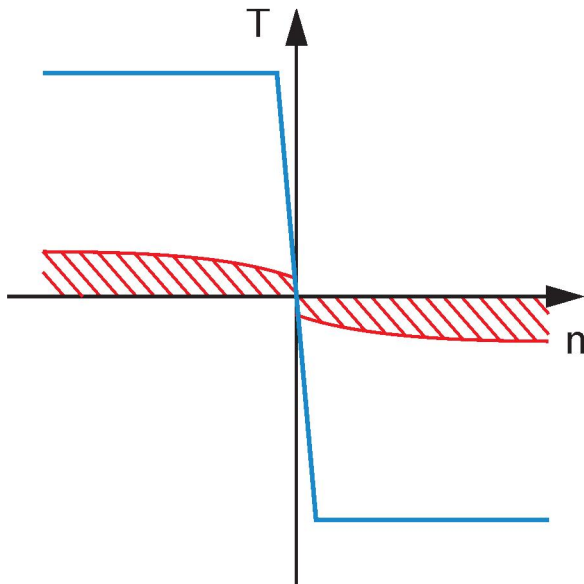
Using LVDAC-EMS with the Four-Quadrant Dynamometer/Power Supply provides access to the basic functions available in the Manual control mode plus a broad selection of advanced functions not available in the Manual control mode. Furthermore, extra information is provided for each control function. All 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).

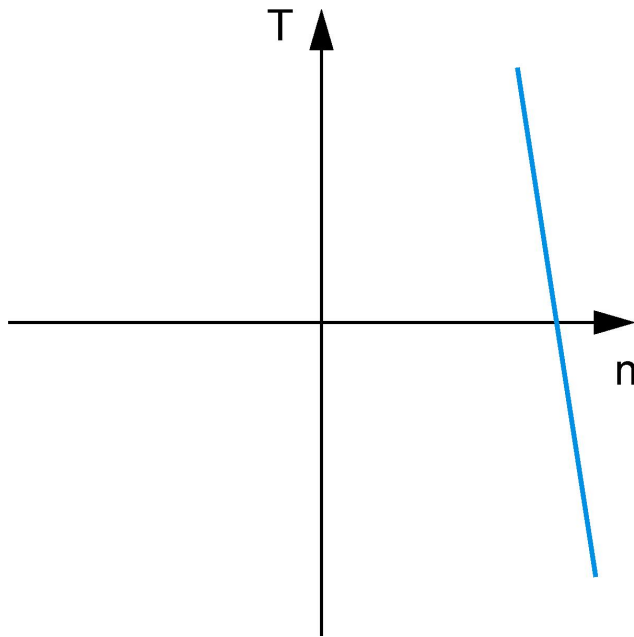
Function Description (Dynamometer Operating Mode)

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.

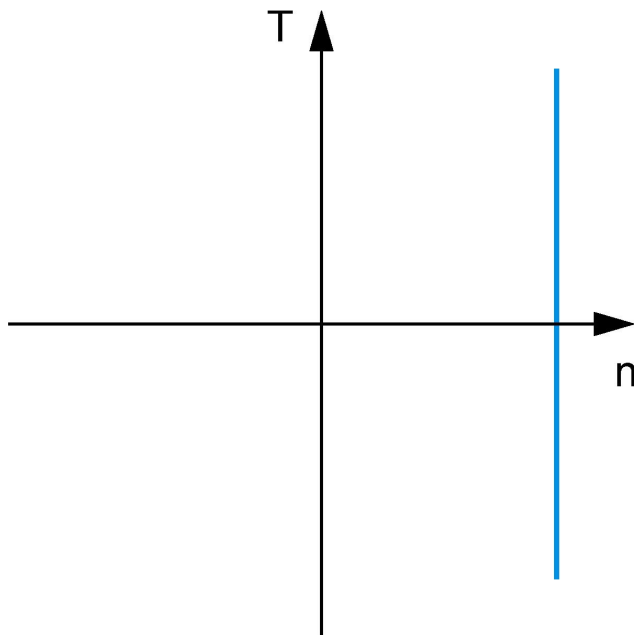
Clockwise Prime Mover/Brake

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

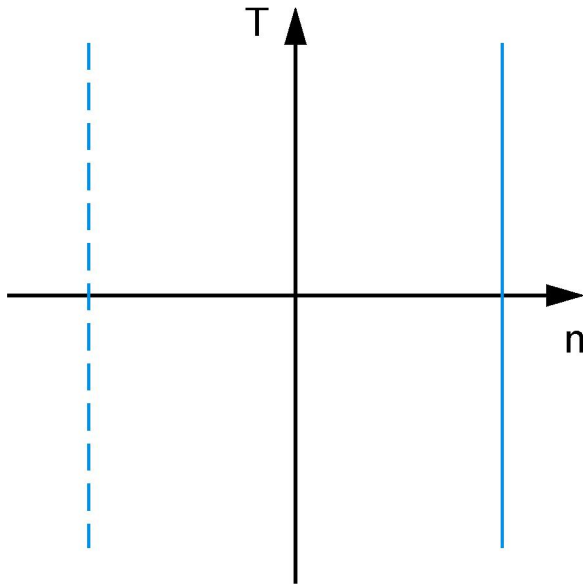
This function uses the permanent-magnet dc machine to make the machine coupled to the Four-Quadrant Dynamometer/Power Supply (i.e., the machine under test) rotate clockwise at a fixed speed. Closed-loop control is used to maintain the rotation speed constant under varying load conditions. A speed command 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.

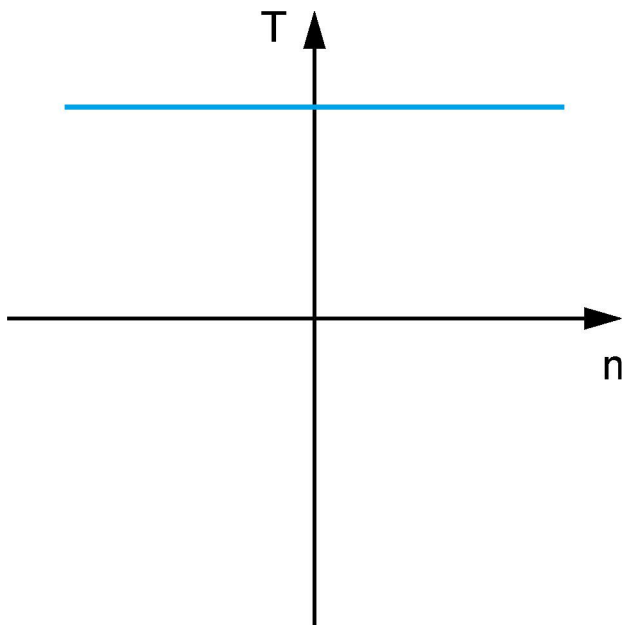
Four-Quadrant, Constant-Speed Prime Mover/Brake



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

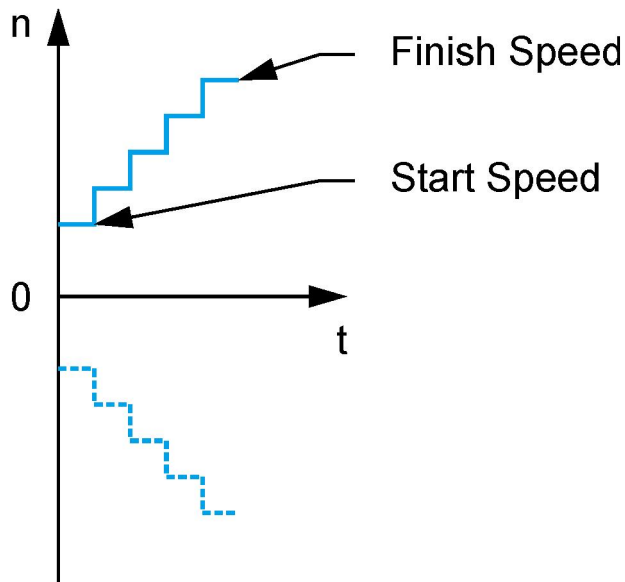
under test. The function can also indicate the machine temperature when the temperature sensor of the machine under test (if so equipped) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply.

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

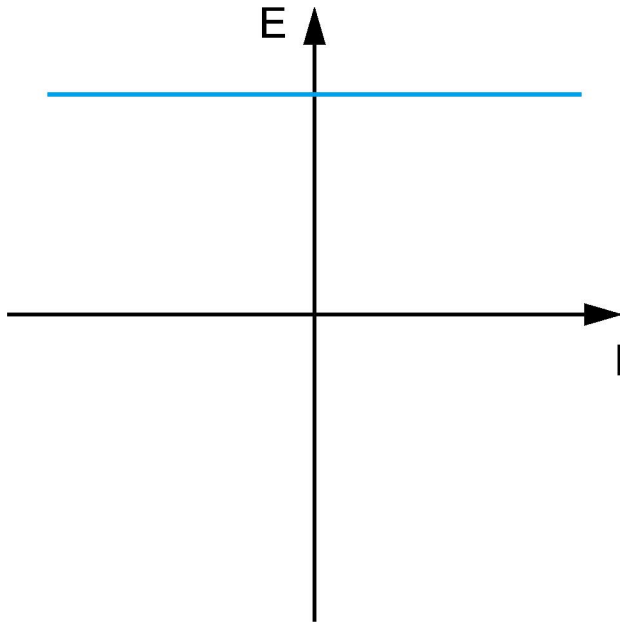


This function uses the permanent-magnet dc machine to make the machine coupled to the Four-Quadrant Dynamometer/Power Supply (i.e., the machine under test) rotate at various speeds within a specific range, in a certain number of steps and in a certain time interval. Closed-loop control is used to ensure 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

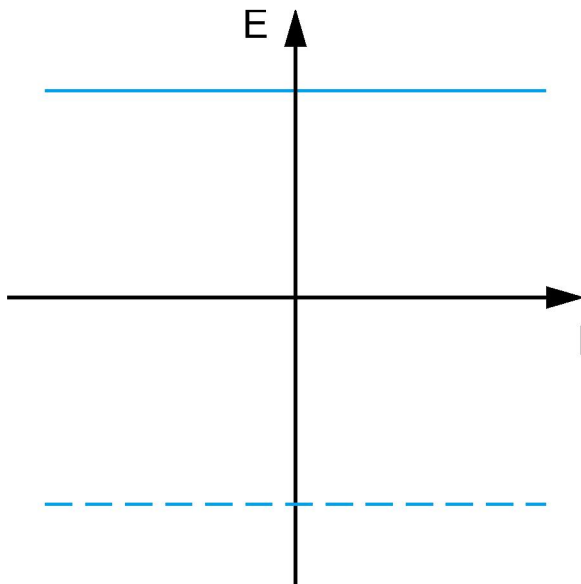


This function uses the four-quadrant power supply to implement a DC voltage source having a positive polarity. The source can either source or sink current (two-quadrant operation). A voltage command entered by the user determines the value of the source voltage. The function indicates the voltage, current, 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

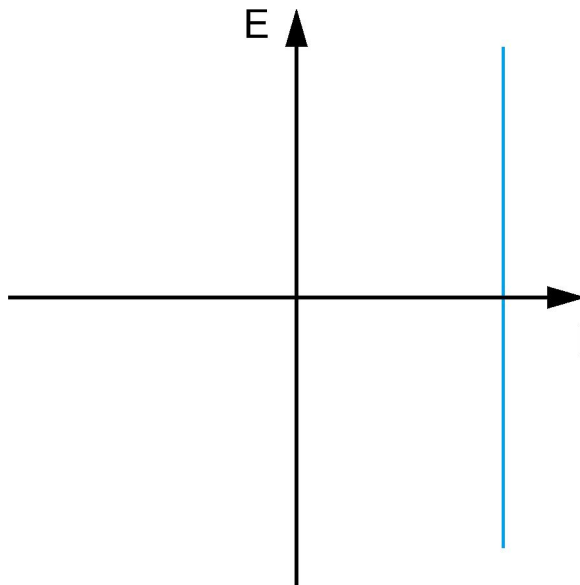
Same as the Positive Voltage Source function except for the polarity.

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.

sensor is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply.

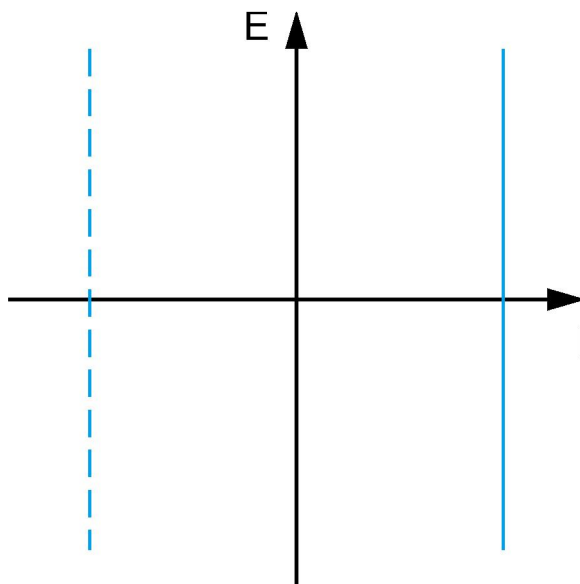
Positive Current Source

Quadrant Dynamometer/Power Supply.

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-

Negative Current Source

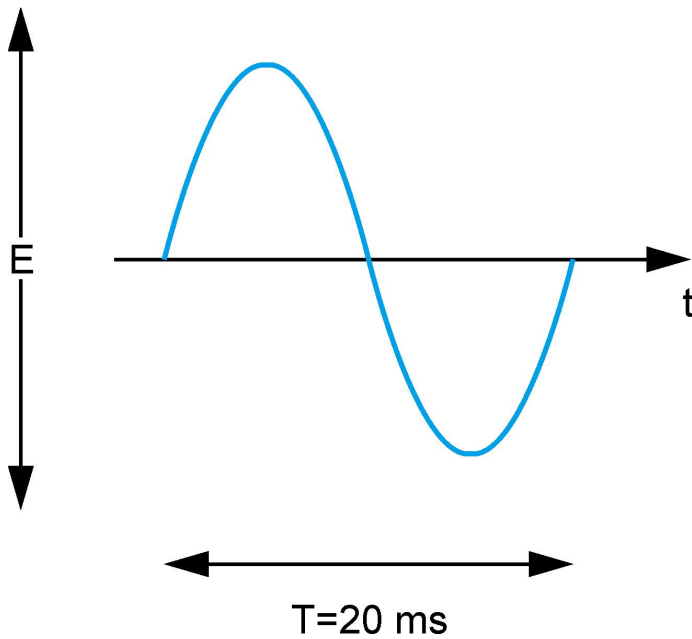
Same as the Positive Current Source function except for the direction of current flow.

DC Current Source

indicate circuit temperature (e.g., battery temperature) when a temperature sensor is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply.

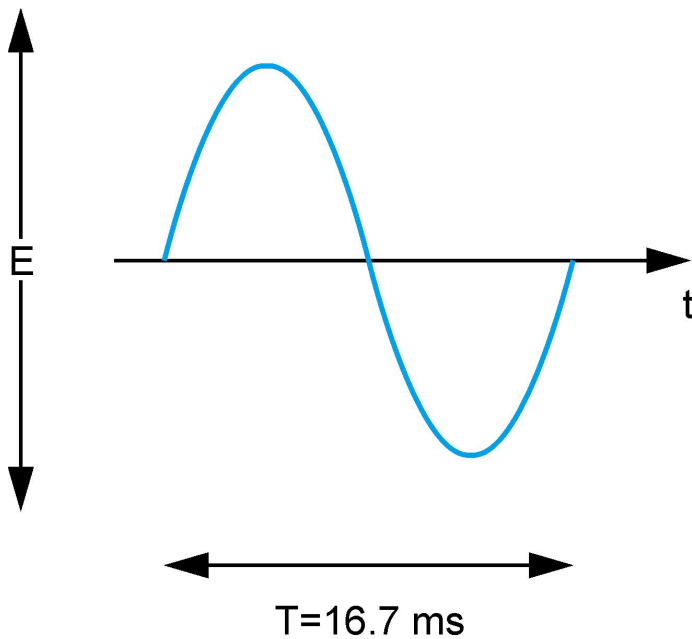
This function uses the four-quadrant power supply to implement a DC current source that either sources current (positive polarity) or sinks current (negative polarity) at its output. The polarity of the voltage across the source can be either positive or negative no matter the direction of the source 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

50 Hz Power Source

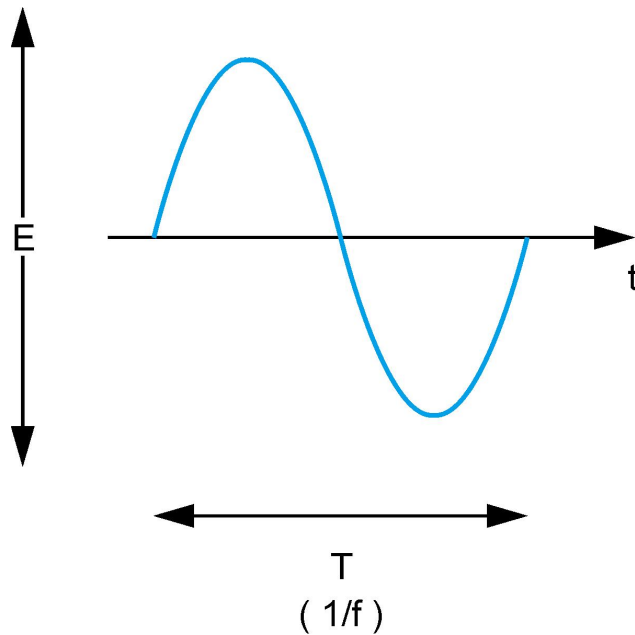


This function uses the four-quadrant power supply to implement a non-regulated variable-voltage 50 Hz power source. A voltage command entered by the user determines the rms value of the "no-load" source voltage. The source can either source or sink current no matter if the source voltage polarity (instantaneous) 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.

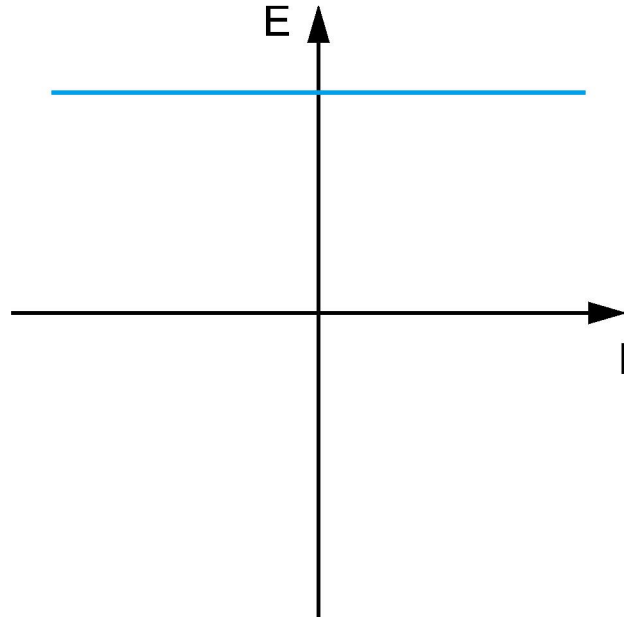
60 Hz Power Source



Same as the 50 Hz Power Source function except for the frequency.

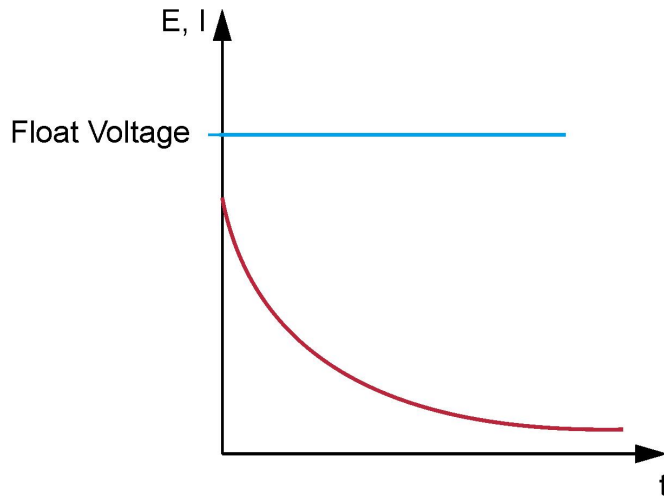
AC Power Source

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



Legend 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 (LVDA-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 module functions available in each control 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



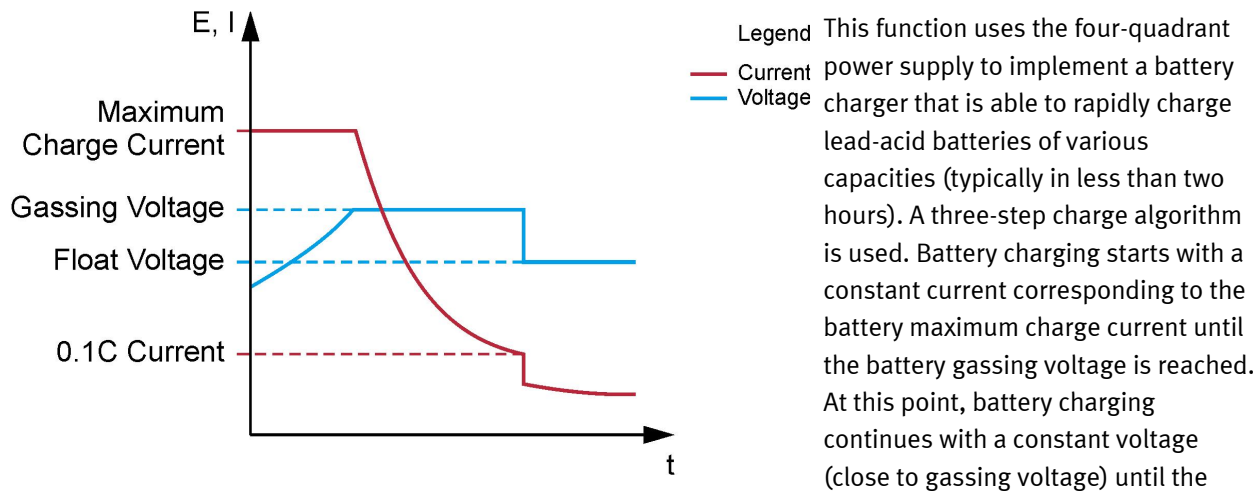
This function uses the permanent-magnet dc machine to recreate the behavior of a hydraulic turbine with a synchronous generator. The torque-speed characteristics at the shaft of the machine coupled to the Four-Quadrant Dynamometer/Power Supply (e.g. the Synchronous Generator, Model 8241) is the same 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.

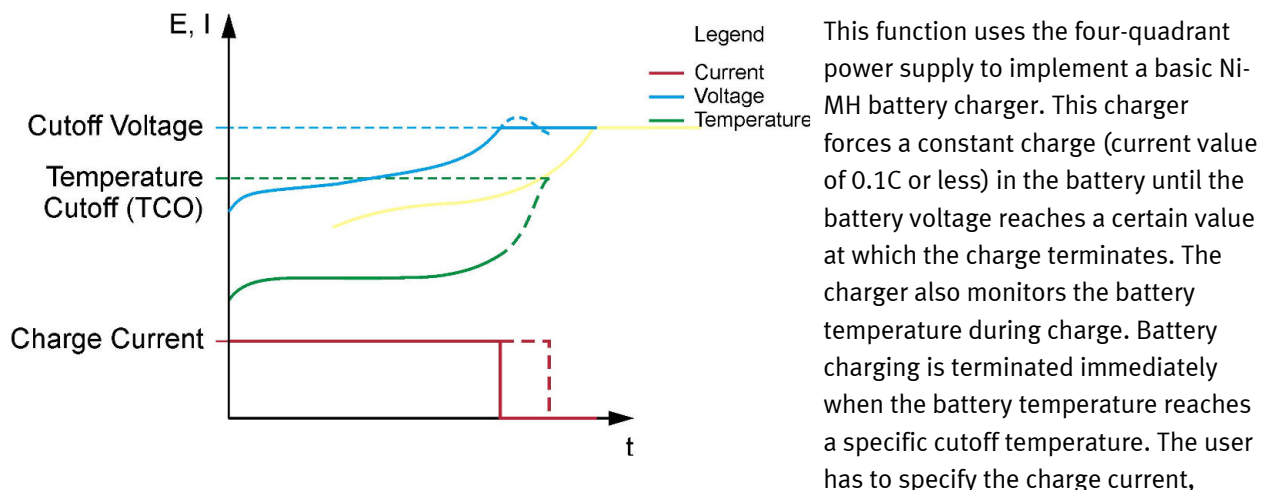
Optional Function Description (Power Supply Operating Mode)

Lead-Acid Battery Charger (Fast), Model 8968-4



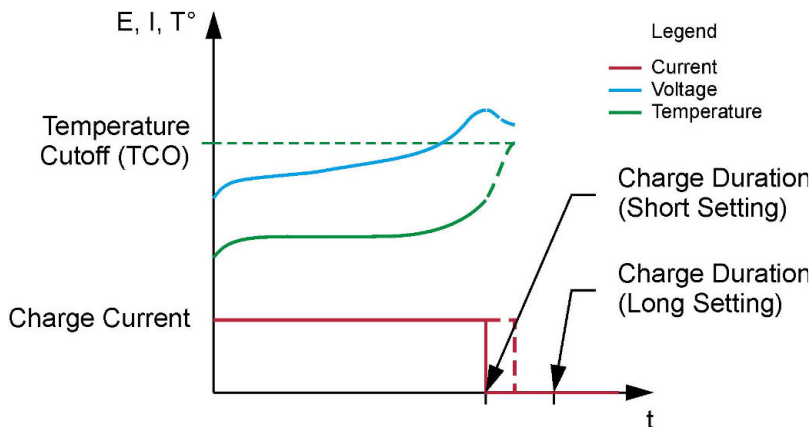
charge current decreases to 0.1 C. Then, constant-voltage charging continues but at a lower voltage (float charging voltage). The user has to specify the following four battery characteristics for the charger to achieve proper charge control: maximum charge current, gassing voltage, 0.1C current (10% 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



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.

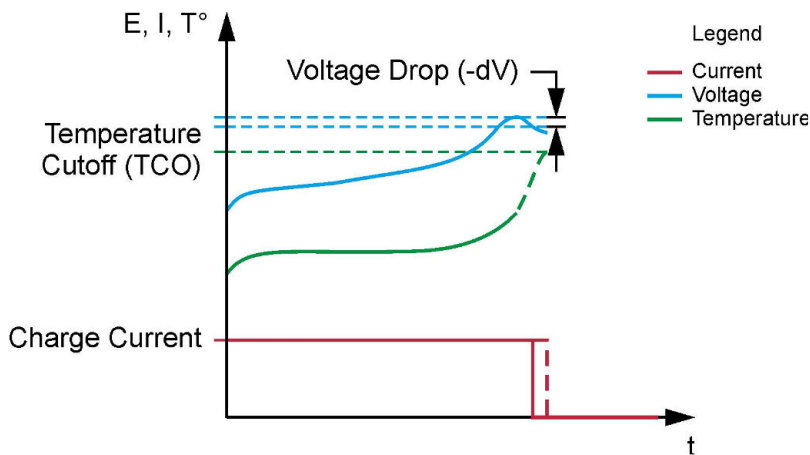
Ni-MH Battery Charger (Constant-Current Timed Charge with TCO), Model 8968-5



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.

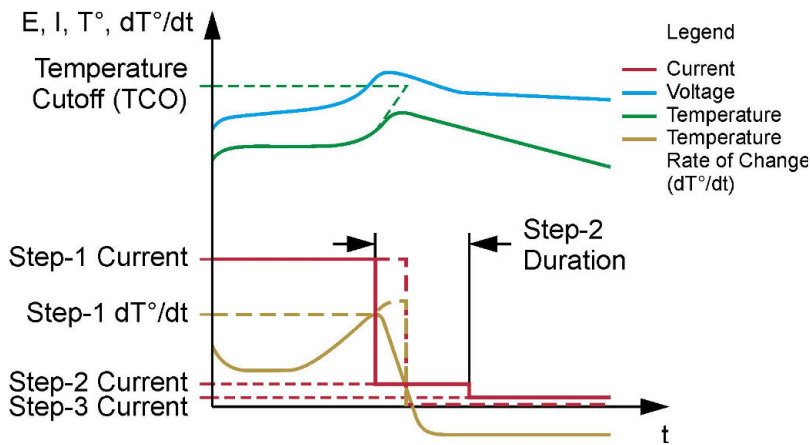
Ni-MH Battery Charger (Constant-Current Charge with -dV and TCO), Model 8968-5



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.

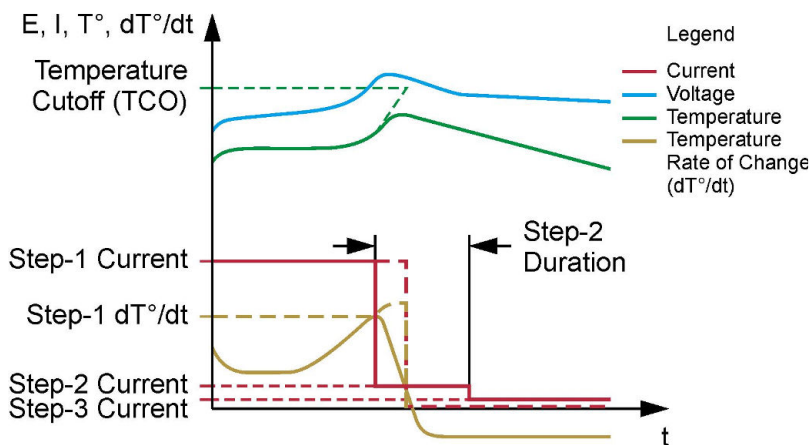
Ni-MH Battery Charger (Constant-Current Charge with dT°/dt and TCO), Model 8968-5



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.

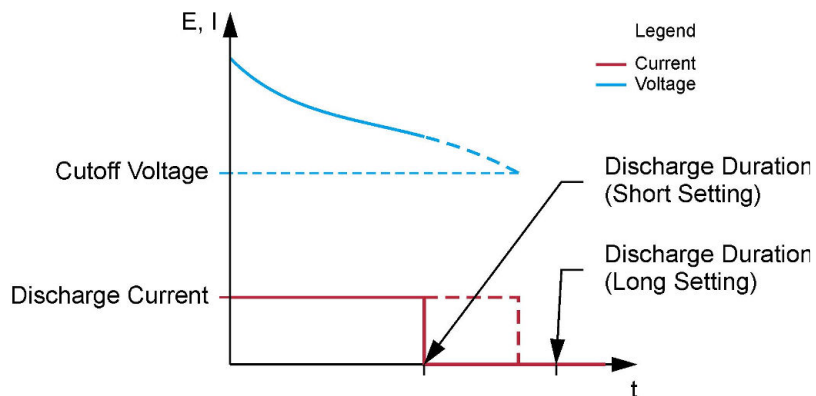
Ni-MH Battery Charger (three-step Charge with TCO), Model 8968-5



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.

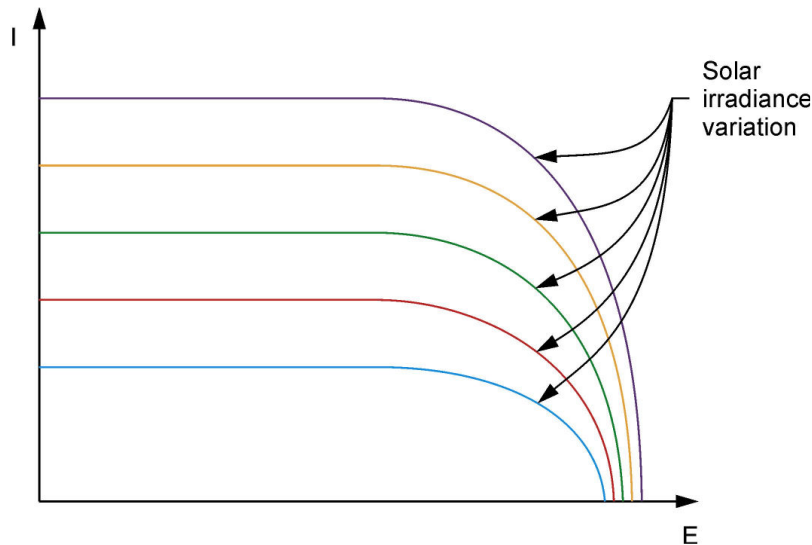
Battery Discharger (Constant-Current Timed Discharge with Voltage Cutoff), Model 8968-4 or Model 8968-5



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 8960-2, 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 8960-2, to unlock the SDK features.

Optional Control Functions	Control Mode	
	Manual (Stand-Alone)	Computer-Based (LVDA-EMS)
Dynamometer Operating Mode		
Small Wind-Turbine Emulator		X
Hydraulic Turbine Emulator		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 $-\Delta V$ and TCO)		X
Ni-MH Battery Charger (Constant-Current Charge with $\Delta T^\circ/\Delta t$ 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

Optional Equipment

Qty	Description	Model number
1	SCADA for LVDAC-EMS _____	8094377 (8973-00)

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, Model 8960-2, 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
- 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

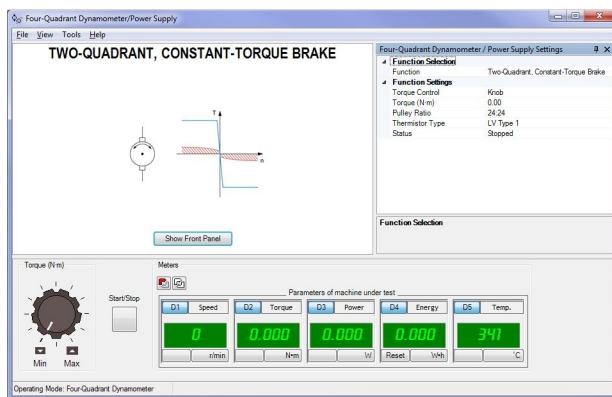
- Positive Voltage Source
- Negative Voltage Source
- 200 V DC Bus
- Positive Current Source
- Negative Current Source
- 50 Hz Power Source
- 60 Hz Power Source
- Lead-Acid Battery Float Charger

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

Parameter	Value
	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	
Status	On or off
Lead-Acid Battery Float Charger	
Float Voltage	0-150 V

Standard Functions (computer-based control) Set 581437 (8968-20)



The Standard Functions (computer-based control) Set is a package of control functions that can be activated in the Four-Quadrant Dynamometer/Power Supply, Model 8960-2, 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

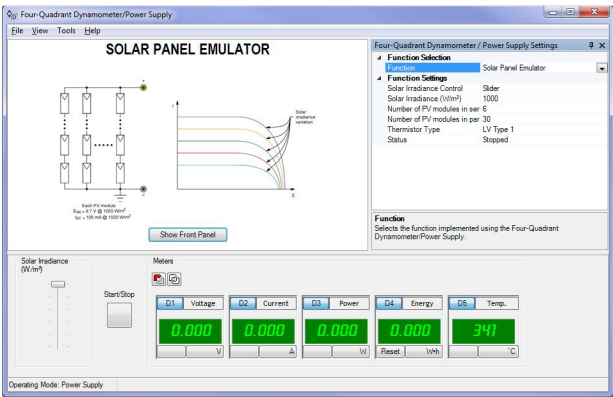
- Positive Voltage Source
- Negative Voltage Source
- DC Voltage Source
- Positive Current Source
- Negative Current Source
- DC Current Source
- 50 Hz Power Source
- 60 Hz Power Source
- AC Power Source
- Lead-Acid Battery Float Charger

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	
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

Parameter	Value
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·m ² (0.119-23.73 lb·ft ²)
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

Solar Panel Emulator Function Set
581440 (8968-60)



The Solar Panel Emulator Function Set is a function that can be activated in the Four-Quadrant Dynamometer/Power Supply, Model 8960-2, 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, 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.

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/m ²
Number of PV Modules in Series	1-7 modules
Number of PV Modules in Parallel	5-45 modules

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

Qty	Description	Model number
1	Personal Computer _____	579785 (8990-00) ¹¹

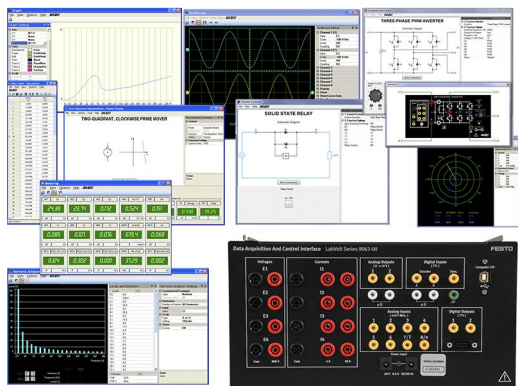
Optional Equipment

Qty	Description	Model number
1	24 V AC Power Supply _____	579696 (30004-20) ¹²

¹¹ 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.

¹² 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.

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

Qty	Description	Model number
1	Personal Computer _____	579785 (8990-00) ¹³
1	24 V AC Power Supply _____	579696 (30004-20) ¹⁴

Specifications

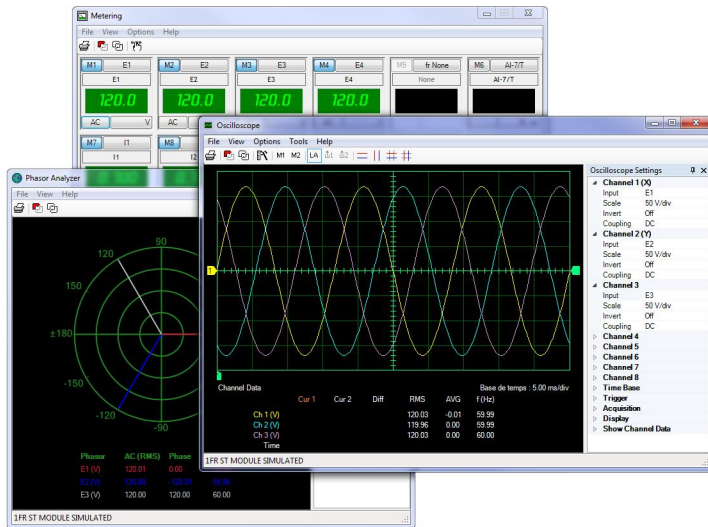
Parameter	Value
Insulated Voltage Inputs (4)	
Range (Low / High Scales)	-80 to +80 V / -800 to + 800 V (user-selectable through software)
Impedance (Low / High Scales)	326.6 k Ω / 3.25 M Ω
Bandwidth	DC to 65 kHz (-3 dB)
Accuracy	1% (dc to 10 kHz)
Insulation	800 V
Measurement Category	CAT II (283 V ac/400 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 m Ω / 50 m Ω
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 M Ω
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	$\leq \pm 1.5$ LSB
Differential Non-Linearity	$\leq \pm 1$ 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	$\leq \pm 8$ 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 k Ω
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	

¹³ 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.

¹⁴ 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
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)

Computer-Based Instrumentation Function Set 581452 (9069-10)



The Computer-Based Instrumentation Function Set, Model 9069-1, includes the following computer-based instruments:

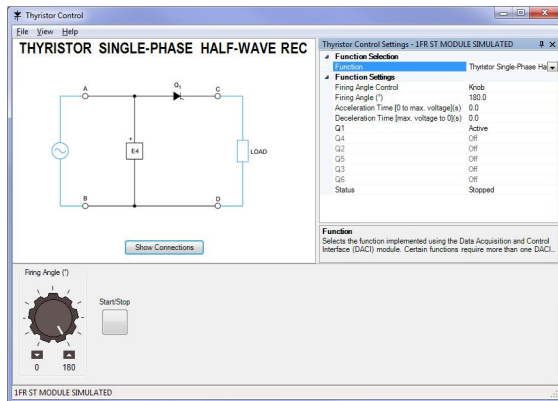
- Metering
- Data Table and Graph
- Oscilloscope
- Phasor Analyzer
- Harmonic Analyzer

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

Parameter	Value
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

Thyristor Control Function Set 581454 (9069-30)



The Thyristor Control Function Set enables the following thyristor-based devices to be implemented using the Data Acquisition and Control Interface, Model 9063, and the Power Thyristors, Model 8841:

- 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

Parameter	Value
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
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

Home Energy Production Control Function Set 581455 (9069-40)



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, Model 9063, the IGBT Chopper/Inverter, Model 8837-B, and the Insulated DC-to-DC Converter, Model 8835:

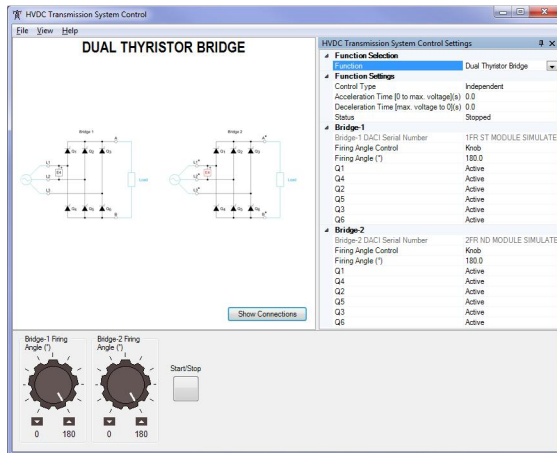
- Single-Phase Stand-Alone Inverter
- Single-Phase Grid-Tied Inverter
- Solar Power Inverter (LF Transformer)

- 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

High-Voltage DC (HVDC) Transmission System Control Function Set 579790 (9069-70)



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, Model 9063, and two Power Thyristors, Model 8841:

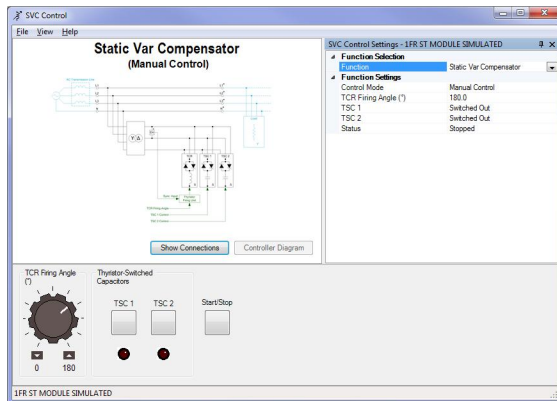
- Dual Thyristor Bridge
- Monopolar HVDC Transmission System
- 12-Pulse Converter

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, β)
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 or off

Parameter	Value
Feedback Filter Cutoff Frequency (for Each Bridge)	10-180 Hz
12-Pulse Converter	
Firing Angle	0-180°
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)



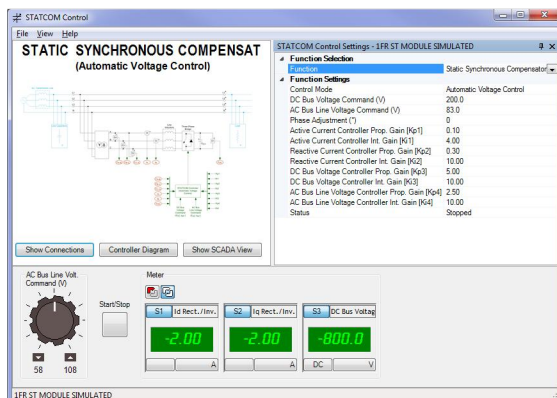
The Static Var Compensator (SVC) Control Function Set enables the following devices required for the study of SVCs to be implemented using the Data Acquisition and Control Interface, Model 9063, and the Power Thyristors, Model 8841:

- 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	0-180°
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	-90° to 90°

Static Synchronous Compensator (STATCOM) Control Function Set 581460 (9069-B0)



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, Model 9063, and the IGBT Chopper/ Inverter, Model 8837-B:

- 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°

Optional Equipment Description

Mobile Workstation (Optional) 579755 (8110-20)



The Mobile Workstation is a ready-for-use workstation that consists of two fully assembled modules: a Workstation, Model 8134-2, mounted on a Mobile Storage Cabinet, Model 89117-1. Four rubber-tire swivel casters allow easy movement of the workstation in the laboratory classroom. The lower portion of the workstation serves as a storage cabinet with two hinged panels and a lock handle. Immediately above the storage cabinet is a pullout work surface with a scuff- and burn-resistant laminate finish. The upper portion of 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.



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.



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

Optional Equipment

Qty	Description	Model number
1	Industrial Controls Single-Rail Workstation _____	581243 (3105-A0) ¹⁵
1	Industrial Controls Double-Rail Workstation _____	585964 (3105-B0) ¹⁶
1	External Shelf for the Mobile Workstation _____	581465 (36653-00) ¹⁷

Specifications

Parameter	Value
Physical Characteristics	
Intended Location	On the floor (stands on casters)
Dimensions (H x W x D)	1660 x 935 x 665 mm (65.4 x 36.8 x 26.2 in)
Net Weight	77.1 kg (170 lb)

Storage Shelves (Optional) 579756 (8150-10)



The Storage Shelves module contains five shelves, each of which can accommodate four full-size EMS modules or eight half-size EMS modules. Stainless steel rails guide the modules on the storage shelves and protect them against wear. The Storage Shelves module requires assembly. A diagram is provided to facilitate assembly. Note that this model cannot stand by itself and must be attached to a wall.

Optional Equipment

Qty	Description	Model number
1	Dust Cover for Model 8150 _____	587006 (8992-00)

Specifications

¹⁵ This add-on workstation allows modules from the Industrial Controls Training Systems, Models 8036, to be installed in the EMS workstation. Refer to the 8036 datasheet for more information.

¹⁶ This add-on workstation allows modules from the Industrial Controls Training Systems, Models 8036, to be installed in the EMS workstation. Refer to the 8036 datasheet for more information.

¹⁷ Extra shelf to be mounted on side of the Mobile Workstation.

Parameter	Value
Physical Characteristics	
Intended Location	On the floor and attached to a wall
Dimensions (H x W x D)	1980 x 1225 x 480 mm (78 x 48.2 x 18.9 in)
Net Weight	TBE

Full-Size Blank EMS Module (Optional) 579757 (8160-00)



The Full-Size Blank EMS Module is used to fill unused locations in a workstation, preventing students from accessing electrical or moving parts inside the other modules. Combined with the use of safety bars to prevent students from removing modules, blank EMS modules ensure student safety during lab exercises.

Specifications

Parameter	Value
Physical Characteristics	
Dimensions (H x W x D)	308 x 287 x 415 mm (12.1 x 11.3 x 16.3 in)
Net Weight	TBE

Half-Size Blank EMS Module (Optional) 579758 (8161-00)



The Half-Size Blank EMS Module is used to fill unused locations in a workstation, preventing students from accessing electrical or moving parts inside the other modules. Combined with the use of safety bars to prevent students from removing modules, blank EMS modules ensure student safety during lab exercises.

Specifications

Parameter	Value
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

Wind Turbine Generator/Controller (Optional) 579487 (8216-00)



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)

Timing Belt (Optional) 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)

Digital Multimeter (Optional) 579782 (8946-20)



The Digital Multimeter consists of an Amprobe AM-510 Tool Kit Digital Multimeter with Battery Test. 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)

Multimeters Module (Optional) 586888 (8946-A0)

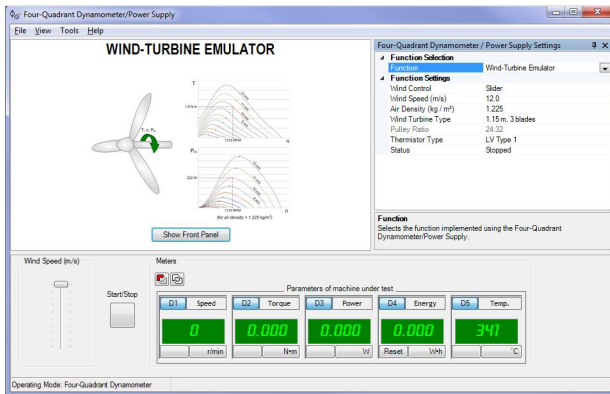


The Multimeters Module, Model 8946-A, consists of three Digital Multimeters, Model 8946-2, installed on the front panel of a half-size module. This allows the Multimeters Module to be inserted in a Workstation, just like any other module.

Specifications

Parameter	Value
Multimeters	
Quantity	3
Voltage Range	0-600 V dc and ac
Current Range	0-10 A dc
Resistance Range	0-20 MΩ
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

Turbine Emulator Function Set (Optional) 579783 (8968-30)



The Turbine Emulator Function Set is a package of control functions that can be activated in the Four-Quadrant Dynamometer/Power Supply, Model 8960-2, enabling the module to emulate the operation of various types of turbines.

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.

Specifications

Parameter	Value
Control Functions	
Control Functions	Wind-Turbine Emulator
	Hydraulic-Turbine 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/m ³ (0.07-0.09 lb/ft ³)
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

Parameter	Value
Pulley Ratio	24:24, 24:12, 24:32 (different pulley ratios are available depending on the wind turbine type)
Inertia J	0.02-0.4 kg·m ² (0.475-9.492 lb·ft ²) (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·m ² (7.119 lb·ft ²)
Pulley Ratio	24:24

Personal Computer (Optional) 579785 (8990-00)



The Personal Computer consists of a desktop computer running under Windows® 10. A monitor, keyboard, and mouse are included.

Specifications

Parameter	Value
Power Requirements	
Current	2 A
Service Installation	Standard single-phase ac outlet

Smart Grid Technologies Training System (Manuals on CD-ROM) (Optional) 579724 (86361-A0)

List of Manuals

Description	Manual number
Electric Power Technology Training Equipment (User Guide) _____	591259 (38486-E0)
Home Energy Production (Student Manual) _____	591868 (86361-00)
Home Energy Production (Instructor Guide) _____	591872 (86361-10)
Static Var Compensator (SVC) (Student Manual) _____	591941 (86370-00)
Static Var Compensator (SVC) (Instructor Guide) _____	591942 (86370-10)
Static Synchronous Compensator (STATCOM) (Student Manual) _____	591943 (86371-00)
Static Synchronous Compensator (STATCOM) (Instructor Guide) _____	591944 (86371-10)
HVDC Transmission Systems (Student Manual) _____	591979 (86380-00)
HVDC Transmission Systems (Instructor Guide) _____	591980 (86380-10)
Computer-Based Instruments for EMS (User Guide) _____	592016 (86718-E0)

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