Equipment set TP 8012-2 Wind Power (Complete)
596085 (8012-2C)

Table of Contents

General Description

Wind power study in a classroom

Just like solar power, wind power is getting more attention due to its ease of use and cost-effective installation. The small wind turbines represent a lot of decentralized production nodes that have to be taken into account in today's electrical network.

Our wind power learning solutions come in a modular way which can also be mixed with other learning solutions. The packages start with an introduction to wind power using real wind turbine parts into a safe working environment along with our dynanometer that recreates realistic wind condition as well as the real power-torque curves. Once the introduction is done, student will experiment energy production to supply power to AC and DC loads.

Computerized tools made for learning

To guide students through their learning path, Festo Didactic provides state-of-the-art data acquisition tools for easy, safe and fast measurements in order to speed up the setup time but also reduce the downtime of using standard measuring instruments.

The Data Acquisition and Control Interface comes also with an oscilloscope, a phasor analyzer, a data table and a graph on specifically designed software optimized for learning purposes. In the same vein, the Dynamometer provided connects to your computer through USB using the same software in order to set it up quickly and easily to enhance the learning experience and recreates wind turbine conditions in the classroom environment.

Features

- Flexible packages for specific training and budget needs

- A4 form factors

- Modular approach giving opportunity to combine these packages with other topics

- New and safer grounding methods between the modules

- Wind Turbine Emulator embedded in a flexible Dynamometer

- Real wind turbine parts in safe working environment

- Top of the line data acquisition and control interface designed for learning purposes

Training Content:

- Voltage-Speed Characteristics

- Torque-Current Characteristics

- Power versus Wind Speed

- Storing Energy from a Wind Turbine into Batteries

- Stand-Alone Wind Power Systems for DC Loads

- Stand-Alone Wind Power Systems for AC Loads

List of components:

- 1x Wind Turbine Generator/Controller

- 1x DC 48 V Lamps

- 1x AC 230 V Lamps

- 1x 48 V Lead-Acid Battery Pack

- 1x AC 24 V Power Supply

- 1x 1 AC 230 V Stand-Alone Inverter

- 1x 4-Quadrant Power Supply and Dynamometer Controller

- 1x 4 Quadrant Dynamometer Motor

- 1x Data Acquisition and Control Interface (including computer-based instrumentation for 2x current inputs and 2x voltage inputs)

- 1x Timing Belt

- 1x Protective Guard - Side-by-side

Equipment set TP 8012-2 Wind Power (Complete)The training system in Wind Power Fundamentals and Production shall be a modular system that provide fundamentals training on wind turbine small-scale generators and energy production with wind and usage to power DC and AC loads.

It shall include the following features:

- Modular in design to allow new equipment to be added to existing laboratories without any needless duplication of equipment also share equipment between workstations
- All modules able to be inserted into a standard workstation
- Symbols and diagrams specific to each module shall be clearly silk-screened on the faceplates
- Standard color-coded 4 mm safety sockets shall be used to interconnect all system components
- Wind turbine emulator embedded in a flexible dynamometer controller
- Fail-safe generator/dynamometer mechanism that does not allow operation without protective guards
- Grounding method between modules that prevents connection with live voltage
- Complete computer data acquisition (including multiple meters, oscilloscope, data table and graph) connected to the same software as the dynamometer
- Real wind turbine parts in safe working environment

The accompanying teachware shall cover the following topics both theoretically and experimentally:

- Magnetism Principles
- Voltage-Speed Characteristics
- Torque-Current Characteristics
- Power-Wind Speed Relationship
- Storing Energy from the Wind into Batteries
- Stand-alone network for DC loads
- Stand-alone network for AC loads
- Inverters
- Energy efficiency of load types
- Components selection

All workbooks shall be available as PDF files on a CD-ROM for an unlimited license.

Consisting of:

- 1x Batteries
- 1x Wind Turbine Generator
- 1x Set of DC lamps
- 1x Set of AC lamps
- 1x Stand-alone inverter
- 1x Resistive Loads
- 1x Power Supply
- 1x Four-Quadrant Dynamometer and Protection Guard and Timing Belt

Features & Benefits

- Flexible packages to match specific training needs and budget
- Top of the line data acquisition and control interface designed for learning purposes
- Wind turbine emulator embedded in a flexible dynamometer
- Real wind turbine parts in safe working environment

- Safe grounding methods between the modules
- Modular approach allowing for expansion to other topics, such as solar power
- Courseware available as eLab courses on Festo LX or in print or PDF format

List of Equipment

Qty	Description	Model number
1	Wind Turbine Generator / Controller	595061 (8216-PC)
1	Wind Turbine Load Resistors	594819 (8217-PC)
1	Resistive Load	594820 (8311-PC)
1	DC 48V Lamps	595055 (8313-PC)
1	AC 230 V Lamps	8165858 (8314-QC)
1	48 V Lead-Acid Battery Pack	8174051 (8802-QC)
1	AC 24V Power Supply	772050 (8826-PC)
1	1AC 230V Stand-Alone Inverter	595052 (8833-PC)
1	4-Quadrant Power Supply and Dynamometer Controller (including Manual and Computer-Based Control, Lead-Acid Battery Charger, Turbine Emulator)	596127 (8960-TC)
1	4 Quadrant Dynamometer Motor	595062 (8961-PC)
1	Data Acquisition and Control Interface	595912 (9063-QC)
1	Timing Belt	793141 (54379-00)
1	Protective Guard - Side-by-Side	794195 (54959-02)

Additional Equipment Required to Perform the Exercises

Qty	Description	Model number
1	Tabletop Workstation (DIN A4)	8153360 (8180-00)
1	Digital Multimeter	579782 (8946-20)
1	Connection Lead Set and Grounding Kit	595916 (8951-R0)
1	Timing Belt	793141 (54379-00)
1	Protective Guard - Side-by-Side	794195 (54959-02)

Optional Measurement

Qty	Description	Model number
1	Data Acquisition and Control Interface	594499 (9063-RC) [1]
1	AC 24 V Wall Mount Power Supply	579698 (30004-2A)

Workstation

Qty	Description	Model number
1	Mobile Frameline, complete model without energy duct	8075133 (6301-30) [2]
1	Frameline mobile table	8087149 (6301-40)
1	Tabletop Double-Sided Workstation (DIN A4)	8158409 (8181-00) [3]

---

[1] Requires a 24 V AC Power Supply.

[2] Can replace the required Tabletop Workstation.

[3] Accomodates 2 teams (one on the front, one in the back). Can replace the required Tabletop Workstation.

Equipment Description

Wind Turbine Generator / Controller
595061 (8216-PC)

The Wind Turbine Generator/Controller consists of the generator and controller of an actual small-scale wind turbine, mounted in an A4 size housing. The module includes a three-phase diode rectifier 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, and diode rectifier.

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	110 V – 5 A
Physical Characteristics	
Dimensions (H x W x D)	211 x 200 x 370 mm
Weight	8.7 kg

Wind Turbine Load Resistors
594819 (8217-PC)

The Wind Turbine Load Resistors consists of a module housing three wire-wound power resistors. Six safety banana jacks on the module front panel provide access to each resistor. Each resistor is protected by a circuit breaker. The three resistors 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.

Specifications

Parameter	Value
Resistors	
Quantity	3
Resistance Values	15 Ω
Nominal Voltage	38 V ac/dc
Resistance Value Accuracy	± 5%
Power	84 W
Current	2,53 A
Overcurrent Protection	
Type	Thermal circuit breaker on each resistor
Current	3 A
Conformity/Directives	CE and RoHS
Physical Characteristics	
Dimensions (H x W x D)	297 x 266 x 140 mm
Net Weight	5,0 kg

Resistive Load
594820 (8311-PC)

The Resistive Load consists of a module housing nine wire-wound power resistors arranged in three identical banks. Each bank consists of three resistors connected in parallel that can be switched on or off with toggle switches to obtain various resistance values. This allows the total (equivalent) resistance of each bank to be increased or decreased by steps. Six safety banana jacks on the module front panel provide access to each resistor bank. The three resistor banks can be connected separately for operation in three-phase circuits. Also, the three resistor banks can be connected together for operation in single-phase circuits.

The Resistive Load is commonly used in conjunction with other basic load modules, like the Inductive Load and the Capacitive Load to experiment with the effects of different types of loads on a circuit.

Specifications

Parameter	Value
Resistors	
Quantity	Three identical banks of three resistors
Resistance Values (Each Group)	1100/2200/4400 Ω
Nominal Voltage	230 V ac/dc
Resistance Value Accuracy	± 5%
Load at Nominal Voltage (Each Bank)	
Power	84 W
Current	0,523-0,366 A
Steps	Seven, of equal increment
Current Increment	0,523 A
Conformity/Directives	CE and RoHS
Physical Characteristics	
Dimensions (H x W x D)	297 x 266 x 140 mm
Net Weight	5,5 kg

DC 48V Lamps
595055 (8313-PC)

The DC 48V Lamps module allows the user to compare two types of loads on a stand-alone dc network.

Specifications

Parameter	Value
Lamps	
Types	LED and incandescent
Voltage	48 V dc
Current	1.5 A
Protections	
Power Input	Reverse polarity and overvoltage (60 V)
Physical Characteristics	
Dimensions (H x W x D)	297 x 133 x 140 mm
Weight	2.1 kg

AC 230 V Lamps
8165858 (8314-QC)

The AC 230 V lamps is an A4 module that provides two different 230 V lamps. An incandescent lamp and a LED lamp are included which allows comparing these different loads.

48 V Lead-Acid Battery Pack
8174051 (8802-QC)
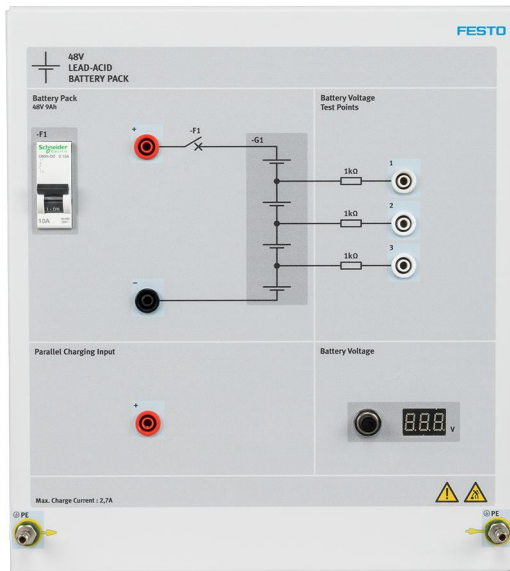
The 48 V Lead-Acid Battery Pack consists of four 12 V lead accumulators mounted in series. The voltage of each individual battery can be measured via 4 mm safety jacks on the front panel. The batteries have a power switch, common charging input, a battery selector switch and a battery voltage indicator.

© Festo Didactic

AC 24V Power Supply
772050 (8826-PC)

The AC 24 V power supply is an A4 module that provides auxiliary power for various system components.

Features

- Auxiliary power supply, 24 V AC, max. 2.5 A

- Thermal overload protection included in main switch

- Case for use in the A4 frame or as standing tabletop device on the attached rubber feet

- Protective conductor connection, 4 mm² minimum diameter and deliberately unmistakable with 4 mm safety plug connections to prevent mix-up

- All connections with safety plug connections, 4 mm size for power connections, 2 mm size for safety voltage signals

Specifications

Parameter	Value
Module Requirements	
Maximum Current	0,3 A
AC Power Network Installation	230 V – 50/60 Hz, must include live, neutral, and ground wires
Outputs	
Fixed AC 1-Phase	24 V – 2,5 A
Conformity/Directives	CE and RoHS
Physical Characteristics	
Dimensions (H x W x D)	297 x 133 x 140 mm
Net Weight	2,8 kg

1AC 230V Stand-Alone Inverter
595052 (8833-PC)

The 1AC 230V Stand-Alone Inverter is a pure sine wave inverter. It uses a Mean Well TS-400 inverter with a protective circuit on its battery input.

Specifications

Parameter	Value
Inverter	
Type	Stand alone pure sine wave
AC Output	
Power	300 W
Voltage	230 V – 50 Hz
Current	1.4 A
Battery Input	
Recommended Battery Pack Voltage	48 V
Protections	
Battery Input	Reverse polarity and overvoltage (64 V)
AC Output	Inverter built-in short-circuit and overload protection
Physical Characteristics	
Dimensions (H x W x D)	297 x 266 x 212 mm
Weight	4.0 kg

4-Quadrant Power Supply and Dynamometer Controller (including Manual and Computer-Based Control, Lead-Acid Battery Charger, Turbine Emulator)
596127 (8960-TC)

The 4-Quadrant Power Supply and Dynamometer Controller can perform a wide variety of functions, like DC voltage or current source, AC source, battery charger, solar panel emulator, constant speed or torque brake and wind or hydraulic turbine emulator.

The module is powered from a single phase outlet and acts as a green device, feeding back mechanical or electrical energy it receives to the power network with unity power factor. All inputs and outputs are protected against improper connections and overvoltage/overcurrent conditions.

For the operation of the 4-Quadrant Power Supply and Dynamometer Controller different sets of functions can be enabled by purchasing the respective firmware. Although these firmware functions can be bought individually, we have bundled the most popular ones in several packages.

Features:

- Works as power supply or dynamometer controller

- Wide variety of available functions in both main modes

- Available functions depend on activated firmware functions

- Allows basic operation in manual or full functionality with computer based controls

- Green device, feeds energy it receives back to the power grid

- All I/Os protected against improper connection or overload

- Protective conductor connection, 4mm² minimum diameter and deliberately unmistakable with 4mm safety plug connections to prevent mix-up

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 8960-3, 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
	Positive Constant-Torque Prime Mover/Brake

Parameter	Value
	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)
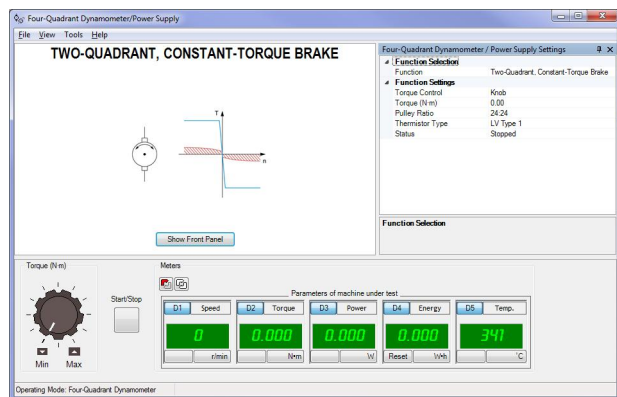
The Standard Functions (computer-based control) Set is a package of control functions that can be activated in the Four-Quadrant Dynamometer/Power Supply, Model 8960-3, enabling the module to perform a wide variety of functions in each of its two operating modes (Dynamometer and Power Supply).

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
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)

Parameter	Value
Pulley Ratio	24:24, 24:12, or 24:32
Four-Quadrant, Constant-Speed Prime Mover/Brake	
Speed Control	Software knob, 8960 module knob, or 8960 command input
Speed	0-2500 r/min
Pulley Ratio	24:24, 24:12, or 24:32
Speed Sweep	
Start Speed	-3000 r/min to 3000 r/min
Finish Speed	-3000 r/min to 3000 r/min
Number of Steps	0-50 steps
Step Duration	2-10 s
Record Data to Table	Yes or no
Pulley Ratio	24:24, 24:12, or 24:32
Mechanical Load	
Load Type	Flywheel, fan, grinder, conveyor, calender, crane, user defined
Inertia	0.005-1 kg·m² (0.119-23.73 lb·ft²)
Friction Torque	0.05-3 N·m (0.44-26.55 lbf·in)
Pulley Ratio	24:24, 24:12, or 24:32
Positive/Negative Voltage Source	
Voltage Control	Software knob, 8960 module knob, or 8960 command input
Voltage	0 V to 147 V / -147 V to 0 V
DC Voltage Source	
Voltage Control	Software knob, 8960 module knob, or 8960 command input
Voltage	-147 V to 147 V
Positive/Negative Current Source	
Current Control	Software knob, 8960 module knob, or 8960 command input
Current	0 A to 5 A / -5 A to 0 A
DC Current Source	
Current Control	Software knob, 8960 module knob, or 8960 command input
Current	-5 A to 5 A
50 Hz/60 Hz Power Source	
Voltage Control	Software knob, 8960 module knob, or 8960 command input
No-Load Voltage	0-140 V
AC Power Source	
No-Load Voltage	0-140 V
DC Offset Correction	-1000 to 1000
Frequency	10-100 Hz
Lead-Acid Battery Float Charger	
Float Voltage	0-150 V

Turbine Emulator Function Set
579783 (8968-30)
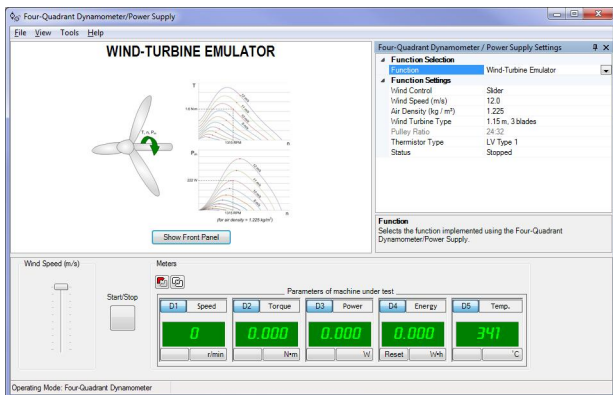
The Turbine Emulator Function Set is a package of control functions that can be activated in the Four-Quadrant Dynamometer/Power Supply, Model 8960-3, enabling the module to emulate the operation of various types of turbines.

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/m³ (0.07-0.09 lb/ft³)
Wind Turbine Type	1.15 m with 3 blades, 1.15 m with 3 blades and gearbox, 0.72 m with 3 blades and passive stall
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·m² (0.475-9.492 lb·ft²) (only available for certain wind turbine types)
Gear Ratio R	0.5-2 (only available for certain wind turbine types)
Hydraulic-Turbine Emulator	
Vane Control	Software slider or 8960 command input
Turbine Type	300 W Francis
Vane Maximal Speed	0-100%/s
Runner Inertia	0.005-1 kg·m² (7.119 lb·ft²)
Pulley Ratio	24:24

Lead-Acid Battery Charger Function Set
581438 (8968-40)
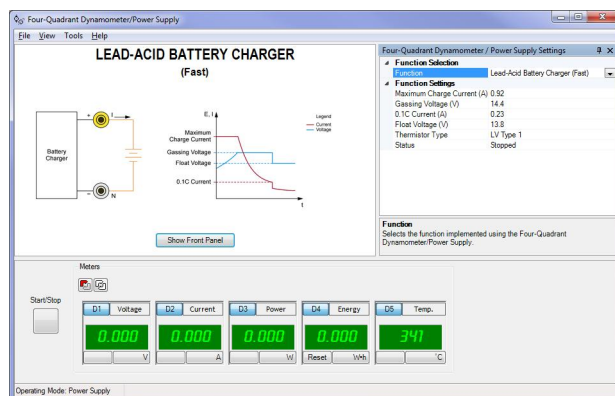
The Lead-Acid Battery Charger Function Set is a package of control functions that can be activated in the Four-Quadrant Dynamometer/Power Supply, Model 8960-3, enabling the module to implement a lead-acid battery charger, as well as a battery discharger.

The Lead-Acid Battery Charger control function is only available in computer-based mode. This means that the function performed by the Four-Quadrant Dynamometer/Power Supply is selected, set, and monitored using the LVDAC-EMS software. The following control functions are available in the set:

Power Supply operating mode

- Lead-Acid Battery Charger (Fast):

This function uses the four-quadrant power supply to implement a battery charger that is able to rapidly charge lead-acid batteries of various capacities (typically in less than two hours). A three-step charge algorithm is used. Battery charging starts with a constant current corresponding to the battery maximum charge current until the battery gassing voltage is reached. At this point, battery charging continues with a constant voltage (close to gassing voltage) until the charge current decreases to 0.1 C. Then, constant-voltage charging continues but at a lower voltage (float charging voltage). The user has to specify the following four battery characteristics for the charger to achieve proper charge control: maximum charge current, gassing voltage, 0.1C current (10% of battery capacity), and float charging voltage. The function indicates the voltage, current, electrical power, and energy at the charger output. The function can also indicate battery temperature when the temperature sensor of the battery (if so equipped) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply. The function can also indicate battery temperature when the temperature sensor of the battery (if so equipped) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply. The license for the Lead-Acid Battery Charger, Model 8968-4, is required to activate the Lead-Acid Battery Charger (Fast) function in the Four-Quadrant Dynamometer/Power Supply.

- Battery Discharger (Constant-Current Timed Discharge with Voltage Cutoff):

This function uses the four-quadrant power supply to sink a constant current from a battery, thereby discharging the battery at a specific rate, during a specific period. The discharger also monitors the battery voltage during discharge. Battery discharging terminates immediately when the battery voltage decreases to a specific cutoff voltage. The user has to specify the discharge current, discharge duration, and cutoff voltage for the discharger to achieve proper discharge control. The function indicates the voltage, current, electrical power, and energy at the discharger output. The function can also indicate battery temperature when the temperature sensor of the battery (if so equipped) is connected to the Thermistor Input of the Four-Quadrant Dynamometer/Power Supply. The Battery Discharger function is perfectly suited to measure discharge characteristics of batteries at various rates as well as to bring a battery to a specific depth of discharge before a battery charging experiment. The license for the Lead-Acid Battery Charger, Model 8968-4, or the license for the Ni-MH Battery Chargers, Model 8968-5, is required to activate the Battery Discharger (Contant-Current Timed Discharge with Voltage Cutoff) function in the Four-Quadrant Dynamometer/Power Supply.

Specifications

Parameter	Value
Control Functions	
Control Functions	Lead-Acid Battery Charger (Fast)
	Battery Discharger (Constant-Current Timed Discharge with Voltage Cutoff)
Lead-Acid Battery Charger (Fast)	
Maximum Charge Current	0-5 A
Gassing Voltage	0-150 V
0.1C Current	0-5 A
Float Voltage	0-150 V
Battery Discharger (Constant-Current Timed Discharge with Voltage Cutoff)	
Discharge Current	0-5 A
Discharge Duration	0-2000 min
Cutoff Voltage	0-150 V

4 Quadrant Dynamometer Motor
595062 (8961-PC)

The 4 Quadrant Dynamometer Motor is a permanent magnet DC motor that can be coupled to the 4 Quadrant Power Supply and Dynamometer Controller. As an add-on to the 4 Quadrant Power Supply and Dynamometer Controller, it provides access to all mechanical features of this device. The 4 Quadrant Dynamometer Motor can be coupled face to face or side by side with a motor/generator. A guard protects the user from unintended start of the motor, without the guard the motor does not start.

Specifications

Parameter	Value
Motor	
Magnetic Torque	0 to 3 N·m (0 to 27 lbf·in)
Direction of Rotation	CW / CCW
Speed	0 to 2500 r/min
Nominal Power	350 W
Protection	
User protection	Guard with interlocking start
Motor protection	Overload by the 4 Quadrant Power Supply and Dynamometer Controller
Physical Characteristics	
Dimensions (H x W x D)	232 x 207 x 377 mm
Weight	14.8 kg

Data Acquisition and Control Interface
595912 (9063-QC)

The Data Acquisition and Control Interface (DACI) is versatile and complete device in an A4 module used for measuring, observing, and analyzing electrical and mechanical parameters in electric power systems and power electronics circuits. For these purposes, a set of computer-based instruments are available. All measurements require a USB connection to a PC running the accompanying data acquisition and control software. This software, as well as all available upgrades, is free and can be downloaded anytime on the Festo Didactic website.

Timing Belt
793141 (54379-00)

The Timing Belt is a high-quality industrial Syncro-Cog® timing belt made of rubber whose teeth exactly mesh with the geared pulley fitted on the shaft of the electrical machines. The Timing Belt is supplied in a fixed length appropriate for coupling two adjacent machines together without slippage between them.

The range of applications of the Timing Belt includes the coupling of the Wind Turbine Generator and Controller with the Dynamometer Motor of the training equipment sets and with other machines of Festo Didactic.

Timing Belt

The Timing Belt is a high-quality industrial Syncro-Cog® timing belt made of rubber whose teeth exactly mesh with the geared pulley fitted on the shaft of the electrical machines. The Timing Belt is supplied in a fixed length appropriate for coupling two adjacent machines together without slippage between them.

The range of applications of the Timing Belt includes the coupling of the Wind Turbine Generator and Controller with the Dynamometer Motor of the training equipment sets and with other machines of Festo Didactic.

Protective Guard - Side-by-Side
794195 (54959-02)
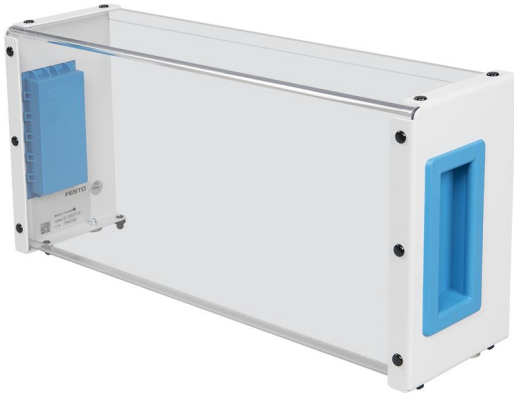
The Protective Guard must be used when coupling two electrical machines side-by-side with a timing belt in order to provide a safe working environment. It is made of see-through glass in a heavy-duty case and offers the necessary safety. For easy handling, the case has two ergonomically shaped recessed grips on the lateral faces.

Protective Guard – Side-by-Side

This protective guard must be used when coupling two electrical machines side-by-side with a timing belt in order to provide a safe working environment. It is made of see-through glass in an heavy-duty case and offers the necessary safety.

Optional Equipment Description

Mobile Frameline, complete model without energy duct (Optional)
8075133 (6301-30)

Mobile Frameline basic frame and setup with two DIN A4 lines and one ER line for individual lab and workshop design. Highly flexible and universal for basic and further technical training. Can be positioned back-to-back, space-saving storage of 3 frames compactly in a row at a depth of one meter also possible.

Features:

- Basic frame made of powder-coated steel pipe, light gray color RAL 7035

- Height adjustment via grid: 1340 – 1670 mm

- Four foot stabilizers with guide rollers and clamping brakes (roller diameter 75 mm)

- Tilt-proof

- Vertical aluminum profiles with profile slots

- Dimensions (W x D x H): 1505 x 700 x 1340 - 1670 mm

Mobile Frameline, complete model without energy duct

Mobile Frameline basic frame and setup with two DIN A4 lines and one ER line for individual lab and workshop design. Highly flexible and universal for basic and further technical training. Can be positioned back to back, space-saving storage of 3 frames compactly in a row at a depth of one meter also possible.

- Basic frame made of powder-coated steel pipe, light gray color RAL 7035
- Height adjustment via grid: 1340 – 1670 mm
- Four foot stabilizers with guide rollers and clamping brakes (roller diameter 75 mm)
- Tilt-proof
- Vertical aluminum profiles with profile slots

Dimensions (W x D x H): 1505 x 700 x 1340 – 1670 mm

Frameline mobile table (Optional)
8087149 (6301-40)

Technical data:

- Dimensions (W x D x H): 1500 x 700 x 780 mm, with 2 fixed castors and 2 TPE sliders

- Table with four legs in accordance with DIN EN 1729, stable, welded design with light gray frame and legs made from precision profile steel tubing

- Tabletop made from 25 mm, three-ply, quality chipboard E1 in accordance with DIN 68765, melamine resin coating in light gray, and additional overlay edges, with 3 mm ABS edge band, homogeneously sealed

- Table legs inwardly offset to be adapted to the Mobile Frameline

Frameline mobile table

Technical data

- Dimensions (W x D x H): 1500 x 700 x 780 mm, with 2 fixed castors and 2 TPE sliders
- Table with four legs in accordance with DIN EN 1729, stable, welded design with light gray frame and legs made from precision profile steel tubing
- Tabletop made from 25 mm, three-ply, quality chipboard E1 in accordance with DIN 68765, melamine resin coating in light gray, and additional overlay edges, with 3 mm ABS edge band, homogeneously sealed
- Table legs inwardly offset to be adapted to the Mobile Frameline

Tabletop Workstation (DIN A4) (Optional)
8153360 (8180-00)

This tabletop workstation is designed to safely house the DIN A4 modules. It consists of a mounting frame with 3 rows and lead holder on the side. The bottom row can be removed to place other laboratory equipment without compromising stability.

The workstation is designed to be quickly assembled on-site. Rails can be assembled without further adjustments thanks to threaded holes. The base part of the workstation is equipped with proper grounding and rubber feet, but it can also be screwed to any surface.

Features:

- The bottom row can be removed without losing any structural strength if required

- Assembly of the workstation does not need precise alignment of the rows and uses preset holes in the vertical profile side bars to ease up assembly

- Lead holder on the side for safety laboratory cables

Tabletop Workstation (DIN A4)The Tabletop Workstation shall consists of a basic mounting frame with 3 DIN A4 rows for laboratory installations.

The following features shall be included:

- The bottom row can be removed without losing any structural strength if required
- Assembly of the workstation does not need precise alignment of the rows and uses preset holes in the vertical profile side bars to ease up assembly
- Lead holder on the side for safety laboratory cables

The following minimum technical requirements shall be met:

- Number of rows: 3
- Overall width smaller than 1550 mm
- Length available per row longer than 1150 mm

Tabletop Double-Sided Workstation (DIN A4) (Optional)
8158409 (8181-00)

Tabletop Double-Sided Workstation (DIN A4)

This double-sided tabletop workstation is designed to safely house the DIN A4 modules. It consists of a mounting frame with 2 rows and a lead holder on each side . Two teams of students can work simultaneously.

The workstation is designed to be quickly assembled on-site. Rails can be assembled without further adjustments thanks to threaded holes. The base part of the workstation is equipped with proper grounding and rubber feet, but it can also be screwed to any surface.

Tabletop Double-Sided Workstation (DIN A4)The Double-Sided Tabletop Workstation shall consists of a two basic mounting frames with 2 DIN A4 rows each mounted on the same set of feet for back-to-back laboratory installations.

The following features shall be included:

- Assembly of the workstation does not need precise alignment of the rows and uses preset holes in the vertical profile side bars to ease up assembly
- Lead holder on the side for safety laboratory cables (each side)The following minimum technical requirements shall be met:
- Number of rows: 2 on each side (total of 4)
- Overall width smaller than 1550 mm
- Length available per row longer than 1150 mm

Digital Multimeter (Optional)
579782 (8946-20)

The Digital Multimeter consists of an Extech EX350 Digital Multimeter. It is ideal to perform voltage, current, and resistance measurements in exercises.

Specifications

Parameter	Value
Voltage	
Ranges	0-600 V ac/dc
Current	
Range	0-10 A ac/dc
Resistance	
Range	0-40 MΩ
Physical Characteristics	
Dimensions (H x W x D)	182 x 90 x 45 mm (7.17 x 3.54 x 1.77 in)
Net Weight	354 g (0.78 lb)

Connection Lead Set and Grounding Kit (Optional)
595916 (8951-R0)

The Connection Lead Set and Grounding Kit contains the necessary leads to build up the necessary circuits and also ground adequately all the equipment for a safe working environment. It includes different lengths of 4mm safety connection leads and jumpers (for short connections) coded with different colors to find out easily which lead to use depending on the distance between the connections. It also includes the necessary grounding leads which comes with a different type of safe connector to avoid misconnections.

Features

- Length color-coded leads with 4 mm safety banana plugs

- Length color-coded leads with 2 mm banana plugs

- Innovative grounding approach with external pins instead of standard 4 mm sockets to avoid misconnections

- Long-lasting and extra-flexible leads

- Protective conductor connection, 4 mm² minimum diameter and deliberately unmistakable with 4 mm safety plug connections to prevent mix-up

- Safest grounding approach in a didactical/educational environment

- All connections with safety plug connections, 4mm size for power connections, 2 mm size for safety voltage signals

Specifications:

- 4 mm Safety Banana Plug Leads: 1 mm² cross section, 19 A max., 600 V, CAT II

- 2 mm Banana Plug Leads: 0.5 mm², 10 A max., 30 V AC, 60 V DC

- Grounding leads: 1 mm² cross section, 19 A max., 600 V, CAT II

Connection Lead Set and Grounding Kit

This set contains the necessary leads to build up the necessary circuits and also ground adequately all the equipment for a safe working environment. It includes different lengths of 4mm safety connection leads and jumpers (for short connections) coded with different colors to find out easily which lead to use depending on the distance between the connections. It also includes the necessary grounding leads which comes with a different type of safe connector to avoid misconnections.

Features:

- Length color-coded leads with 4 mm safety plugs
- Length color-coded leads with 2 mm safety plugs
- Innovative grounding approach with external pins instead of standard 4 mm sockets to avoid misconnections
- Long-lasting and extra-flexible leads
- Safest grounding approach in a didactical/educational environment

Data Acquisition and Control Interface (Optional)
594499 (9063-RC)

The Data Acquisition and Control Interface (DACI) is a versatile USB peripheral used for measuring, observing, and analyzing electrical and mechanical parameters in electric power systems and power electronics circuits. For these purposes, a set of computer-based instruments are available for the DACI. These instruments 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 (www.labvolt.com).

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.
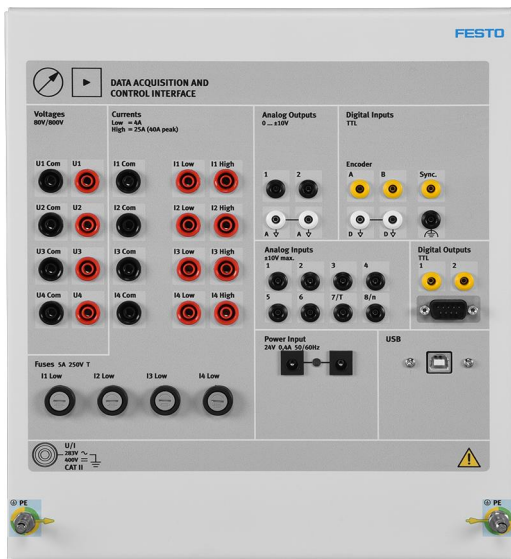
LVDAC-EMS

The LVDAC-EMS software is a freeware which can be downloaded anytime from the Festo Didactic website (www.labvolt.com). The LVDAC-EMS software is a user-friendly tool that facilitates the use of the various functions which can be implemented with USB peripherals such as the Data Acquisition and Control Interface (DACI) and the Four-Quadrant Dynamometer / Power Supply.

The LVDAC-EMS software also includes a firmware update for the DACI. When a DACI is connected to a newer version of LVDAC-EMS, the user can easily update the module using a simple update wizard.

Metering
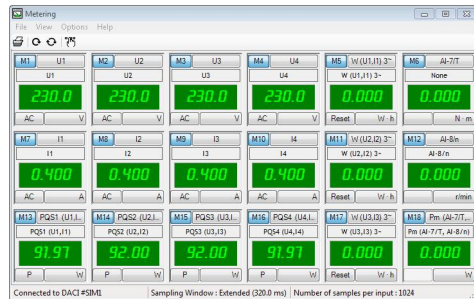
Metering window.

The Metering window displays up to eighteen meters that can be configured to measure a multitude of parameters (e.g., voltage, current, active power, reactive power, apparent power, efficiency, impedance, power factor, frequency, energy, torque, speed, mechanical power, phase angle, phase shift). The name of each meter can be edited to identify the measured circuit parameter. The voltage and current meters have several modes of operation that allow measurement of the mean (DC) value, RMS value, crest factor, RMS value of a particular harmonic (up to the 15th), RMS value of the harmonics, and total harmonic distortion (THD). The layout of the meters in the Metering window can be customized by the user.
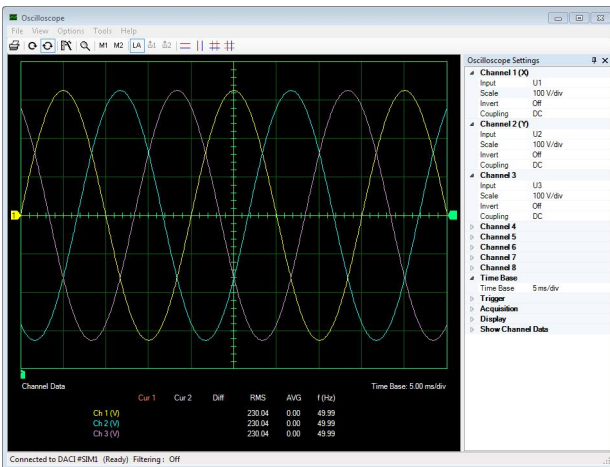
Oscilloscope

Oscilloscope window.

The Oscilloscope can display up to eight waveforms simultaneously. Each waveform is of a different color for easy identification. Each channel has independent vertical controls similar to those found on conventional oscilloscopes. An automatic scale setting function allows the sensitivity of each channel to be set automatically according to the magnitude of the observed parameter. The time base and trigger controls are similar to those found on most oscilloscopes. The RMS value, average value, and frequency of each of the observed parameters can be displayed in a table in the Oscilloscope window. Two vertical cursors can be activated to perform precise measurements at particular points on the displayed waveforms. The Oscilloscope has two memory channels for saving the displayed waveforms.
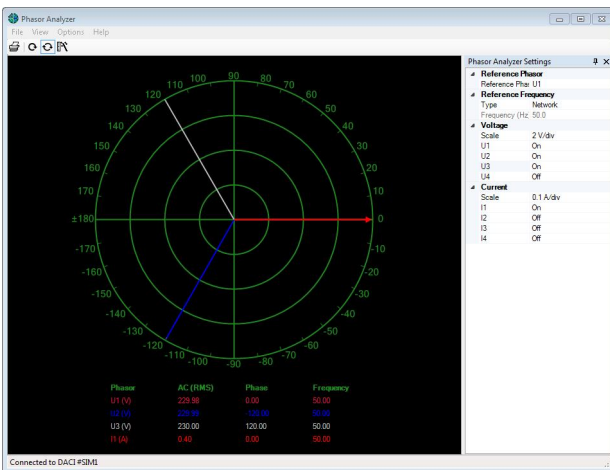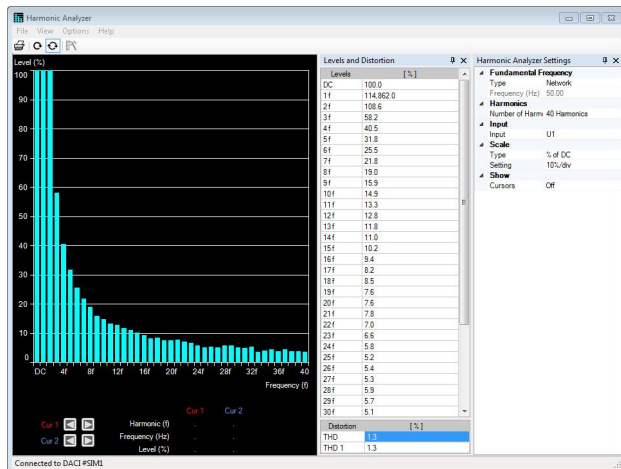
Phasor Analyzer

Phasor Analyzer window.

The innovative Phasor Analyzer displays the phasors related to measured voltages and currents instead of the values and waveforms related to these voltages and currents. The Phasor Analyzer allows circuit voltages and currents to be monitored easily for relative amplitudes and phase differences simply by looking at their respective phasors. This produces a unique and dynamic display of the voltages and currents in a circuit (especially in three-phase circuits) that cannot be obtained with conventional instruments. The RMS value, phase angle, and frequency of the voltage or current related to each phasor are displayed in a table in the Phasor Analyzer window.

Harmonic Analyzer

Harmonic Analyzer window.

The Harmonic Analyzer allows observation and analysis of the harmonic components in the measured voltages and currents. The fundamental frequency can either be set to the ac power network frequency, manually by the user, or automatically to the frequency of the fundamental component of the selected voltage or current. The number of harmonic components displayed can be varied between 5 and 40. The harmonic components of the selected voltage or current can be displayed using a vertical scale graduated in either absolute or relative values. Various vertical scale settings are available. A group of data displays in the Harmonic Analyzer indicates the values of the dc component, fundamental component, and harmonic components of the selected voltage or current, as well as the total harmonic distortion (THD). Vertical and horizontal cursors can be activated to perform precise measurements at particular points on the display.

Data Table and Graph
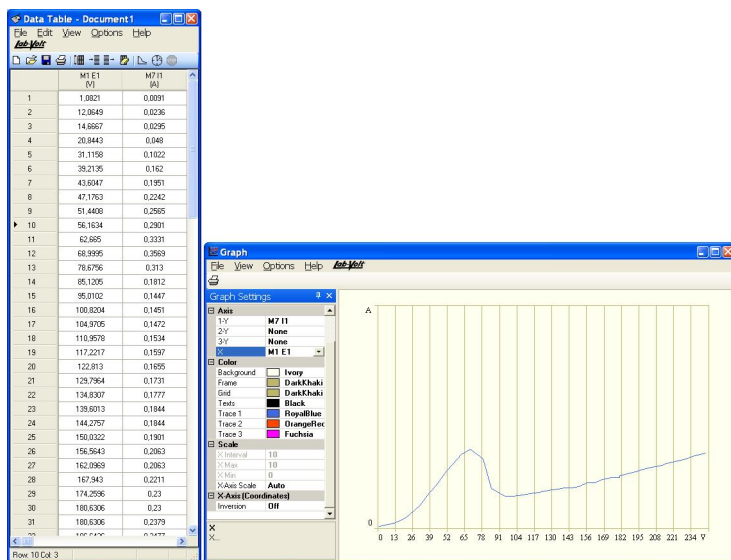
Data Table and Graph.

The values indicated by the meters or indicators of all computer-based instruments and control functions (see later in this section for more detail about control functions) in LVDAC-EMS can be recorded in the Data Table window. A timer option is provided to help record data at specific time intervals. The values recorded in the Data Table can be saved to a file. The recorded data can also be used to plot graphs by selecting which parameter(s) to plot in the Graph window. This allows lab results to be plotted quickly and easily. More complex graphs can be created by exporting the contents of the Data Table window to any popular spread sheet program, such as Microsoft® Excel®.

Additional Equipment Required to Perform the Exercises

Qty	Description	Model number
1	AC 24 V Wall Mount Power Supply	579698 (30004-2A)

Software

Qty	Description	Model number
1	SCADA for LVDAC-EMS	8094377 (8973-00) [4]
1	Complete Function Set	581451 (9069-00)
1	Chopper/Inverter Control Function Set	581453 (9069-20)
1	Thyristor Control Function Set	581454 (9069-30)
1	Home Energy Production Control Function Set	581455 (9069-40)
1	Three-Phase PWM Rectifier/Inverter Control Function Set	581456 (9069-50)
1	BLDC Motor/PMSM Control Function Set	581457 (9069-60)
1	High-Voltage DC (HVDC) Transmission System Control Function Set	579790 (9069-70)
1	Static Var Compensator (SVC) Control Function Set	581458 (9069-80)
1	Software Development Kit (SDK)	581459 (9069-90) [5]
1	Synchronous Generator Control Function Set	579788 (9069-A0)
1	Static Synchronous Compensator (STATCOM) Control Function Set	581460 (9069-B0)
1	Synchroscope Function	579789 (9069-C0)
1	Doubly-Fed Induction Generator (DFIG) Control Function Set	587056 (9069-D0)
1	Power Line Series Compensation Function Set	581461 (9069-S0)

Specifications

Parameter	Value
Power Requirements	
Voltage	24 V
Maximum Current	0,4 A
Frequency	50/60 Hz
Insulated Voltage Inputs (4)	
Range (Low / High Scales)	-80 to +80 V / -800 to + 800 V (user-selectable through software)
Impedance (Low / High Scales)	326,6 kΩ / 3,25 MΩ
Bandwidth	DC to 65 kHz (-3 dB)
Accuracy	1% (dc to 10 kHz)
Insulation	800 V between input channels, 400 V versus ground
Maximum Voltage (Any Terminal vs GND)	283 V ac / 400 V dc
Measurement Category	CAT II (283 V ac/400 V dc versus ground)
Insulated Current Inputs (4)	
Range (Low / High Scales)	-4 to +4 A / -25 to +25 A (40 A peak)
Impedance (Low / High Scales)	50 mΩ / 5 mΩ
Bandwidth	DC to 65 kHz (-3 dB)
Accuracy	1% (dc to 10 kHz)
Insulation	800 V between input channels, 400 V versus ground
Maximum Voltage (Any Terminal vs GND)	283 V ac / 400 V dc
Analog Inputs (8)	
Voltage Range	-10 to +10 V
Impedance	> 10 MΩ
Bandwidth	DC to 125 kHz
Measured Parameters	User-selectable through software
Parameter-to-Voltage Ratio	User-determined through software
Measurement Category	CAT II (283 V ac/400 V dc versus ground)
A/D Converter for Insulated and Analog Inputs (16)	
Type	Successive approximation
Resolution	12 bits
Integral Non-Linearity	≤ ±1,5 LSB
Differential Non-Linearity	≤ ±1 LSB

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

[5] For MatLab, LabView, etc.

Parameter	Value
Maximum Sampling Rate	600 ksamples/s (one channel)
FIFO Buffer Size	16 ksamples
Analog Outputs (2)	
Voltage Range	-10 to +10 V
Operational Load Impedance	> 600 Ω
D/A Converter for Analog Outputs (2)	
Type	Resistor string
Resolution	12 bits
Integral Non-Linearity	≤ ±8 LSB
Differential Non-Linearity	-0,5 to +0,7 LSB
Digital Inputs (3)	
Types	Encoder (2), synchronization (1)
Signal Level	0-5 V (TTL compatible)
Maximum Input Frequency	50 kHz
Impedance	5 kΩ
Digital Outputs (9)	
Types	Control (6 on a DB9 connector and 2 on 2 mm banana jacks), synchronization (1 on a DB9 connector)
Signal Level	0-5 V (TTL compatible)
Maximum Output Frequency	20 kHz (software-limited)
Impedance	200 Ω
Control Functions	
Activated Set	Two-Phase Computer-Based Instrumentation Function
	Extension Mode
Communication Port	
Type	USB 2,0
Accessories	
Included Accessories	2 m USB interconnection cable (1), 24 V power cable (1)
Conformity / Directives	CE and RoHS
Physical Characteristics	
Dimensions (H x W x D)	297 x 266 x 140 mm
Net Weight	4,6 kg

AC 24 V Wall Mount Power Supply (Optional)
579698 (30004-2A)

The 24 V AC Power Supply is used to power specific modules of the Electric Power Technology Training Systems, such as the Data Acquisition and Control Interface, the IGBT Chopper/Inverter, and the Power Thyristors.

Specifications

Parameter	Value
Power Requirements	
Maximum Current	0,3 A
AC Power Network Installation	230 V – 50/60 Hz, must include live, neutral, and ground wires
Power Outputs	
Fixed, Single-Phase AC	24 V – 2,5 A

Parameter	Value
Conformity/Directives	
CE	Yes
RoHS	Yes
Physical Characteristics	
Dimensions (H x W x D)	297 x 133 x 140 mm
Net Weight	2,8 kg