SG105

# Advanced Home Energy Production Training System

## Overview

The training system is designed to provide a comprehensive and practical learning experience in the field of home energy production, the system is equipped with all necessary components to construct a real domestic energy production system, the system combines a modular design approach to help the student construct the electrical energy using safety cables to connect between components for experimentation. Additionally, data acquisition software is provided to enhance the learning experience.



## Specifications

**Wind Turbine Generator/Controller**
**Code: (SG105.01)**

- The module rectifies the out of three phases of wind turbine generator safely. In addition, the module includes built-in resistors to dissipates different power levels. So, the trainee can study and test wind power turbine characteristics curves in the training system.

- Technical Data:
  - » Rectify the turbine's AC output to DC via a built-in diode rectifier (600 V – 6 A).
  - » Control and manage the generated power through integrated power resistors (three resistors, each rated 15 Ω – 100 W) for load testing.
  - » Restable fuses 6 A.

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**Monocrystalline Silicon Solar Panel**
**Code: (SG105.02)**

- The Solar Panels are mounted on benches.
- They are the solar inputs for solar experiments and training on solar power generation, performance testing, and integration with other system components such as batteries and converters.
- Technical Data:
  - » Quantity: 2
  - » Type: Monocrystalline Silicon
  - » Number of Cells: 18

**Solar Panel Test Bench**
**Code: (SG105.03)**

- The Solar Panel Test Bench functions is a controlled setup for testing and experimenting with solar panels indoors by providing power and environmental control, using a halogen lamp to simulate sunlight, incorporating a ventilation system to manage heat during illumination, and offering adjustable parameters such as a single-turn potentiometer to control luminous flux during experiments and the incented angle of halogen lamp
- Technical Data:
  - » Halogen Lamp.
  - » Ventilation System.
  - » Potentiometer: Single Turn – 500 Ω – 2 W
  - » Quantity 3.
  - » This Azimuth angle and tilt angle 65 degrees with step angle 5 degrees.

**Pyranometer**
**Code: (SG105.04)**

- A pyranometer measures solar radiation in W/m² from a hemispherical view. With the use of thermopiles, so, the incoming solar radiation can be measured.
- Technical Data:
  - » Spectral Range: 310 to 2800 nm .
  - » Maximum Solar Irradiance: 2000 W/m²
  - » Field of View: 180° .
  - » Operating Temperature Range: -40°C to +80°C (-40°F to +176°F).

**Resistive Load**
**Code: (SG105.05)**

- This module contains nine power resistors arranged in three banks (Three resistors in each bank). Resistors of each bank are arranged in parallel connection by toggle switch for each resistor to obtain multiple values.
- Three resistor banks can be used separately in 3-phase circuits or can be connected together in single phase circuits
- Technical Data:
  - » Resistance Values (Each Group):
    - 1100 / 2200 / 4400 Ω.
  - » Nominal Voltage:
    - 220 V ac/dc.
  - » Fuse protected.
  - » Thermal protection.

**Inductive Load**
**Code: (SG105.06)**

- It Contains nine iron core power inductors arranged in three banks (Three inductors in each bank) Inductors of each bank are arranged in parallel connection by toggle switch for each inductor to obtain multiple values. Three inductor banks can be used separately in 3 phase circuits or can be connected together in single phase circuits.
- Technical Data:
  - » Inductance Values (Each Bank):
    - 3.5/7/14 H
  - » Reactance Values (Each Bank):
    - 1100 / 2200 / 4400 Ω .
  - » Nominal Voltage 220 V – 50 Hz.

**Capacitive Load**
**Code: (SG105.07)**

- It contains nine capacitors arranged in three banks ( Three capacitors in each bank).
- Capacitors of each bank are arranged in parallel connection by toggle switch for each capacitor to obtain multiple values.
- Three capacitive banks can be used separately in 3 phase circuits or can be connected together in single phase circuits.
- Technical Data:
  - » Capacitance Values (Each Bank):

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- 0.72/1.45/2.89 µF

» Reactance Values (Each Bank):

- 1100 / 2200 / 4400 Ω .

» Nominal Voltage 220 V – 50 Hz .

» Maximum Voltage 440 V.

**Filtering Inductors/Capacitors**
**Code: (SG105.08)**

- Filtering Inductors/Capacitors consist of two filters (one as a low frequency filter, one as a high frequency filter). The low frequency filter consists of an inductor and a capacitor. The High frequency filter consists of two inductors and one capacitor.
- Technical data:

» Low frequency filter

» Inductor : 50 mH - 5A - up to 500 Hz .

» Capacitor : 21.0 uF - 450 V .

» High frequency filter

» Inductor : 2 of 8 mH - 2.5A - up to 20 KHz .

» Capacitor : 1.5 uF - 450 V.

**AC Power Network Interface**
**Code: (SG105.09)**

- The module that connects equipment to an AC power grid, facilitating power distribution and management. In addition, there is a boost converter coil that facilities the boosting low voltage to the utility grid voltage level.
- Technical Data:

» AC Power Inlet (Rating 220 V - 1.5 A - 50 Hz)

» Type C14 connector (Circuit Breaker 1 A )

» AC Power Outlet

» Rating 220 V - 4 A - 50 Hz

» Type CEE 7-7 (type E)

» Solid-State Relay

- Coil Rating 3 to 32 V dc - 15 mA

» Contact Rating 24 to 240 V - 8 A - 50 Hz

» Filtering Inductor 12 mH - 9 A - 0 to 20 kHz

**Transformer Model**
**Code: (SG105.10)**

- The transformer module used in grid connection to increase the voltage of the electrical power to a higher level suitable for grid transmission.
- Technical Data

» 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.

**Lead-Acid Battery Pack**

**Code: (SG105.11)**

- The module lead-acid batteries can be used for grid connection to provide grid stability and energy storage for renewable energy sources.
- Technical Data

» Type 4 valve-regulated lead-acid batteries

» Voltage 64 V (12 V for each battery)

» Capacity 9 Ah

» Maximum Charge Current 2.7 A

» Maximum Discharge Current 7 A

» Parallel Charging Input 64 V maximum

» Auto-Reset Protective Fuse

» Battery 5 A (hold current), 10 A (trip current)

» Test Point 0.1 A (hold current), 0.2 A (trip current)

**Insulated DC-to-DC Converter Model**

**Code: (SG105.12)**

- An insulated DC-DC boosting converter is a crucial component in renewable energy systems, enabling efficient voltage conversion from a lower input to a higher output.
- Technical Data:

» Input

- Rating 285 W - 40-55 V dc

» Output Rating

- 250 W - 300-440 V dc

» Switching Control Inputs

- Quantity 2

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- Signal Level 0-5 V (TTL compatible)

**IGBT Chopper/Inverter**

**Code: (SG105.13)**

- Contains Six IGBTs, Filtering capacitor ,dumping resistor, Brake Chopper, and two resettable DC Link circuit breakers
- Protected against short-circuits. Over voltage, Over current, Overheat conditions
- Six IGBTs used for choppers and inverters implementation
- One IGBT with internal dumping resistor used for excess power dissipation of the
- DC Bus and can be controlled separately
- USB Socket for PC Connection.
- Technical Data
  - » DC Bus
    - Maximum Voltage 770 V
    - Maximum Current 6 A
    - Filtering Capacitor 450 µF
    - Protections
    - DC Bus Overvoltage 810 V
    - DC Bus Circuit Breaker 6 A
    - IGBT Electronic Overcurrent 12 A
    - IGBT Overheat About 70°C » Dumping Circuit
    - Voltage Threshold 660 V
    - Resistor 250 Ω, 100 W
    - Switching Control Signals
    - Level 0/5 V
    - Frequency Range 0-20 kHz
  - » Controlling Algorithm:
    - Buck Chopper ( Low and High Side Switching ) with or without feedback
    - Boost chopper with Feedback
    - Buck / Boost Chopper
    - Four-Quadrant Chopper
    - Single Phase Inverter (180 Degree Modulation, PWM) .
    - Three Phase Inverter (180 Degree Modulation, PWM, Constant V/f).

**Four-Quadrant Dynamometer/ Power Supply**

**Code: (SG105.14)**

- The Four-Quadrant Dynamometer test bench is a complete testing system for generating electric power. It consists of a digital controller, a brake and a software. The system combines of speed torque control.
- The controller has the following features:
  - » Dynamic and static four-quadrant operation
  - » Selectable operating modes/machine models (torque control, speed control.
- Integrated galvanically isolated amplifier for voltage and current meas u remen t
  - » Colour touch display
  - » Four-quadrant monitor
  - » Isolated USB interface
  - » Connection voltage: 400V, 45...65Hz
  - » The machine has thermal monitoring and, in conjunction with the controller, it constitutes a driving and braking system that is free of drift and requires no calibration.
  - » In addition to. The Dynamometer consists of servo and PMSM.
- Technical Data:
  - » Dynamometer Mode
    - Direction of Rotation CW / CCW
    - Speed 0 to 2500 r/min
    - Nominal Power 350 W
  - » Power Supply Mode
    - DC Voltage 0 to ± 150 V
    - AC Voltage (RMS) 0 to 105 V (no-load)
    - DC Current 0 to ± 5 A
    - AC Current (RMS) 0 to 3.5 A
    - Maximum Output Power 500 W
    - AC Frequency 10 to 120 Hz
  - » Control Functions
    - Standard Functions (Manual Control),
    - Standard Functions (Computer-Based Control),
      - » Turbine Emulator.
      - » Lead-Acid Battery Charger.
      - » Solar Panel Emulator.

**Data Acquisition and Control Interface**

**Code: (SG105.15)**

- The DACI Module is a data acquisition and control interface in one module. It

Used for monitoring, analyzing, controlling the power system modules.

- Technical Data:
  - » Metering
  - » 18 Meter via ( 4 Power Voltage inputs, 4 Power Current Inputs, 8 Process inputs, 2 Speed measurement inputs )
  - » Single and Three Phase Power Analyzer (Volt, ampere, active power, reactive power, apparent power, Power factor) selected from Metering inputs
  - » Oscilloscope
    - 8 Channels selected from Metering inputs
    - Vertical : 2-500 V/Div
    - Time Base: 100uS to 10 S/Div
  - » Phasor Analyzer
    - Voltage : 2-200 V/ Div
    - Current : 0.1 - 5 A/Div
  - » Harmonic Analyzer
    - Fundamental Frequency : 1-1400 Hz
    - Number of Harmonic Components : 5-40
    - Saving data tables and graphs
  - » Advanced Functions :
    - Chopper-Inverter Functions
    - Buck Chopper (Low and High Side Switching) with or without feedback
    - Boost chopper with Feedback
    - Buck / Boost Chopper
    - Four-Quadrant Chopper
    - Single Phase Inverter (180 Degree Modulation, PWM)
    - Three Phase Inverter ( 180 Degree Modulation, PWM, Constant V/f )
    - Insulated DC to DC Converter
    - Four Quadrant DC Motor Control ( With or without Current Control )

## Experiments

**Stand-Alone Home Energy Production**

- Investigating and performing the following activities:
  - » Battery under-voltage protection circuit
  - » Operation of the voltage feedback loop
  - » Power limitation circuit
  - » Insulated stand-alone inverter
  - » Frequency and RMS value of the system's output voltage

**Single-Phase Grid-Tied Inverter (PWM Rectifier/Inverter)**

- Investigating and performing the following activities:
  - » Operation of the current control loop Experiments
  - » Single-phase grid-tied inverter » Active and reactive current commands
  - » Controlling active power flow and reactive power flow
  - » DC bus voltage vs. the local AC power network voltage

**Grid-Tied Home Energy Production using a Solar or Wind Power Inverter without DC-to-DC Converter**

- Investigating and performing the following activities:
  - » Grid-tied home energy production using solar power or wind power
  - » Solar or wind power inverter implemented using the LF transformer without DC-to-DC converter topology
  - » Solar or wind power inverter implemented using the transformerless without DC-to-DC converter topology
  - » Operation of the MPP tracker in a solar power inverter implemented without a DC-to-DC converter

- **Grid-Tied Home Energy Production Using a Solar or Wind Power Inverter with DC-to-DC Converter**

- Investigating and performing the following activities:
  - » Solar or wind power inverter implemented using the transformerless

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with DC-to-DC converter topology
- » Solar or wind power inverter implemented using the LF transformer with DC-to-DC converter topology
- » Operation of a solar or wind power inverter using a DC-to-DC converter.
- » Operation of the MPP tracker in a solar or wind power inverter using a DC-to- DC converter

**Large-Scale Energy Storage: A Step in the Implementation of the Smart Grid**

- Investigating and performing the following activities:
  - » Meeting the daily peak demand for electric power
  - » Grid-to-battery and battery-to-grid energy exchanges
  - » Using large-scale energy storage to help meet the daily peak power demand
  - » Using plug-in electric vehicles (PEVs) and plug-in hybrid electric vehicles (PHEVs) to implementlarge-scalaccommodate eneraccommodatey storage in AC powaccommodater networks

**The Solar Panel (Photovoltaic Panel)**

- Investigating and performing the following activities:
  - » Photovoltaic cell, module, and panel
  - » Characteristic E-I curve of a PV cell
  - » Electric power output
  - » Irradiance
  - » Standard test conditions (STC)
  - » Efficiency
  - » Lab-Volt Solar Panel Test Bench
  - » Lab-Volt Monocrystalline Silicon Solar Panel

**Storing Energy from Solar Panels into Batteries**

- Investigating and performing the following activities:
  - » Energy storage
  - » Lead-acid batteries
  - » Battery charge using a PV module
  - » Battery connected to a PV module in the dark
  - » Equivalent diagram of a PV cell
  - » Blocking diode

**Effect of Temperature on Solar Panel Performance**

- Investigating and performing the following activities:
  - » Effect of temperature on the output voltage and current
  - » Effect of temperature on the output power

**Effect of Shading on Solar Panel Operation**

- Investigating and performing the following activities:
  - » Effect of partial shading on PV panel operation
  - » Bypass diodes to mitigate the effect of shading on PV modules connected in series
  - » Blocking diodes to mitigate the effect of shading on PV modules connected in parallel

**Solar Panel Orientation**

- Investigating and performing the following activities:
  - » Introduction to the importance of solar panel orientation
  - » Earth's orbit
  - » Sunlight at Earth's surface
  - » Solar declination and Sun's path in the sky
  - » Solar altitude angle at solar noon
  - » Optimal orientation of fixed PV panels
  - » Sun tracking systems

**Voltage-Speed characteristics of a wind turbine generator**

- Investigating and performing the following activities:
  - » Magnetic field
  - » Permanent magnets
  - » Electromagnetic induction
  - » Generators used in small-scale wind turbines
  - » Period and frequency of electrical waveforms
  - » Relationship between the rotation speed and the voltage induced by a wind turbine generator
  - » Wind Power Investigating and performing the following activities:
  - » Electrical energy measurement units.

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» Wind turbine classification. Horizontal-axis wind turbines (HAWT). Vertical-axis
» wind turbines (VAWT). Small-scale wind power.

**Solar Panel Performance vs. Insolation**

- Investigating and performing the following activities:
  » Solar panel performance vs. insolation Pyranometer

**Power vs. Wind Speed**

- Investigating and performing the following activities:
  » Air density
  » Kinetic energy in the wind
  » Calculating wind power
  » Relationship between wind power and wind speed
  » Relationship between torque, rotation speed, and rotational mechanical power
  » Conversion of wind power into rotational mechanical power and electrical power
  » Typical torque vs. speed curve at the wind turbine roto
  » Torque vs. speed and mechanical power vs. speed curves at the wind turbine rotor for different wind speeds
  » Current vs. voltage and electrical power-vs.-speed curves at the wind turbine generator output for different wind speeds
  » Wind turbine generator efficiency

**Torque-Current characteristics of a wind turbine generator:**

- Investigating and performing the following activities:
  » Torque
  » Force produced by interacting
  » magnetic fields
  » Magnetic field around a conductor
  » Magnetic field in a loop of wire (electromagnet
  » Loops of wire used in electric generators (generator windings)
  » Repulsion force opposing the rotation

**Storing the Energy Produced by Wind Turbines in Batteries:**

- Investigating and performing the following activities:
  » Storage of electrical energy
  » Connection of a small-scale wind turbine to batteries
  » Automatic tracking of the maximum power point (MPP)
  » Protection against battery overcharging
  » Protection against wind turbine overspeeding

**Battery Fundamentals**

- Investigating and performing the following activities:
  » Description
  » Battery types
  » Cell vs. battery
  » Operation during discharge and charge cycles
  » Open-circuit voltage
  » State-of-charge
  » Voltage regulation and internal resistance
  » Battery capacity
  » Depth of discharge
  » Life cycle

**Discharge Characteristics**

- Investigating and performing the following activities:
  » Cutoff voltage vs. discharge rate
  » Effect of the discharge rate on the available capacity and discharge duration time
  » Effect of temperature on the available capacity
  » Energy released during discharge cycle
  » Specific energy and energy density
  » Sulfation

**Battery Charging Fundamentals**

- Investigating and performing the following activities:
  » Charging fundamentals
  » Valve regulated lead-acid battery (VRLA)
  » Gassing voltage
  » Rules for proper charging
  » Charge efficiency

**Battery Charging Methods**

- Investigating and performing the following activities:
  » Constant-current charging method

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- » Constant-voltage charging method
- » Modified constant-voltage charging method
- » Float charging method
- » Trickle charging method

**Single-Phase Power Transformers**

**Voltage and Current Ratios**

- Investigating and performing the following activities:
  - » Transformer voltage and current ratios
  - » Step-up and step-down transformers
  - » Determining the voltage and current ratios of a transformer

**Transformer Winding Polarity & Interconnection**

- Investigating and performing the following activities:
  - » Introduction to transformer winding polarity
  - » Transformer winding polarity in schematic diagrams
  - » Determining the polarity of transformer windings using an oscilloscope
  - » Series connection of transformer windings
  - » Determining the polarity of transformer windings using a voltmeter
  - » Parallel connection of transformer windings

**Transformer Losses, Efficiency, and Regulation**

- Investigating and performing the following activities:
  - » Transformer losses
  - » Transformer efficiency
  - » Transformer voltage regulation

- **Transformer Rating**
- Investigating and performing the following activities:
  - » Transformer rating
  - » Determining the current rating of a transformer winding
  - » Transformer saturation
  - » Determining the voltage rating of a transformer winding

**High-Frequency Power Transformer Operation**

- Investigating and performing the following activities:
  - » High-frequency power transformers in switched-mode power supplies and insulated DC-to-DC converters
  - » Power efficiency of SMPS and insulated DC-to-DC converters
  - » Topologies of SMPS and insulated DC- to-DC converters
  - » Insulated DC-to-DC converter implemented using a push-pull converter

**The Autotransformer**

- Investigating and performing the following activities:
  - » Autotransformer operation
  - » Autotransformer circuit analysis
  - » Power rating of conventional transformers and autotransformers

**Effect of Frequency on Transformer Rating**

- Investigating and performing the following activities:
  - » Transformer saturation vs. frequency
  - » Transformer rating vs. frequency

## Scope of Delivery

- Advanced Home Energy Production Training System (SG105)
- Hard copy user manual

## Options

- Digital Content (BI01)

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