SG100

Smart Grid Electrical Power Generation

Overview

Smart Grid Electrical Generation teaches students the fundamentals of building a basic power station. It covers two main areas: simulating a stand-alone power plant using a synchronous generator and SCADA software, and understanding grid connection requirements like phase, voltage, and frequency. Students practice both manual and automatic synchronization and explore how different electrical loads affect currents and voltages.



Specifications

Three phase synchronous machine Code: (SG100.01)



- This machine can be configured as a grid tied synchronous generator which helps in power factor correction. Also, it can be configured as a stand-alone generator to power three phase loads
- Technical data:
  - » Nominal shaft speed: 1500 rpm
  - » Rated output power: 1000 W
  - » Rated input voltage: 220 VAC /380 VAC (Delta/Star)

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» Rated operating frequency: 50Hz

Exciter controller with de-excitation relay Code: (SG100.02)



- The exciter voltage controller is used to excite the rotor of synchronous machine.
- Included in the module is a digital input to de-excite the field windings immediately.
- Technical Data:
  - » Rated output voltage is the rated excitation voltage of supplied synchronous machine
  - » ON/OFF switch with digital input override terminal for switching module
  - » Digital input capability for voltage boosting and decreasing
  - » Analog input using potentiometer for setting operating voltage
  - » De-excitation terminal for inhibiting output
  - » Inputs and outputs: 4-mm safety sockets

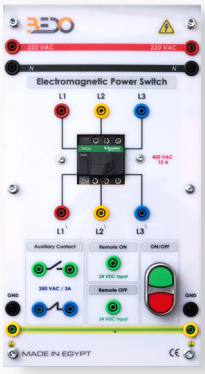
Servo machine test Stand Code: (SG100.03)



- The servo-machine test bench is a complete testing system for examining electrical machines and drives. It consists of a digital controller, and its software.
- The system combines state of- the-art technology with ease of operation.
- The system also allows manual and automated synchronization to be carried out.
- The controller has the following features:
  - » Selectable operating modes/ machine models (torque control, speed control)
  - » Interface for reading electronic nameplates EDD of the machines under test
  - » Includes mechanical power measurement
  - » Color touch display
  - » Isolated USB interface
  - » Connection voltage: 400V, 45...65Hz
- The motor and sensor leads are connected via polarity-safe plugs.
  - » 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
- Technical Data:
  - » Maximum speed: 1750 RPM
  - » Maximum Voltage: 3~, 220V phase; or suitable supply voltage for the servo driver
  - » Motor Maximum Capacity : 2 kw
  - » Resolver resolution: 3000 pulses/ revolution
- Software features:
  - » Measurement, calculation and display of mechanical and electrical variables (Speed, torque, mechanical power output, current, voltage, active, apparent and reactive power, efficiency, power factor). Reading Electronic nameplates of the machines under test. Simultaneous display of measured and calculated values (e.g. instant display of efficiency)
  - » Measurement of voltage and current (including RMS values even for Non-sinusoidal waveforms)
  - » Speed or torque-controlled operation
  - » Recording of variables over time
  - » Programming of limiting values of speed or torque to prevent inappropriate loading of the machine under test.
  - » Operation in all four quadrants (display of generated torque)
  - » Export of graphics and measurements

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Electromagnetic switch
Code: (SG100.04)



- Electromagnetic switch can be used as a power cutoff switch for three-phase applications.
- The power module can be operated manually and remotely.
- Technical Data:
  - » Rated remote signal voltage: 24 VDC / 0.5 A; or dry contacts
  - » Normally-open push button for enabling three-phase output
  - » Normally-closed push button for breaking three-phase output
  - » Auxiliary contacts (1N.O + 1N.C)
  - » Digital input terminal for overriding pushbutton using external control Signal
  - » Power contacts rated capability: 400VAC VAC / 10 A
  - » Auxiliary contacts rated capability: 250VAC, 3A.

Synchronization Unit
Code: (SG100.05)



- Synchronization Unit is used along with synchronous machines for bus tying purposes. Included in this module is a set of three pilot indicators, zero difference voltmeter, double voltmeter, double frequency meter, digital synchroscope and a manual synchronizing switch with synchronization acknowledge feedback terminal.
- Technical Data:
  - » Manual synchronization power switch: 400VAC, 10A
  - » Synchronization status feedback terminal: 24 V DC, 2A or a Dry contact
  - » Pilot indicators operating voltage: 500 VAC
  - » Zero voltmeter measuring range: 0....400V
  - » Double frequency measurement range: 47 to 53 HZ
  - » Double voltmeter measurement range: 0 to 500 V
  - » Digital synchronoscope:
    - Generator input voltage: 300 V-AC max. (Ph-N)
    - Generator input frequency: 0-70 Hz.
    - Reference Busbar voltage: 300 V-AC max. (Ph-N)
    - Reference Busbar frequency: 50/60 Hz.
    - Digital inputs: 0 - 30 V-DC DC
    - Supply Range: 9.0 to 33.0 V-DC
    - Automatic synchronization enable selectors
    - Operating voltage: 220V

Synchronous Machine Control Unit
Code: (SG100.06)



- Synchronous Machine Control Unit is used in conjunction with the exciter controller and electromagnetic switch.
- The unit contains an energy meter that measures the electrical parameters of three phase power, as well as able to draw variables versus time and draw vector diagrams.
- In addition, the unit can be interfaced

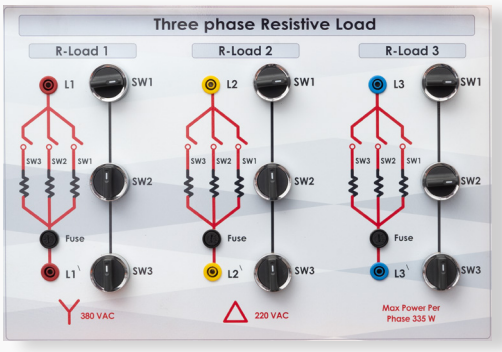
with a SCADA system through ethernet to control the level of excitation voltage and enable, as well as disable the output of three-phase alternator.

- Display technical data:
  - » Universal supply input (both AC & DC): 220 V AC, DC
  - » Measurement inputs voltage: 10 – 300 V AC,
  - » Measuring current: 0.2 – 5.50 A AC
  - » Measuring frequency: DC – 500Hz
  - » True RMS measurements 3.5" TFT LCD, 320x240 pixels
  - » Internal battery backed-up real time clock
  - » Harmonic distortion display (63 harmonics) Oscilloscope
  - » Waveform display
  - » Phasor diagram display
  - » Max demand display
  - » 2x configurable relay outputs 2x optoisolated, configurable digital inputs
  - » Dual active-reactive power counters
  - » Both mains & generator energy metering
  - » Voltage transformer ratio for MV applications
  - » Supported wiring topologies:
  - » 3 phases, 4 wires (star)
  - » 3 phases, 3 wires, 3 CTs
  - » 3 phases, 3 wires, 2 CTs (L1-L2)
  - » 3 phases, 3 wires, 2 CTs (L1-L3)
  - » 3 phases, 4 wires, delta
  - » 2 phases, 3 wires, L1-L2
  - » 1 phase, 2 wires (L-N)
- **Measurements:**
  - » Phase to phase voltages: U12-U23- U31-Uavg
  - » Phase to neutral voltages: V1-V2-V3-Vavg
  - » Phase currents: I1-I2-I3
  - » Active power: P1-P2-P3-Psum
  - » Reactive power: Q1-Q2-Q3-Qsum
  - » Apparent power: S1-S2-S3-Ssum
  - » Power factor (cos-phi): cos1-cos2- cos3-Σcos
  - » Active power counters: pc1-pc2
  - » Reactive power counters: qc1-qc2
  - » Phase to neutral voltages vector angles
  - » Phase to phase voltages vector angles

- Digital inputs/outputs:
  - » 2x digital outputs for Increment/ Decrement Exciter voltage terminals
  - » 2x digital outputs for Enable/Disable Exciter controller
  - » 2x digital outputs for enabling/breaking power circuit through power module switch
  - » 1x digital input for synchronization power switch status

Three phase Resistive Load

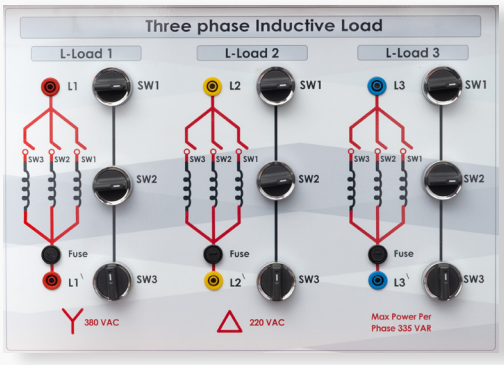
Code: (SG100.07)



- Three phase Resistive Load can be used as a static active power load. The resistive power demand per phase is incremented in discrete steps.
- Technical data:
  - » Rated operating voltage: 220VAC / 380VAC
  - » Number of steps per phase: 5
  - » Minimum loading capability per phase: 66 Watt
  - » Maximum loading capability per phase: 335 Watt

Three phase Inductive Load

Code: (SG100.08)



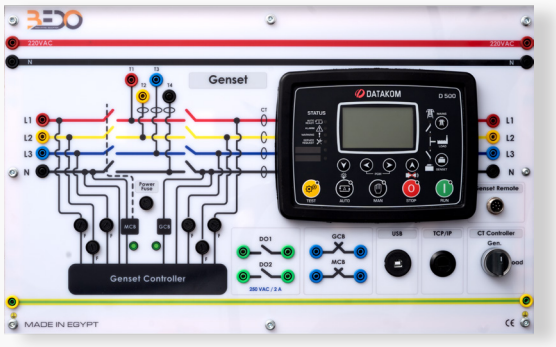
- Three phase Inductive Load can be used as a static reactive power load. The inductive power demand per phase is

incremented in discrete steps.

- Technical data:
  - » Rated operating voltage: 220VAC / 380VAC
  - » Number of steps per phase: 7
  - » Minimum loading capability per phase: 66 VAR
  - » Maximum loading capability per phase: 335 VAR

Genset Controller
Code: (SG100.09)

- This module is a complete engine



generator control and protection with advanced, peer-to-peer paralleling functionality.

- This controller has an integrated programmable logic functionality provides which can often eliminate the need for additional PLC control, hence can work in stand-alone mode.
- Also, it included a SCADA system. This module could act as an automatic voltage regulator in automatic synchronization mode.
- Remote control via interface and discrete/analog inputs for adjusting speed, frequency, voltage, power, reactive power, and power factor set points with assist of SCADA system
- **Control Features:**
  - » Automatic synchronization
    - ◦ Automatic power control
    - ◦ Automatic voltage control
    - ◦ Automatic frequency control
  - » Breaker control logic (open and closed transition)
  - » Automatic, Manual, Stop, and test operating modes
  - » Single and multiple gen-set operation
  - » Mains parallel multiple-unit operation (up to 32 gen-set)
  - » Auto mains failure and stand-by operation
  - » Import / export limits (kW and kVAR)
  - » Speed (frequency), V, P, and Q remote control via analog input or interface
  - » Load/var sharing for up to 32 gensets
  - » Freely configurable Engine: speed / frequency match PID controllers
- **Protection Features**
  - » Generator: voltage / frequency (ANSI: 59 / 27 / 81O / 81U)
  - » Generator: overload, reverse (ANSI: 32 / 32R)
  - » Generator: unbalanced load (ANSI: 46)
  - » Generator: time-overcurrent (ANSI: 51)
  - » Generator: ground fault (ANSI: 50G)
  - » Engine: overspeed / under-speed (ANSI: 12 / 14)
  - » Mains: voltage / frequency (ANSI: 59 / 27 / 81O / 81U)
  - » Mains: phase shift / rotation field (ANSI:78)
  - » Grid: rotation field
  - » Grid: voltage/frequency/phase shift/ ROCOF (ANSI 59/27/81O/81U/78)
- **Genset Controller Interfacing module (Not Included)**
  Code: (SG100.09)
  - » **RS-485 Communication Module**
    - ◦ Purpose: Provides a SCADA interface to an external supervisory control and data acquisition system.
    - ◦ Protocol: supports Modbus RTU or other common industrial protocols over RS-485.
  - » **Analog I/O Expansion Module**
    - ◦ Function: Used for speed control interfacing, particularly useful when integrating with systems such as a servo bench.
    - ◦ Input/Output Type: Analog signals (e.g., 0-10V, 4-20mA)

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- Application: Enables external power control, useful for dynamic testing or hybrid system integration.

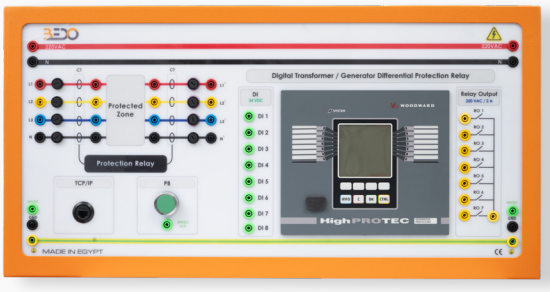
» **3x Mains CT (Current Transformer) Inputs Module**

- Function: For monitoring three-phase current from the mains supply.
- Application: Essential for load sharing, power metering, and protection logic in the controller.

» **Synchronization Module**

- The automatic synchronization module enables the genset controller to:
  - Synchronize the generator with:
    - » Utility grid (mains), or another generator (parallel operation)
      - Match parameters like:
        - Voltage
        - Frequency
        - Phase angle

Digital Transformer / Generator differential protection relay
Code: (SG100.10)



- Provides various protective functions specifically tailored to the protection of generator.
- The device offers in addition to differential protection various communication and backup protection functions. Furthermore, this module can be used for transformer protection.
- Technical data:
  - » Digital inputs: 8
  - » Binary output relay: 7
  - » Number of current inputs: 8 (1 A and 5 A) with automatic CT
  - » Power supply range: 24 VDC – 270 VDC / 48 VAC – 230 VAC
- Protection features:
  - » Generator differential protection (2 windings), Id
  - » Curve with zero point and three settable slopes and highest element (Id>>)
  - » Inrush stabilisation / detection of 2nd, 4th and 5th harmonics
  - » Restricted earth fault IdG, IdG>>
  - » Time overcurrent and short circuit protection (non-directional)
  - » Multiple reset options (instantaneous, definite time) for ANSI 50N/50
  - » Unbalanced load protection with evaluation of the negative phase sequence currents 2 46
  - » Overload protection with thermal replica for transformers, alarm and trip threshold
  - » Inrush detection with evaluation of the 2nd harmonic
  - » Earth overcurrent and short circuit protection (non-directional)
  - » External alarm and trip functions
- Supervision features:
  - » Circuit breaker failure protection for both circuit breakers
  - » Trip circuit supervision
  - » Current transformer supervision
  - » THD supervision

Field ground protection module (DC injection/AC-Injection Currents) (ANSI: 64F)

Code: (SG100.11)



- Ground relays alert personnel visually and through alarm output contacts when a DC switchgear structure or rectifier becomes grounded through a breach in

the insulation. Annunciation occurs when the voltage sensing trip system has been by passed by grounding. The relay also alerts personnel when a leakage or fault occurs between the bus and structure (hot structure).

- Technical data:
  - » Input Power supply: operates on 220 AC
  - » Supply Current: 200 mA @ 24 VDC, Via limiting resistance
  - » Testing applied Voltage: 25 VDC Output
  - » Trip Setting – Hot: 30-45 VDC

Motor protection switch
Code: (SG100.12)



- Similar to the power switch module except that the three-phase power contacts are closed and opened manually. Another feature included is the thermal cutoff capability. An integrated knob within the manual switch can be adjusted through a screwdriver to set the overload current at which power circuit is interrupted.
- Technical data:
  - » Current setting range: 1.4 ….2.5A
  - » Rated switching capability: 250VAC, 12A

Three phase power analyzer
Code: (SG100.13)



- Three phase power analyzer is used to measure and analyze electrical quantities for three phase power circuits. It is useful when integrating it with a three phase asynchronous machine (Stand-alone) to monitor current demand, harmonics from source, as well as power factor under various loading conditions.
- Technical data:
  - » Harmonic resolution: 31st harmonic detection
  - » Nominal Full Scale: 400Vac L-N, 690Vac L-L
  - » Withstand voltage: 1500Vac continuous 3250Vac, 50/60Hz for 1 minute
  - » Metering Frequency 46Hz~64Hz
  - » Pickup Voltage 10Vac
  - » Accuracy 0.2% full scale
  - » Metering Range 0~10 A AC Withstand 20Arms continuous, 100Arms for 1 second, non-recurring
- Resolution features:
  - » Voltage: 0.1V (range: 20V ~ 1000kV)
  - » Current 0.001A (range: 5mA ~ 5000A)
  - » Power 1W (range: -9999MW ~ 9999MW)
  - » Reactive Power: 1VAR (range: -9999MVAR ~ 9999MVAR)
  - » Apparent Power: 1VA (range: 0~9999MVA)
  - » Power Demand: 1W (range: -9999 MW~ 9999 MW)
  - » Reactive Power Demand: 1VAR (range: -9999MVAR~9999MVAR)
  - » Apparent Power Demand:1VA (range: 0~9999MVA)
  - » Power Factor: 0.001 [range: -1.000(cap) ~ 1.000(ind)]
  - » Frequency: 0.01Hz (range: 46.00~64.00Hz)
  - » Active Energy: 0.1kWh (range: 0~99999999.9kWh)
  - » Reactive Energy: 0.1kVARh (range: 0~99999999.9kVARh)
  - » Apparent Energy: 0.1kVAh (range: 0~99999999.9kVAh)
  - » Harmonics: 0.1% (range: 0.0%~100.0%)
  - » Phase Angle: 0.1° (range: 0.0° ~ 359.9°)

Experiments

- Relation between electrical frequency & prime mover speed
- Relation between injected reactive power and excitation voltage of alternator
- How to generate electricity with the same frequency, voltage magnitude and phase sequence similar to that of the grid.
- Manual Synchronization methods:
  - » Dark lamp method
  - » Two-bright, one-dark lamp method
  - » Synchroscope method
- Active power control technique
- Effect of under-excitation and overexcitation on synchronous machine (reactive power flow)
- How to use SCADA system to control generator excitation voltage, as well as governor speed to meet synchronization condition
- How to set power limits using SCADA for fail-safe condition to prevent alternator instability condition
- How to adjust the pick-up current for generator protection
- Effect of wrong CT configuration on differential protection tripping.
- How to manually set Over-current relay to protect against short circuit and overcurrent condition
- How to protect three phase machine against counter rotation, overvoltage and under-voltage conditions
- Protecting three-phase machines during a phase failure using voltage imbalance relay
- Preventing motoring of synchronous generator due to low speed failure using reverse power relay
- Monitoring dual earth fault condition in excitation winding using field grounding detection relay

Scope of Delivery

- Smart Grid Electrical Power Generation (SG100)
- Hard Copy User Manual

Options

- Digital content (BI01)

Required for Operation

- Machine & Drive Lab Supply Unit(ML100)

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