PS - 001

Power Systems Laboratory

Overview

The power systems laboratory is an advanced lab that is designed to introduce trainees to fields of electrical power systems, power generation, transmission lines. The laboratory consists of modules that includes all necessary and advanced components to allow trainees to understand and study the previous fields. Also, the laboratory is supplied with experimental units of electrical machines for further experiments.



Specifications

Synchronous Machine Test Stand
Code: (PS-001.1)



The Synchronous Machine Test Stand used to calculate and demonstrate the motor efficiency, feed with variable DC supply, create circuit of electromagnetic braking and create circuit of prime mover.

Required Supply:

- Rated input voltage: 220 VAC (L + N + E)
- Rated supply current per phase: 4A
- Rated supply frequency: 50/60 Hz

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Features:

- 1kW synchronous machine mechanically coupled to a 1kW DC shunt motor
- DC shunt motor serves as prime mover (turbine) for synchronous generator
- Rotor winding terminals, as well as stator winding terminals of synchronous machine are accessible through 4mm safety terminals
- DC Excitation supply voltage is provided to excite the rotor windings of synchronous machine
- The field current and field voltage can be monitored through the DC metering panel
- The DC excitation voltage is set by adjusting the knob of an autotransformer connected to a bridge rectifier
- A load cell is attached to the test stand to send a feedback signal on the current load torque applied on the shaft
- The shaft is coupled to a DC tachogenerator that provides feedback of the current rotational speed

Generation Module

Code: (PS-001.2)



The Generation Module introduces trainees to the difference between power supplies and power generation and how the power generation is performed.

Required Supply:

- Rated input voltage: 220/380 VAC (3P+ N + E)
- Rated supply current per phase: 16A
- Rated supply frequency: 50/60 Hz

Features:

- **Auxiliary power supplies:**
  - Variable DC power supply: 0 ~ 350VDC, current rating: 10 A
  - Three-phase variable AC power supply: 0 ~ 290/500 VAC L-N/L-L, current rating: 6A, frequency: 50/60 Hz
  - Fixed DC power supply: 350VDC, current rating: 6A
  - Fixed AC power supply: 220/380 VAC L-N/L-L, current rating: 10A, frequency: 50/60 Hz
  - Low power AC power supply: 24 VAC, current rating: 2A, frequency: 50/60 Hz
- **DC Metering Panel:**
  - 4-Digit seven segment display
  - Configurable decimal point: 4
  - Max. DC reading: 600VDC, 25A DC
  - Min. DC reading: 0 VDC, 0.00A DC
  - Sample rate: 3 readings / second
  - Display refresh: 3 refresh / second
  - Resolution: 1000mV @ 600V range, 10mA @ 15A range
  - Serial communication: RS485 protocol
- **AC Power Analyzers:**
  - Phase Voltage (V1, V2, V3)
  - Phase angles (V1, V2, V3)
  - Line Voltage (V12, V23, V31)
  - Current (I1, I2, I3, In)
  - Current and Voltage Unbalance
  - Active Power (P1, P2, P3, Psum)
  - Reactive Power (Q1, Q2, Q3, Qsum)
  - Complex Power (S1, S2, S3, Ssum)
  - Power Factor (PF1, PF2, PF3, PFtotal)
  - Frequency (Hz)
  - Load type indicator (four quadrant)
  - Several types of demand calculation: total active power demand, total reactive power demand, total apparent power demand, phase A current demand, phase B current demand, and phase C current demand
  - Accumulates energy for kWh, kVARh and kVAh
  - Total harmonic distortion (THD)
  - Total Demand distortion (TDD)
  - Serial communication: TCP/IP protocol
  - Resolution: 100mV @ 500V range, 10mA @ 20A range

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Step-UP Substation Module

Code: (PS-001.3)



The Step-UP substation module introduces trainees to the step up operation using a transformer with different connections (star and delta) and synchronization operation between generators using different types of synchronization devices.

Required Supply:

» Rated input voltage: 220/380 VAC (3P+ N + E)
» Rated supply current per phase: 6A
» Rated supply frequency: 50/60 Hz

Features:

» Single three-phase step-up power transformer rated at 3kVA, 380/600 VAC.
» Transformer can be connected in the following configuration: 1) star-delta, 2) star-star, 3) delta-delta, 4) delta-star)
» HV side potential transformer 900/300 VAC
» Inter-winding fault terminal on secondary side and primary side of transformer
» Can receive electrical power from three independent stand-alone synchronous generator/alternator
» Synchronization switch for each alternator
» Reference bus: Grid can be set as the reference bus or a stand-alone alternator can be set as the reference
» Synchronization method:
  • Synchronoscope method
  • Three-dark lamp method
  • Two bright one dark lamp method
» High side and Low side AC Network analyzer:
  • Input phase voltage range: 0…300V AC
  • Input line voltage range: 0…500V AC
  • Measuring current range: 0…10A AC
  • Frequency measuring range: 45...65 Hz
  • Active power per phase measurement + total active power
  • Reactive power per phase measurement + total reactive power
  • Apparent power per phase measurement + total apparent power
  • Power factor per phase
  • kWh and kVARh measurement
  • Serial communication: RS485 protocol
  • Resolution: 100mA @ 25A range, 100mV @ 500V range

Power Transmission Line Module

Code: (PS-001.4)



The Power Transmission Line Module simulates different types of power transmission lines with different types of loads, in addition to simulating faults of power transmission lines.

Required Supply:

» Rated input voltage: 220/380 VAC (3P+ N + E)
» Rated supply current per phase: 6A
» Rated supply frequency: 50/60 Hz

Features:

» Two independent three-phase step-down power transformer rated at 3kVA, 600/380 VAC
» Transformers can be configured as: 1) star-delta, 2) star-star, 3) delta-delta, 4) delta-star)
» Voltage regulation on HV side using 5-step tapping switch
» Two independent outgoing feeders with digital metering panel
» Load transfer on HV side through bus bar coupler (tie-breaker)
» Metering panel:
  • Input phase voltage range: 0…300V AC
  • Input line voltage range: 0…500V AC
  • Measuring current range: 0…10A AC
  • Frequency measuring range: 45...65 Hz
  • Active power per phase measurement + total active power

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- Reactive power per phase measurement + total reactive power
- Apparent power per phase measurement + total apparent power
- Power factor per phase
- kWh and kVARh measurement
- Serial communication: RS485 protocol
- Resolution: 100mA @ 25A range, 100mV @ 500V range

Three-phase Complex Load Module

Code: (PS-001.5)



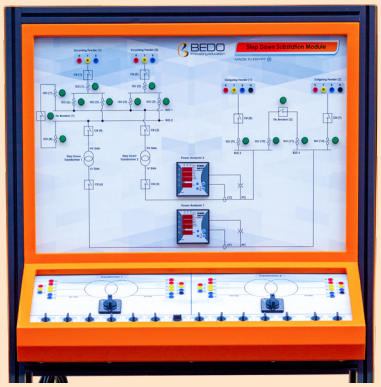
The Three-phase Complex Load Module introduces trainees to different types of loads and how to control them.

Features:

» Three phase complex load
» 1kW resistive load
» 1kVAR inductive load
» 1kVAR capacitive load
» Incremental increase in active load per phase in the following steps: 90W, 170W, 300W
» Incremental increase in lagging reactive load per phase in the following steps: 100VAR, 200VAR, 300VAR
» Incremental increase in leading reactive load per phase in the following steps: 70VAR, 150VAR, 230VAR

Step-down Substation Module

Code: (PS-001.6)



The Step-down Substation Module introduces trainees to step down transformation from 380 VAC to 220 VAC, in addition to controlling loads buses using isolators and circuit breakers.

Required Supply:

» Rated input voltage: 220/380 VAC (3P+ N + E)
» Rated supply current per phase: 6A
» Rated supply frequency: 50/60 Hz

Features:

» Two independent three-phase step-down power transformer rated at 3kVA, 600/380 VAC
» Transformers can be configured as: 1) star-delta, 2) star-star, 3) delta-delta, 4) delta-star)
» Voltage regulation on HV side using 5-step tapping switch
» Two independent outgoing feeders with digital metering panel
» Load transfer on HV side through bus bar coupler (tie-breaker)
» Metering panel:
» Input phase voltage range: 0…300V AC
» Input line voltage range: 0…500V AC
» Measuring current range: 0…10A AC
» Frequency measuring range: 45...65 Hz
» Active power per phase measurement + total active power
» Reactive power per phase measurement + total reactive power
» Apparent power per phase measurement + total apparent power
» Power factor per phase
» kWh and kVARh measurement
» Serial communication: RS485 protocol
» Resolution: 100mA @ 25A range, 100mV @ 500V range

Dynamometer Module

Code: (PS-001.7)



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The Dynamometer Module is used to calculate and demonstrate the motor efficiency, feed with variable DC supply, create circuit of electromagnetic braking and create circuit of prime mover.

Required Supply:

» Rated input voltage: 220/380 VAC (3P+ N + E)
» Rated supply current per phase: 10A
» Rated supply frequency: 50/60 Hz

Features:

» In motoring mode, active power input exerted by prime mover (turbine/DC shunt) can be calculated using torque meter and rotational speed indicator
» Speed of prime mover/governor (hence frequency, is controlled using a speed feedback-loop. The speed of shaft is fed back to an SCR DC drive through a DC tacho-generator or armature voltage feedback which in turn maintains the shaft speed (frequency) at set point.
» The set is provided with SCR speed control unit provides adjustable current limit, hence torque/active power limit can be set
» The set is also supplied with an IR voltage compensation to provide speed regulation throughout 60:1 speed range
» Minimum and maximum speed of prime mover can be set, as well as adjustable linear acceleration and deceleration times.
» Output torque of DC motor (prime mover) can be controlled through field weakening technique
» Field resistance control is achieved through adding a resistance in series with the field coil in an increment of 4-steps
» In brake mode, a 3-step resistive-load is provided to apply load across the DC-generator
» DC generator can be mechanically coupled with the motor under test to apply a negative electro-magnetic torque on the shaft of motor under test, in turn acts as a mechanical load on the shaft
» Torque feedback is fed to a torque indicator through a 4-wire load cell attached to the motor set, so load torque can be measured
» DC tacho-generator with a resolution of 0.06V/RPM feeds rotational speed to a speed indicator, therefore shaft speed can be measured
» DC meter panel is provided to measure the excitation voltage, armature voltage, field current and armature current fed to the DC shunt motor (prime mover/DC generator)
» 1Hp variable frequency drive is provided to supply three phase power to three phase induction motors through a linear V/F control technique.
» Touch screen is provided to set the operating base frequency, base voltage and motor poles for the VFD
» The output of the VFD can be enabled/ disabled, as well as frequency command is entered to the VFD through the virtual buttons and sliders depicted on the touch screen
» Serial Communication: RS485 protocol
» DC metering panel:
  • Sampling cycle: 50ms
  • Display method: 7 segment display (RED)
  • Voltage measuring range: 0…500V DC
  • Current measuring range: 0…10A DC
» Torque meter panel:
  • NO. OF LOAD CELLS IN PARALLEL and SUPPLY max 8 (350 ohm); 5 VDC / 120 mA
  • LINEARITY / ANALOG OUTPUT LINEARITY: < 0.01% F.S.; < 0.01% F.S.
  • THERMAL DRIFT / ANALOG OUTPUT THERMAL DRIFT: < 0.0005% F.S./°C; < 0.003% F.S./°C
  • A/D CONVERTER: 24 bit (16000000 points)
  • MEASUREMENT RANGE: ±39 mV
  • MAX SENSITIVITY OF USABLE LOAD CELLS: ±7 mV/V
  • MAX CONVERSIONS PER SECOND: 300 conversions/second

Analog Meters Module

Code: (PS-001.8)



The analog meters module introduces trainees to various types of AC and DC meters and how to connect them and use them in measurements, this module can be connected to any other module to take measurements.

Features:

» Direct Voltage measurement
- 0-50V DC range
- 0-300V DC range

» Direct Current measurement
- 0-500mA DC range
- 0-10A DC range

» Alternating Voltage measurement
- 0-300V AC range
- 0-800V AC range

» Alternating Current measurement
- 0-600mA AC range
- 0-2.5A AC range

» Single phase power factor measurement
- 0.5 lag…1…0.5 lead

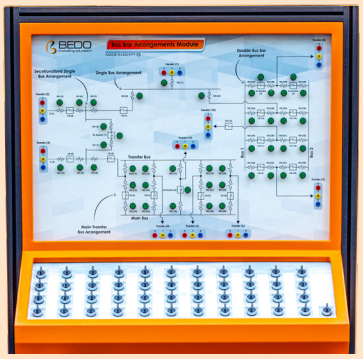
» Total three phase active power measurement
- -1000W…0…+1000W

» Total three phase reactive power measurement
- -1000VAR…0…+1000VAR

Optional Modules (Not Included):

Code: (PS-001.9)

- **Bus-bar Arrangement Module**
  Code: (PS-001.9.1)



The Bus-bar Arrangement Module is used to create an interconnected grid (a combination of loads and sources together in a wide network).

Required Supply:

» Rated input voltage: 220/380 VAC (3P+ N + E)

» Rated supply current per phase: 2A

» Rated supply frequency: 50/60 Hz

Features:

» The unit provides four types of substation topologies:
- Single Bus-bar arrangement
- Single Bus-Bar Arrangement with Bus Sectionalization
- Main and Transfer Bus Arrangement
- Double Bus Double Breaker Arrangement

» There are 10 feeders which can be connected to either three-phase loads or three-phase source

» Coupling of bus bars is achieved through tie-breaker control switch

» Power isolator can disconnect bus bar through isolator control switch

- **Auxiliary Modules**
  Code: (PS-001.9.2)



The Auxiliary Module introduces trainees to rectifier operation using diodes and how to protect diodes from over current in addition to using relays for control and self – latching principle.

Required Supply:

» Rated input voltage: 220/380 VAC (3P+ N + E)

» Rated supply current per phase: 6A

» Rated supply frequency: 50/60 Hz

Features:

» The unit provides three-phase full-bridge rectifier circuit to generate auxiliary DC supply

» Time-triggered faults can be inserted to power system modules through using timer and arc resistors

» Arc resistors can be used to generate

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inter-turn fault inside transformer or phase-to-ground fault
- » Single phase ammeter is provided to measure fault current
- » Time of fault is settable in the range of 0.1sec...60min
- » Embedded relay latching circuit is provided to connect auxiliary contacts of relay to external contactors
- » Relay is activated through Start and Reset buttons

Experiments

- Three-phase synchronous machine connected as a generator
- Determining electrical parameters of a three-phase synchronous machine
- Performance characteristics of a synchronous machine obtained by v-curves and inverted v-curves
- Relation between generated EMF and DC excitation voltage under no load condition
- Relation between governor speed and electrical frequency
- Calibrating max output torque and reference speed for prime mover (governor)
- Configuration of power transformer in different configurations (delta-star, star-star, star-delta, delta-delta)
- Synchronizing three-phase alternator with grid using digital Synchronoscope method
- Synchronizing three-phase alternator with grid using three-dark lamp method
- Synchronizing three-phase alternator with grid using two bright one dark lamp method
- Effect of Inter-turn fault on power transformer
- Leakage current due to line capacitance
- Ferranti effect due to unloaded/light load condition on the receiving end of transmission line
- Effect of line unsymmetrical fault currents on the power grid
- Configuration of power transformer in different configurations (delta-star, star-star, star-delta, delta-delta)
- Transferring of load between bus bars without interrupting power supply
- Voltage regulation to compensate for voltage drops in transmission lines or excess received line voltage
- RL load configuration:
  - » Parallel RL star-connected load
  - » Series RL star-connected load
  - » Parallel RL delta-connected load
  - » Series RL delta-connected load
- Effect of Inductive loads on line currents
- Using synchronous machines as synchronous condensers
- Power factor correction using capacitive banks

Scope of Delivery

- Power Systems Laboratory (PS - 001)
  - » Synchronous Machine Test Stand (PS - 001.1)
  - » Generation Module (PS - 001.2)
  - » Step-UP Substation Module (PS - 001.3)
  - » Power Transmission Line Module (PS - 001.4)
  - » Three-phase Complex Load Module (PS - 001.5)
  - » Step-down Substation Module (PS - 001.6)
  - » Dynamometer Module (PS - 001.7)
  - » Analog Meters Module (PS - 001.8)

Options

- Digital content (BI - 01)
- Bus-bar Arrangement Module (PS - 001.9.1)
- Auxiliary Modules (PS - 001.9.2)
- Synchronous Generator Protection Module (PS - 002)
- Step-up Substation Protection Module (PS - 003)
- Step-down Substation Protection Module (PS - 004)
- Load Protection Module (PS - 005)

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