PS101

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

Generation Module
Code: (PS101.01)



- 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

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- Features:
  - » Auxiliary power supplies:
    - – Variable DC power supply: 0 ~ 350VDC, current rating: 10 A
    - – Three-phase variable AC power supply: 0 ~ 240/400 VAC L-N/L-L, current rating: 6A, frequency: 50/60 Hz
    - – Fixed DC power supply: 280 VDC, 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 DCMin. DC reading: 0 VDC, 0.0A DC
      - » Sample rate: 3 readings / second
      - » Display refresh: 3 refresh / second
      - » Resolution: 1000mV at 600V range, 10mA at 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

Step-up Substation Module
Code: (PS101.02)



- 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, 380/660 VAC.
  - » Transformer can be connected in the following configuration:
    - – Star-Delta
    - – Star-Star
    - – Delta-Delta
  - » HV side potential transformer 380/660 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

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» 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…700 V 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 to 25A range, 100mV to 500V range

Power Transmission Line Module Code: (PS101.03)



- 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:
  » Three-phase line simulation of a high voltage overhead power line with different lengths for measuring various operational states (open-line, matched, short-circuit). Scale factor 1/1000 for current and voltage. Automatic modification of wire length as soon as the corresponding overlay is in place.
  » Transmission line length: 150km or 300km
  » Transmission line length: 93.2 miles or 186.4 miles
    - Resistance per phase: 3,6Ohm 7,2 Ohm
    - Inductance per phase: 115mH 230mH
    - Capacity per phase:
    - Line-to-ground: 2 x 0,55µF 1,1µF
    - Max power consumption: 1kW
    - Voltage: up to 3x 400V; 50/60Hz
    - Current: up to 4A
    - Inputs/outputs: 4mm safety sockets

Three-phase Complex Load Module Code: (PS101.04)



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

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

Step-down Substation Module
Code: (PS101.05)



- 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, 660/380 VAC.
  - » Transformers can be configured as:
    - Star-Delta
    - Star-Star
    - Delta-Delta
    - Delta-Star
  - » Metering panel:
    - Input phase voltage range: 0…300V AC
    - Input line voltage range: 0…700V 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 to 25A range, 100mV to 500V range

Dynamometer Module
Code: (PS101.06)



- 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

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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)

» Serial Communication: RS485 protocol

- DC metering panel:

» Sampling cycle: 50ms

» Display method: 7 segment display (RED)

» Voltage measuring range: 0…500V D C

» 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: (PS101.07)



- 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

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» 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: (PS101.08)

- **Bus-bar Arrangement Module (PS101.08.01)**



- 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 Module (PS101.08.02)**

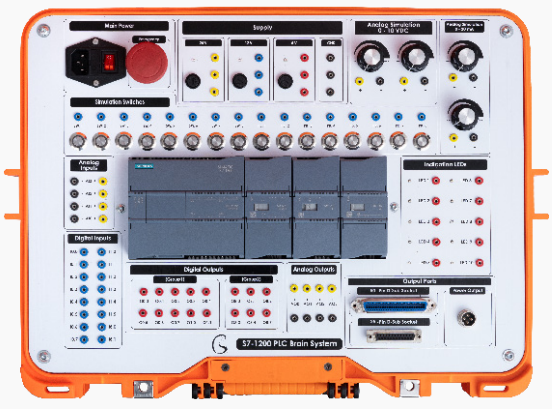


- The Auxiliary Module introduces trainees to rectifier operation using diodes and how to protect diodes from over current in addition to using relays for control and self – latching principle.
- Required Supply:
  - » Rated input voltage: 220/380 VAC (3P+ N + E)
  - » Rated supply current per phase: 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 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

- **Power Factor Controller Module (PS101.08.03)**



- A power factor controller is a device that brings the power factor to the pre-set value. The relay regulates the load power factor through continuously measuring alternating load current and RMS voltage applied across load to calculate the reactive power demanded from the grid by the inductive loads. Capacitors are deactivated or activated for an optimal setting. A sufficient number of capacitors are activated when the load power factor decreases. The capacitors are added in such a way that when capacitive reactive power balance the inductive reactive power, the regulation stops to prevent over-compensation.
- Features:
  - » 7-seg display (4-digit)
  - » Eight-Level Status LEDs » 100mA Current Sensitivity
  - » Automatic Current Transformer Test
  - » Three phase output terminals internally connected to delta-connected
- capacitor bank
- Technical Data:
  - » Trainer supply input: 3-phase 3380/220VAC, 6A
  - » Controller operating voltage: 160 – 260VAC
  - » Controller Operating frequency: 50Hz
  - » Controller internal power consumption: <10W
  - » Controller current measure range: 80mA – 5.5A
  - » Controller relay-out contact rating: 5A/250VAC
  - » Controller number of steps: 7 steps
  - » Capacitor bank compensation power per step: 145 VA
  - » Capacitor bank rated voltage: 400VAC
- **SCADA Monitoring System (PS101.08.04)**



- The SCADA acronym stands for Supervisory Control and Data Acquisition. A SCADA system is a collection of both software and hardware components that allow supervision and control of plants. This module covers local monitoring only without the feature of remote monitoring for cybersecurity reasons. The structural design of a standard SCADA system is based on Remote Terminal Units (RTUs) and Programmable Logic Controllers (PLCs). RTUs and PLCs are microprocessors that communicate with HMI's and interact with field devices (hardware) such as valves, pumps, motors, sensors and much more. The data is routed from the processors to the SCADA computers, where the software interprets and displays the data allowing for operators to analyze and react to system events. Also within the SCADA system is the ability to Record data into a log file
- Features:
  - » Interacts with metering panels to retrieve analog signals such as line currents, line voltages, prime mover speed and developed torque
  - » Ability to draw load demands and energy consumption graphs with respect to time
  - » Communicates with PLC to disable/ enable circuit breakers
  - » Control the active power and reactive power injected to grid
  - » Displays the power flow diagram starting from generation station to load side
  - » Monitors the tripping of protection relays
  - » Enable/Disable Electrical loads on bus bar
  - » Tying synchronous machines with grid with synchronization switch
  - » Displays RMS values for active power demand, reactive power demand, apparent power and power factor
  - » This module is required PC for operation

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Servo machine test Stand
Code:(PS101.09)



- The servo-machine test bench is a complete testing system for examining electrical machines and drives. It consists of a digital controller, a brake and the 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:
  - » Dynamic and static four-quadrant operation
  - » Selectable operating modes/ machine models (torque control, speed control.
  - » Interface for reading electronic nameplates EDD of the machines under test
  - » Integrated galvanically isolated amplifier for voltage and current measurement
  - » Colour touch display
  - » Four-quadrant monitor
  - » 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: 3000 RPM
  - » Maximum Voltage: 3~, 220V
  - » Maximum Current: 12.75A
  - » Motor Maximum Capacity : 3.5 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

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)

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- Configuration of power transformer in different configurations (delta-star, starstar, 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, starstar, 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
- Power factor correction using capacitive banks

Scope of Delivery

- Power Systems Laboratory(PS101)
- Hard Copy User Manual

Options

- Digital content (BI01)

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