SG101

Smart Grid HV Transformers & Transmission Line Training System

Overview

This trainer covers key concepts in electrical power transmission, starting with line testing and impedance matching. It explains the effects of resistance, capacitance, and inductance on power flow. Students learn to choose optimal line configurations and sizes. It also covers parallel transmission and power flow control using phase angle transformers. Protection relays and a fault module allow hands-on experience with system protection.



Specifications

Voltage regulating transformers
Code: (SG101.01)

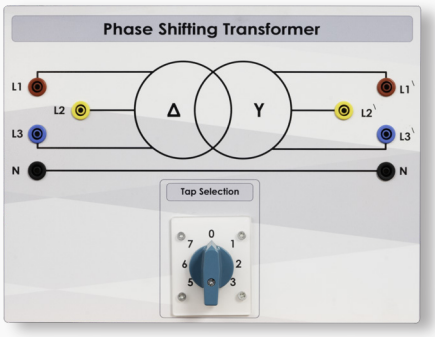


- Unlike a two winding transformer whose input and output windings are galvanically connected, this regulator transformer consists of a common winding and a series winding that are electrically connected to each other to form a booster transformer whose output voltage is in-phase with the supply voltage.

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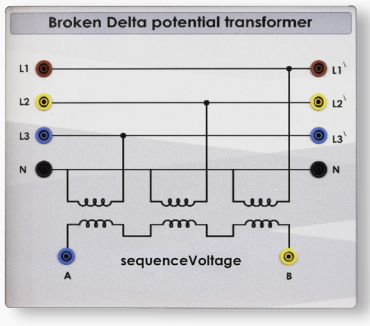
- This module is connected on the upstream of the power grid to compensate for the voltage drop in transmission lines caused by load variation on the transmission line end. In some cases, due to lightly loaded conditions, the receiving end voltage could rise due to Ferranti effect, so regulating the sending end voltage is essential.
- Technical Data:
  - » 3-phase autotransformer
  - » Rated power: 2kVA
  - » Rated primary voltage: 380 VAC
  - » Rated secondary voltage: 0 - 400 VAC Line
  - » Fuse protected, G type

Phase shifting transformer Code:(SG101.02)



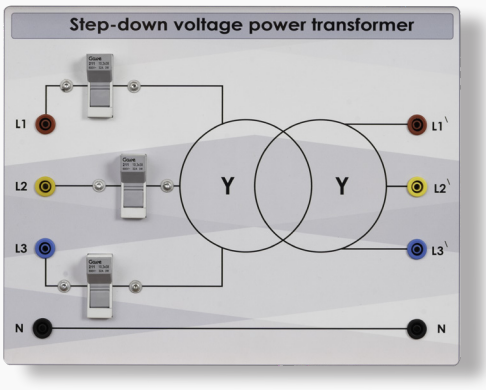
- This is a special type of transformer used for controlling the amount of reactive power flow in transmission line. Shunt compensation has been widely used in transmission system to regulate the voltage magnitude, to improve the voltage quality and to enhance the system stability. This might cause power factor correction on the transmission line.
- Technical Data:
  - » 3-phase isolating transformer » Rated power: 3 kVA
  - » Rated primary voltage: 380 (Line) VAC (Delta Connected)
  - » Rated secondary voltage: 380 VAC (Line) (Star Connected) Broken Delta

Potential Transformer Code:(SG101.03)



- When a ground fault occurs in an ungrounded system, the fault current will be close to zero making it difficult to locate and isolate ground fault using traditional ground overcurrent relay. A parameter that can be used to our advantage in the detection and isolation of ground fault on ungrounded system is the zero-sequence voltage during ground fault. This module uses three single phase measuring transformers. The primary winding is connected in star configuration then attached to the measuring point of interest (typically on a three-wire transmission line) while the secondary winding is connected in a broken-delta configuration and its output are fed as an input signal to the earth fault voltage relay (Numerical Relay).
- Technical Data:
  - » 3-phase voltage transformer (Star – Broken Delta configuration) Rated burden per phase: 20 VA
  - » Rated primary voltage: 380 (Line)
  - » Rated secondary voltage: 57 (Phase)

Step-down voltage power transformer Code: (SG101.04)



- This power transformer is used for decreasing the line voltage to levels which the loads and cable insulation can tolerate.
- Technical Data:
  - » 3-phase power transformer (Star-Star configuration)
  - » Rated power: 1kVA
  - » Rated primary voltage: 400VAC (Line)
  - » Rated secondary voltage: 220 VAC (Line)

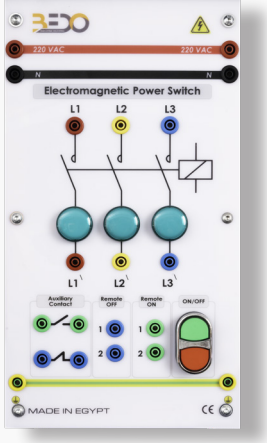
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ARC suppression coil (Peterson coil) Code:(SG101.06)



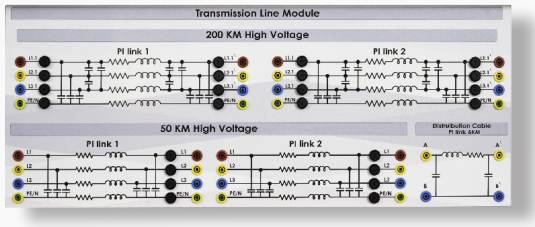
- The system neutral is earthed through a high impedance reactor, a so-called arc suppression coil, which is adjusted to the earth capacitance of the network. By utilizing continuously variable arc suppression coils, ideal compensation of the earth-fault current can be achieved. The value of the inductance in the Petersen coil needs to match the value of the network capacitance.
- Technical Data:
  - » Auxiliary power supply: 220V AC, 2A
  - » Number of steps: 7
  - » Coil power rating: 150 VA
  - » Rated neutral to ground voltage: 220V

Electromagnetic power switch Code:(SG101.07)



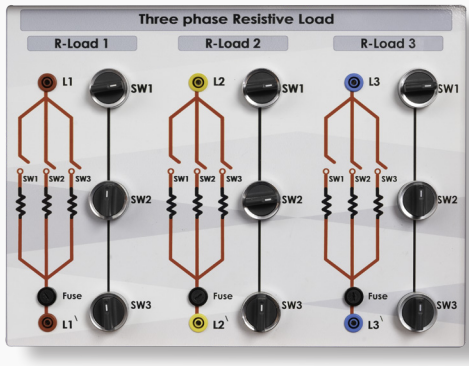
- Electromagnetic power switch can be used as a power cutoff switch for three-phase applications. The power module can be operated manually and remotely.
- Technical Data:
  - » Rated remote signal voltage: 24 VDC/ 0.5 A or Dry contact
  - » Normally-open push button for enabling three-phase output
  - » 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

Transmission line module Code: (SG101.08)



- 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.
- Technical data:
  - » Two high voltage pi-links (200 km)
  - » Two high voltage pi-link (50 km)
  - » One distribution Cable pi-link (6 km)
  - » Rated line current: 3A
  - » Auxiliary supply voltage: 220V, 1A

Three phase Resistive Load Code: (SG101.09)

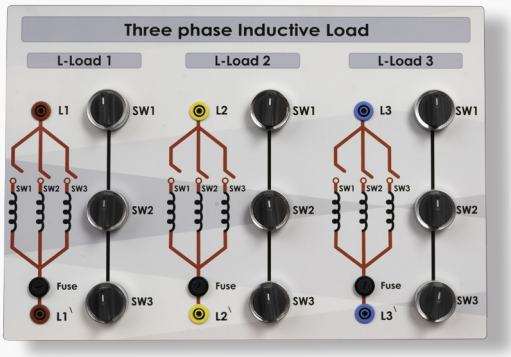


- This module can be used as a static active power load. The resistive power demand per phase is incremented in discrete steps.

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

Three phase Inductive Load Code: (SG101.10)



- 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: 5
  - » Minimum loading capability per phase: 66 VAR
  - » Maximum loading capability per phase: 335 VAR

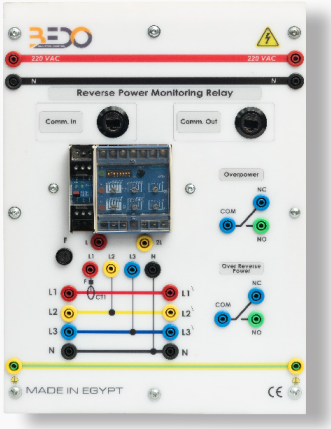
Advanced multimeter Code:(SG101.11)



- This is a handheld device that can be used for measuring electrical parameters in a DC, as well as AC circuit.
- Technical data:
  - » Absolute Maximum DC Current Measurement: 10A dc
  - » Absolute Maximum AC Current Measurement: 10A ac
  - » Absolute Maximum AC Voltage Measurement: 1 0 0 0Vac
  - » Absolute Maximum DC Voltage Measurement: 1000Vdc
  - » Absolute Maximum Resistance Measurement: 60MΩ
  - » Absolute Maximum Temperature Measurement: +1372°C
  - » Absolute Maximum Capacitance Measurement: 600µF
  - » Functions Measured: AC Current, AC Voltage, Battery Test, Capacitance, DC Current, DC Voltage, Diode, Frequency, Resistance, Temperature
  - » True RMS: Yes
  - » Maximum Frequency: 100kHz
  - » Display Type: LCD
  - » AC Current Measurement Resolution: 10nA
  - » DC Current Measurement Resolution: 10nA
  - » DC Voltage Measurement Resolution: 10µV dc
  - » AC Voltage Measurement Resolution: 10µV ac
  - » Resistance Measurement Resolution: 10mΩ
  - » Capacitance Measurement Resolution: 10pF
  - » Temperature Measurement Resolution: 0.1°C
  - » Best Resistance Measurement Accuracy : ±0.5% + 6 Digits
  - » Best DC Voltage Accuracy: ±0.05% + 2 Digits
  - » Best DC Current Accuracy: ±0.1% + 20 Digits

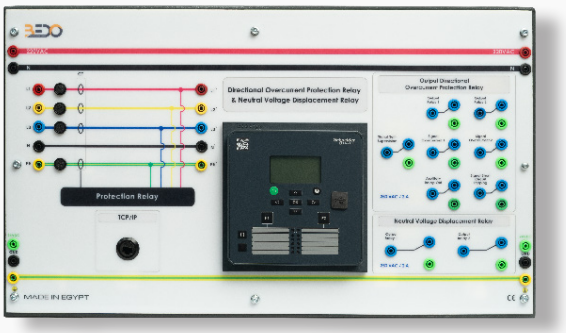
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Reverse power monitoring relay
Code: (SG101.12)



- This module can be used for reverse power detection of generator-set operating in parallel and active power supervision of power systems. For generators operating in parallel with a mains or another generator, it is imperative to supervise the power direction. If for example the prime mover fails the alternator operates as a motor and drives the prime mover (turbine). This module detects the reverse of the power direction and - in case of this error - switches off the alternator. This way, power losses and damages of the prime mover are avoided.
- Technical data:
  - » Analog input voltage signal: 100V, 110, 230 or 400V AC, 35Hz- 74Hz based on DIP switch setting
  - » Analog input current signal: 5A or 1A (using CT)
  - » Auxiliary power supply: 36VAC – 500VAC
  - » Hysteresis set point: 0.8% Pn
  - » Active power supervision: adjustable in the range from 1% to 120% Pn
  - » Reverse power supervision: adjustable in the range from 1 – 30% Pn
  - » Serial data exchange via RS485 interface through external module
  - » Tripping delay setting for P(active)>: 0…100sec
  - » Tripping delay setting for P(reverse)>: 0 … 10sec
  - » Number of relays: 2
  - » Contacts type: 1x changeover contact for each trip relay
  - » Maximum breaking capacity: (ohmic) 1250 VA @250VAC

Multi-Function Numerical Relay
Code: (SG101.13)



- The Numerical Relay is a protection multi function relay designed for universal applications in power systems as feeders, motors, and transformers . It provides comprehensive protection functions and diagrams. In addition it includes non-directional overcurrent, directional overcurrent, earth fault, breaker failures, under/overvoltage, frequency-based protections, and super vision features.
- Key Features:
  - » Power Supply: 48–230V AC/DC
  - » Measuring Inputs:
  - » Phase Current: 1/5 A CT (3 inputs)
  - » Residual Current; (earth current): 1/5 A CT (1 input)
  - » Voltage: 100V/110V VT (4 inputs); three phase transformer and the broken delta transformer
- I/O Capabilities:
  - » Digital Inputs: 16
  - » Digital Outputs: 7 (Could be programmed) + 1 watchdog
  - » Communication Ports: USB (front)
- Communication Protocols:
  - » Modbus, (Ethernet/IP) and USB
- Measurement Functions:
  - » Phase currents, sequence currents, voltages, power (active and reactive), energy, harmonics, frequency, voltage phase to earth voltage phase to phase, power factor, and the current directional angle
- Main Protection Functions

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Overcurrent Protection Function Code: (SG101.14)

- Instantaneous overcurrent (ANSI:50) protection is where a protective relay initiates a breaker trip based on current exceeding a pre-programmed "pickup" value for any length of time. Time overcurrent protection (ANSI:51) is where a protective relay initiates a breaker trip based on the combination of overcurrent magnitude and overcurrent duration, the relay tripping sooner with greater current magnitude. This is a more sophisticated form of overcurrent protection than instantaneous, expressed as a "time curve" relating overcurrent magnitude to trip time.
  - » Trip mentoring interface through a communication port
  - » Contact type: 1x changeover contact for each trip relay
  - » Maximum breaking capacity: ohmic 1250 VA @250VAC or 120 W @ 24VDC
  - » Resetting time from pickup: <95ms
  - » Returning time from trip: 200ms
  - » Current input signal: 5A
- By adjusting the Software it is possible to select from the following tripping characteristics:
  - » Definite time overcurrent protection (DMT)
  - » Definite-Time Overcurrent Protection parameter setting:
  - » I>: 0.1 ... 2 × I n (continuously regulated)
  - » I>>: 1.2 ... 15 × I n (continuously regulated)
  - » TI>: 0 ... 1 sec / 0 ...10 sec / 0 ...100 sec ((continuously regulated))
  - » TI>>: 0... 2.5sec (continuously regulated)
  - » Inverse time overcurrent protection (IDMT) with selectable tripping characteristics
  - » Normal Inverse
  - » Very Inverse
  - » Extremely Inverse
- Inverse-Time Overcurrent Protection parameter setting:
  - » I>: 0.5 ... 2 × I n (continuously regulated)
  - » tI>: 0.1 ... 2 s (continuously regulated)

Natural Voltage Displacement Function Code: (SG101.15)

- This type of protection is generally required with isolated or indirectly earthed neutrals. Under the normal balanced three phase operation, the sum of three-phase to earth voltages, that is, the neutral voltage, should equal zero. Due to the system being isolated/indirectly earthed, when an earth fault occurs, the fault facilitates the connection of one phase with earth, which poses a threat to the system safety. This fault also causes the neutral voltage to rise. This is called the neutral voltage displacement (NVD). Where NVD has been detected, the protection relay can clear the fault by generating the appropriate trip signal.
- Technical data:
  - » Analog input signals of earth fault voltage relay connected to an embedded broken delta
  - » Adjustable hysteresis: 1%, 2% or 5% of the tripping value
  - » Earth fault voltage element can be set in the range from 1 to 120 V AC
  - » Adjustable trip delay in the range from 0 to 100sec
  - » Relay output: 2x changeover contact
  - » Maximum breaking capacity: (ohmic) 1250 VA @250VAC
  - » Trip mentoring interface through a communication port

Voltage Protection Functions:

Overvoltage (ANSI59) / Undervoltage (ANSI27) / Phase Sequence (ANSI47) Code: (SG101.16)

- This module comprehends a digital measuring relay for supervision two, three and four wire systems. It protects electrical power generators, consumers or general equipment against overvoltage and undervoltage conditions. The module has independent overvoltage (U>) and

under-voltage supervision (<U) with separate adjustable pickup values and tripping periods.

- Technical data:
  - » Overvoltage tripping element is adjustable in the range from 95 – 125 % Un
  - » Under-voltage tripping element is adjustable in the range from 75 – 105 % Un
  - » Hysteresis setting for up to 3%
  - » Tripping delay setting for U>/U<: 0…100 sec » Relay mentoring via interface through external module
  - » Number of relays: 2
  - » Contacts type: 1x changeover contact for each trip relay
  - » Maximum breaking capacity: (ohmic) 1250 VA @250VAC
  - » Supervised system voltage according to programmed setting
  - » Phase sequence supervisions via digital input

Directional Phase Over Current Function (ANSI 67)
Code: (SG101.15)

- The measuring principle for determining the direction is based on phase angle measurement and therefore also on coincidence time measurement between current and voltage. Since the necessary phase voltage for deter-mining the direction is frequently not available in the event of a fault, whichever line-to-line voltage follows the faulty phase by 90° is used as the reference voltage for the phase current.
- The protection unit receives the analog input signals of the phase currents transformers while phase voltage from separate input transformer

- Technical data:
  - » Nominal current input: 5A
  - » Nominal voltage input: 220V AC (LN) or 400V AC (L-L)
  - » Trip mentoring interface through a communication port
  - » Directional characteristic angle: 15deg, 27deg, 38deg, 49deg, 61deg, 72deg, 83deg
  - » Selectable protective functions between:
  - » Definite time overcurrent relay
  - » Inverse time overcurrent relay:
  - » Selectable inverse time characteristics:
  - » Normal Inverse (type A)
  - » Very Inverse (type B)
  - » Extremely Inverse (type C)
  - » Setting for I>: 0.2...4.0 x In
  - » Setting for tI>:
    - 0.03 - 260 s (definite time
    - 0.05 - 10 (inverse time)
  - » Setting for I>>: 1...40 x In
  - » Setting for tIE>>: 0.03...2 s Directional feature for application requiring doubly-fed lines.
  - » Number of output relay contacts:
    - Relay contact type: changeover contact
  - » Signal overcurrent (I>): 31, 32, 34 and 41, 42, 44
  - » Signal Short Circuit Tripping (I>>): 51, and 52, 54
  - » Signal self-supervision 71, 72, 74
  - » Maximum breaking capacity: ohmic 1250 VA @250VAC or 120 W @ 24VDC
  - » Trip mentoring interface through a communication port

Experiments

- Determining impedance characteristic and propagation characteristic for a transmission line.
- Effect of line impedance on receiving end voltage
- Relation between load power factor and line currents
- Relation between line voltage drop and load power factor Using regulating transformer to compensate voltage drop on receiving end of T.L
- Ferranti effect phenomena due to lightly

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loaded/ un-loaded transmission line ends Leakage current phenomena due to stray capacitance along transmission line
- Dividing power between parallel transmission lines
- Protecting isolated network against earth faults Protecting loads from over-voltage conditions
- Protecting transformers against overloading conditions
- Phase shift transformer for balancing active power
- Coordinating between directional and overcurrent relays to protect feeders Monitoring protection relays and power flow from source to load (including cable power losses) using SCADA

Scope of Delivery

- Smart Grid HV Transformers & Transmission Line Training System (SG101).
- Hard copy user manual.

Options

- Digital content (BI01)
- Smart Grid Electrical Power Generation (SG100)

Required for Operation

- Machine & Drive Lab Supply Unit(ML100)

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