TERCO

PST 2200
Power System Simulator Laboratory

Contents

Guarantee & Terms

The Guarantee is valid 24 months from delivery.

The guarantee covers repair or exchange of defective parts, due to faulty design or workmanship at our factory.

Detailed conditions of guarantee are specified in our Terms of Guarantee.

All overseas deliveries are shipped in special, made-to-order wooden crates, extremely sturdy and damage-resistant.

Sets of spare parts for 2–3 years of normal operation are included in the modules, wherever necessary. The regular after sales service is performed by the worldwide network of Terco representatives, with the advice and support of our engineers.

TERCO IS ISO 9001 CERTIFIED

Terco reserves the right to make changes in the design and modifications or improvements of the products at any time without incurring any obligations

INTRODUCTION

Today, simulation plays an important roll in training people in various fields.

With a simulator you can train people to make correct decisions under various operating conditions. Moreover, you can demonstrate effects which earlier have been covered in theory only. You have two main simulator models: hardware and software.

The Terco Power System Simulator is a hardware simulator for hands-on training and has been designed for practical training of power engineers and technicians in realistic conditions, close-to-life situations and in a genuine environment.

A variety of training schemes are available for:
- power management staff
- operators of power plants and substations
- maintenance personnel
- teaching of students
- research in universities

The Terco Power System Simulator has been developed in close co-operation with ABB of Sweden – one of the leading suppliers of power facilities world-wide and the Swedish State Power Board. As a result, a real power system has been designed for educational purposes.

All the Protective Relays are constituted by the ABB RELION IED SERIES which are the same protective relays as are used in modern power installations.

IED stands for Intelligent Electronic Device and is State of the Art of protective relays. This conseqently gives the PST the unique feature to be fully compliant with the World Wide Power Industry Standard IEC 61850 in aspect of protection.

What is the main difference between TERCO Power System Simulator and an industrial power system?
Apart from scaled down size, and much lower cost, the main difference consists of three major points:

- The TERCO Power Simulator is designed to endure human errors, performed by the students during training.
- The TERCO Power Simulator includes facilities to simulate typical faults, in order to drill the students in resolute and correct reactions.
- The TERCO Power Simulator enables the students to survey both functions and malfunctions in a complete power system, from generation to utilisation.

The TERCO Simulator is successfully used for training and education in universities and power companies in 20 different countries throughout the world. The rich experience and know-how earned by us and our customers is now at your disposal.

The Equipment
A Terco Standard Simulator is based on five modules:

- PST 2210 Power Plant Module
- PST 2220 Transmission Line & Distribution Module
- PST 2230 Receiving Substation Module
- PST 2240 Load Module
- PST 2250 SCADA Module

Additional Modules
- PST 2270 Mobile Turbine - Generator Module
- PST 2280 Power Factor Controller

All modules are equipedd with wheels for easy moving and flexible set-ups

All modules can be bought and operated individually (except PST 2250) and completed later with further modules.
The Simulator is equipped with high technology state of the art protective relays from ABB.

The Terco Standard Power System Simulator comprises 4 metallic frame works. Each frame holds 2 or 3 rows of 19 inch racks. The size and design of the frames is made to meet modern ergonomical requirements, and it corresponds to modern industrial design.

Easy service access to inner components and wiring is gained via lockable doors, conveniently located at the rear of each unit. Since 1890 almost all electric power and energy is produced by 3-phase synchronous generators. The generators are driven by turbines, which are powered by different sources:

Hydro Power, Thermal Power, Diesel- and Gas Turbine Power, Wind Power or Nuclear Power.

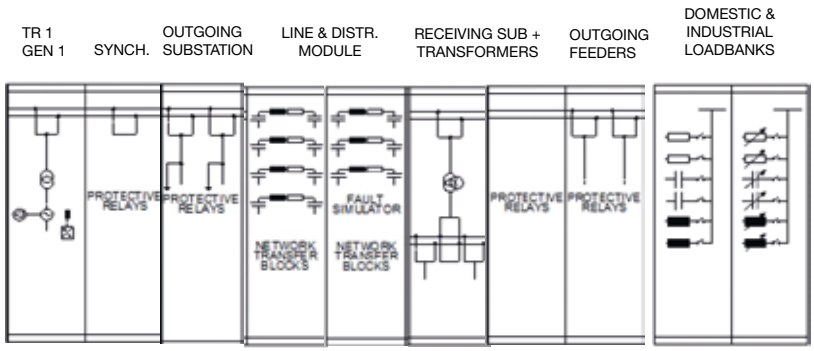
In the Terco Power System Simulator PST 2200, turbine simulation is actuated by a DC-motor and the generator by a small-size synchronous generator which can be delivered with either cylindrical rotor or salient pole rotor.

Two or more turbine generator sections can be delivered as option.

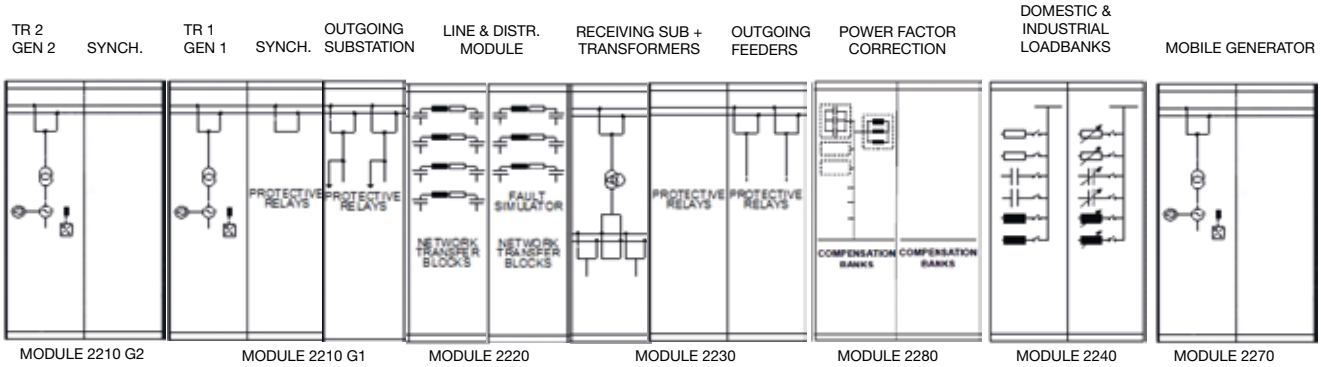
GENERAL INFORMATION

The picture above shows a complete standard Power System Simulator with turbine-generator, power plant section, transmission lines, receiving substation and the load module incl. an induction motor with flywheel.

Lay out of the PST 2200 in the picture



Lay-out of the extended PST 2200



STANDARD CONFIGURATION

PST 2210
POWER PLANT MODULE WITH HIGH VOLTAGE BUSBARS AND OUTGOING LINES.

Switchboard for the Power Plant Simulator including turbine + synchronous generator, rectifiers, instruments, synchronizing- and phasing devices, step-up transformer, current- and voltage transformers, protective relays, indications. A-B-busbars, two outgoing lines (including protective relays, instruments and corresponding switchboard). Two or more turbine-generator sections can be delivered as option.

PST 2220
TRANSMISSION LINES & DISTRIBUTION MODULE

Seven different artificial 3-phase transmission lines with possibilities to change and combine impedance elements to constitute other OH HV-levels as well as cable models for distribution.
All models have coils, capacitors and resistors designed to withstand overload and surges for dynamic as well as static experiments.

PST 2230

RECEIVING SUBSTATION MODULE WITH HIGH VOLTAGE SIDE

Receiving substation with two incoming lines and two outgoing lines including a complete switchboard with instruments and corresponding protective relays. One step-down transformer including protective relays together with the corresponding transformer. Three or more incoming lines, and three or more outgoing lines can be delivered as option.

PST 2240
LOAD MODULE

Load unit with single-phase and three-phase combinations of resistive, inductive and capacitive loads to simulate industrial as well as domestic loads of symmetrical as well as non-symmetrical types. An induction motor with a flywheel is also included.

GENERAL

Necessary switches, instruments, and over-load protections are included. On each module current and voltage transformers as well as protective relay blocks are primarily connected by jumpers. Protective relays etc. may also be tested together with external equipment.

Transmission line impedance elements can be connected in various combinations in order to simulate diverse transmissionlink charactaristics, suitable for testing different protection settings. The possibility of configuring the impedance map structure is very useful when programming the distance protection.

PROTECTION

All the Protective Relays are constituted by the ABB RELION IED SERIES which are the same protective relays as are used in modern power installations.

IED stands for Intelligent Electronic Device and is State of the Art of protective relays. This conseqently gives the PST the unique feature to be fully compliant with the World Wide Power Industry Standard IEC 61850 in aspect of protection.

All protective relays are easily accessible from the control desk where, in addition to providing indications and tripping connections, settings can easliy be made. State of the art multiple zone distance protection can be installed as option on one of the outgoing HV-lines of the HV-substation.

EXPERIMENTS

The protective relays may also be tested in combination with individually chosen line models and loads to provide experiment groups that do not interfere with other experiments on protective relays on the remaining main modules.

Essential measuring tranformers are accessable via outlets on the front junction plate.

PST 2210 POWER PLANT MODULE

PST 2210, The Power Plant Simulator is a standard version IED level 2 with one turbine generator section equipped with protective relays and step-up transformer.

Power generation is represented by a three-phase 1.2 kVA synchronous generator driven by a separately excitated 2.0 kW DC motor as turbine.

The turbine / generator can be manually set for different kW / Hz characteristics.

The operation mode of the turbine / generator can be chosen between manual or automatic control regarding power (frequency) and reactive power (voltage).

Digital Instruments (see instrument description on page 10)

- Three phase instruments
- Volt meters for A- and B- busbar with switches for selecting measurements at different points
- Armature (stator) current
- Armature voltage
- Field current
- Revolutions per minute
- Rotor current for turbine / DC-motor

Generator

The reactance is referred to the nominal values of U and I. The generator can be chosen to have the nominal power 1.2 kVA (standard) or 2.0 kVA as optional.
Both types are designed to have parameters to simulate the real size generators.

The 1.2 kVA generator can be delivered with cylindrical rotor (standard) or with salient poles (optional).

The field controller is a static rectifier, in which settings can be optimised during the tests.
This can be used for automatic or manual control.

More generator data on page 20.

Transformer

A 2 kVA transformer is used as a step-up transformer. The ratio is 1:√3. It is wound to withstand voltage surges without saturation (thus tripping the differential protection). Built-in external impedance elements can be added to simulate different sizes / impedances of the transformer.

The transformer can be given a rating of 50% or 100% by external resistive / inductive impedance elements, which are connected by contactor relay operation from the control-desk. Tappings on the secondary side of the transformer make it possible to change the voltage +/- 5 %.

The step-up main transformer supplies a double-bus system to the outgoing HV-substation.

The transformer has its windings accessible externally on the front panel. This makes it possible to perform tests like no-load and short-circuit test on the transformer separately. Primary as well as secondary voltages and currents can be read on instruments.

Relay Protection for PST 2210/2230

Based on selection of ABB Relion IED Series of relays Terco offers 3 different levels of protection:

- IED Level 1, Basic
- IED Level 2, Standard
- IED Level 3, Advanced

For further information please check page 20

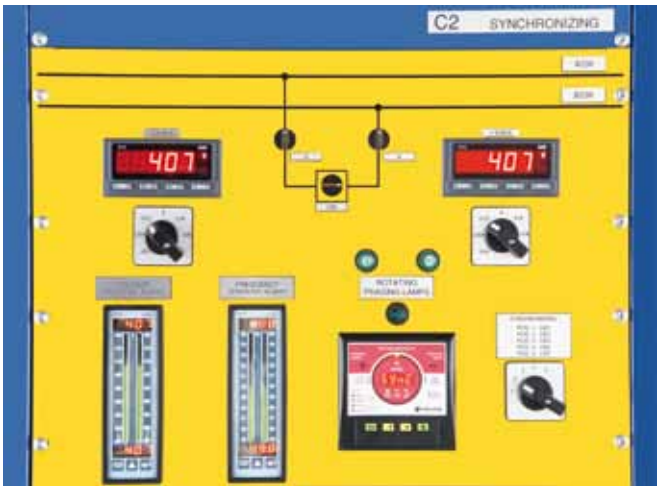
HV Busbars

The HV busbars comprise an A-B system with interconnections for load transfer.

All breaker functions are operated by contactor relays.

The busbars are equipped with the following digital instruments (see description page 10):

- Volt meters for A- and B- busbar with switches for selecting measurements at different points
- Synchroscope and Bargraphs (voltage and frequency) for synchronizing purposes between multiple lines/operators
- Three phase instruments



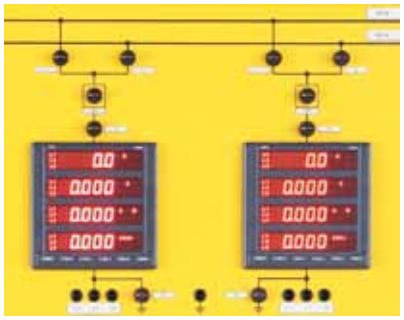
Synchronising panel of the Power Plant Module.

HV Outgoing Substation

The HV outgoing substation comprises two outgoing lines which can be connected to a radial network or a grid network depending on the connections of the transmission line module.

The HV outgoing substation is equipped with two three phase instruments (one for each busbar). See description page 10.
All switches / breakers are operated by contactor relays.
Access to L1, L2 and L3 on both busbars via 4 mm safety sockets.

Possibility to connect external equipment e.g. generator(s), loads etc.



Protections for HV Outgoing Substation IED level 2

The Protections for HV outgoing substation are constituted by:

- One Three-Phase Over Current Protection with Directional Earth Fault Protection for Line 1

- One Three-Phase Over Current Protection with Directional Earth Fault Protection for Line 2.

Available options:

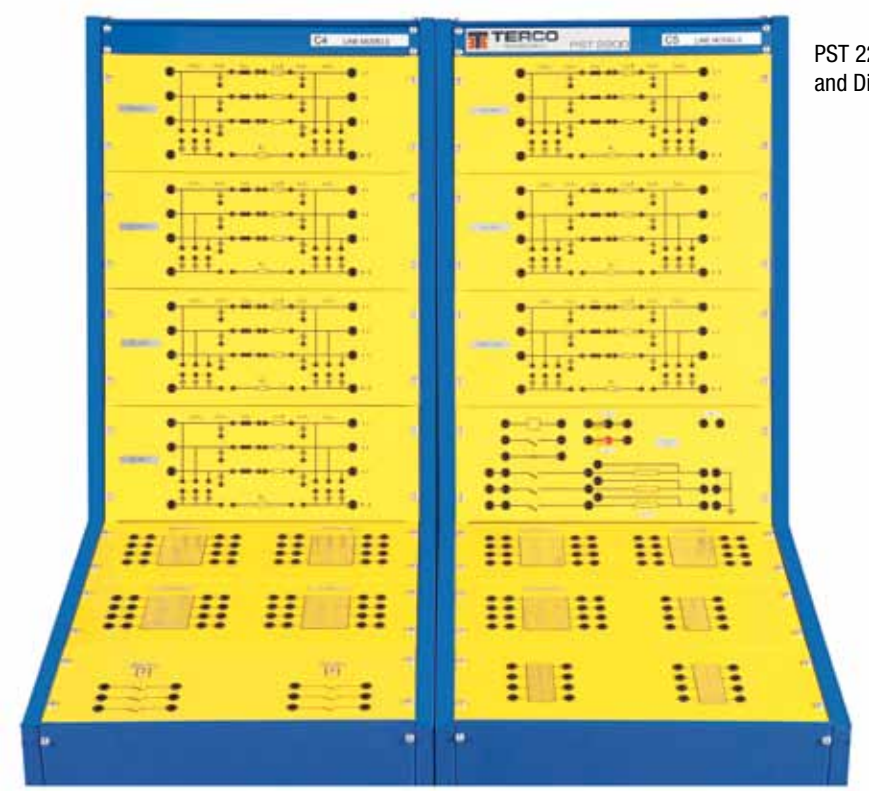
- Line Distance Protection Multiple Zon (IED level 3)

The control elements fitted are mostly of the same industrial type as those currently used in control rooms of power plants and substations.

Circuit breakers are push-button operated with lamp indications for the breaker status. Isolators are manually operated and the physical position indicates open or closed position.

Turbine Generator Set: Power is generated by a 3-ph synchronous generator driven by a separately excitated DC-motor as turbine. The electrical machines set is fully connected electrically and mounted mechanically on a machine bed.

PST 2220 TRANSMISSION LINE & DISTRIBUTION MODULE



PST 2220 Transmission Line and Distribution Module.

Type	Voltage	Transmission ability	Length
Two HV pi-links	230 kV	110 MVA	100 km
One MV pi-link	70 kV	50 MVA	50 km
Two MV pi-link	35 kV	20 MVA	20 km
One distribution OH pi-link	11 kV	5 MVA	5 km
One distribution Cable pi-link	11 kV	5 MVA	5 km

All line models (artificial transmission lines) have the same ratings in the model scale: 400 V, 2 A. This means that it is easy to compare the characteristics and typical behaviour of a high voltage, middle voltage and distribution voltage OH-line as well as a distribution cable when, for example, running at 100 % transmission ability. The transmission models are built for both static and dynamic experiments with overload / overvoltage ability.

Each artificial line model consists of a three-phase pi-link and an earth link. The models are set up on the line model board of the module where the internal connections are chosen by the means of jumpers and lab.leads. All line models are accessible not only on the line model board, but also in parallel as four + four pole blocks in the desk section to give possibilities to arrange radius, grid or mixed networks in a very simple way.

All line models also have parallel four + four pole blocks to provide easy connection to the Receiving Substation and the load banks of the Low Voltage Switchgear.
A fault simulator is also built-in as a separate panel in the Transmission Line and Distribution Module PST 2220.
It has push button operated contactor relays which together with built in resistors can be used to simulate faults of the following types:

- Three-phase short circuits
- Two-phase short circuits
- Short circuits with limited over current
- Isolation earth fault with limited current.

On the transmission lines modules, the impedance elements can be connected in different ways to design other main characteristics of other transmission links suitable e.g. to try different settings of a distance protection.

PST 2230 RECEIVING SUBSTATION MODULE

PST 2230 Receiving Substation Module above is equipped with IED level 2 protection relays with two incoming lines, HV-busbars, step down transformer, middle voltage busbar and two outgoing lines.

The Receiving Substation comprises two incoming lines, two HV-busbars, transformer, two middle voltage busbars, and two outgoing lines. Other combinations are optional.

L1, L2 and L3 are open on both middle voltage busbars via 4 mm safety sockets. It is then possible to connect PST 2230 directly to a network or to a generator as well as to external loads.
All breakers are operated by contactor relays.

Digital Instruments

Three-phase instruments are situated in five positions for measurements of:

- Incoming HV power on each busbar
- Outgoing MV power on each busbar
- Distribution of outgoing MV power on each busbar

Voltmeter instrument for measuring between busbars of incoming power. Measurement point selectable by means of a switch.

Protections (IED level 2)

- Busbar Overcurrent Protection
- Transformer Differential Protection
- HV / MV Overcurrent Protection
- Neutral Point Earth Fault Protection
- Overcurrent (three-phase) and Directional Earth Fault Protection for Outgoing Feeder 1
- Overcurrent (three-phase) and Directional Earth Fault Protection for Outgoing Feeder 2
- Available options same as for PST 2210

For more information about the Protective Relays see page 21.

Transformer

The step-down transformer is a 2 kVA Y-Y-Δ transformer with tappings 100 to 105 % on the secondary side. The Δ-winding is used as an amp-turn balance for non-symmetrical loads.

The transformer has its windings accessable externally to make it possible to perform tests like no-load and short circuit test separately.

The step down transformer can be operated individually and all the terminals are available from the desk.

The neutral points are available for investigating different methods of earthing.

Possible earthing methods are:

a) solid or resistive earth
b) insulated earth
c) Petersen coil

Current transformers are positioned around the transformer and the connections are available from the desk.

PST 2240 Load Module.

PST 2240 LOAD MODULE

3-phase loads R, L and C
controllable in 13 steps each,
manually or by SCADA.

Low Voltage Distribution

The Low Voltage Distribution is constituted by a busbar to which the substation can be connected by the outgoing lines or by one or more transmission models.

From the busbar there are 6 outgoing groups to which loads can be connected. The outgoing groups are equipped with manually operated switches or operated by PC- or remote-control.

All distribution groups are available by 4 mm safety outlets to which loads can be connected with or without external instruments.

Optional Instruments

- Voltmeter with selector switch
- Frequency meters
- Ammeters
- kWh-meters
- Module for measuring V, A, P and Q including PC-interface and software.

Load Groups

The Load Module consists of groups of single phase and three-phase industrial and domestic loads.

The loads are of resistive, capacitive, inductive and active (motor) types: Three 3-phase groups can be varied in small steps which together with the other loads will cover load possibilities from 0–150 % of nominal power.

By jumpers and switches it is possible to create single phase loads as well as other non-symmetrical loads.

One motor with flywheel is enclosed to the load module. Several motors can be added as options to make it possible to study the dynamics of the system as well as the mechanical load sharings between two or more generators. The motor together with the flywheel will constitute a suitable load for the microprocessor operated motor protection (optional) on the outgoing line of the middle-voltage substation.

The Load Module comprises

- Six resistive 1-phase load groups connectable by switches
- Six capacitive 1-phase load groups connectable by switches
- Six inductive 1-phase load groups connectable by switches
- One 13 step 3-phase resistive load bank controlled by increase/decrease switch or PC (SCADA)
- One 13 step 3-phase capacitive load bank controlled by increase/decrease switch or PC (SCADA)
- One 13 step 3-phase inductive load bank controlled by increase/decrease switch or PC (SCADA)
- One induction motor with flywheel and mechanical brake, 0.25 kW

One induction motor Dahlander with flywheel and mechanical brake, 0.25/0.12kW (optional).

Other optional machines are available on request.

THE MEASUREMENT SYSTEM

The complete PST 2200 System utilizes 19 highly advanced microprocessor-controlled measurent devices enabling effortless and comprehensive monitoring of the entire system.
All measurement transducers include a distinct display presenting the measurement in five digits. The microprocessor- based technology enables several important parameters in each unit, where 3-phase units hold a capability to visualize 20 power energy quantities divided into selectable pages (each page displaying 4-parameters at a time).
Two digital bargraphs, each with dual graphs (one for each busbar) comprises the ability to monitor essential parameters in the synchronization process.
The units perform all neccesary operations in independent enclosures, from measuring (directly without transformers etc) to presentation on the display and data acqusition. All units connected together on a databus for instrumentation (optional in SCADA applications).

Power Network Parameter Analyzer

3-phase Instruments

Three 3-phase power network parameter analyzers displaying 20 power energy quantities divided into five selectable pages (each page displaying 4-parameters at a time), featuring for instance:

- Average 3-ph voltage/current
- Visualization of non symmetrical loads
- Both phase-phase and phase-earth voltages
- Independent phase currents
- Average 3-ph active, reactive and apparent power
- Independent phase active, reactive and apparent powers
- Average 3-ph power factor
- Independent phase power factors
- Active, reactive and apparent energy

Bargraphs

Digital bargraphs, each with dual graphs (one for each busbar) comprise the ability to monitor essential parameters in synchronization purposes.

- Voltage - both busbars displayed with LED's and bargraphs (380-420VAC)
- Frequency - both busbars displayed with LED's and bargraphs (45-55Hz)
- Display levels selectable in three different colours for highlighting of significant values.

Single Parameter Analyzer

Single Parameter Analyzer

- Generated voltage
- Generated current
- Two instruments for voltages on A- and B-busbars
- Phase-phase and phase-earth by means of selector switch
- Generator speed
- DC Machine current
- Generator magnetizing

THE LOGICAL BLOCKING SYSTEM

The TERCO Logical Blocking System comprises a network of PLCs. This provides an indespensible protection/support feature by distinctly indicating and blocking forbidden maneuvres, ultimately preventing severe damage to the system. The PLC network acts as a control mechanism for the operator, regardless of operation directly on the PST or remotely from the SCADA system. The PLCs perform the following key functions:

- Keep track of allowed combinations of isolators and circuit breakers
- Gather protection trips and control suitable actions
- Control from SCADA/iFIX reflecting the real environment
- Control of DC Machine speed
- Control of generator magnetizing level
- R, L, C – independent load control (each in thirteen levels)

PST 2250 SCADA SYSTEM FOR POWER SYSTEM SIMULATOR

WHAT IS SCADA

SCADA (Supervisory Control And Data Acquisition) is the general term for a large group of computer systems with special capabilities.
SCADA systems are typically used in industrial applications to control and supervise real-time processes.

HOW DOES SCADA WORK

SCADA gives personnel the ability to closely follow and to enter data into the process. Actual measurements are presented in real time on the computer screen. The system can be controlled remotely through local networks. For the Terco SCADA system this means that any school, institute, university or industry connected to the net can maintain distance learning on the Terco PST 2200 system.

TERCO SCADA SYSTEM

TERCO SCADA System is designed to be used for the Terco Power System Simulator (PST 2200). The Terco SCADA system provides students with the opportunity to remotly control and monitor the system in a ”control room” environment. The teacher has full control, independent of student actions and can also override the student to show how to use and control the PST2200 system.

All breakers and isolators belonging to the simulated power system can be operated from the PC. Faulty operations are prevented/blocked by means of the Logical Blocking System regardless of operation made directly on the PST 2200 or from the SCADA system.

- With Terco SCADA system, synchronization can be performed from SCADA where frequencies and voltages together with synchronization pulses enable synchronization in four different points of the PST 2200 system.
- All instruments, isolators and breakers are indicated on screen even when operated from front panels. This facilitates for the teacher to study the work of the students without interferance.
- It is also possible to connect up to 16 students that can individually control the whole PST through the SCADA system.

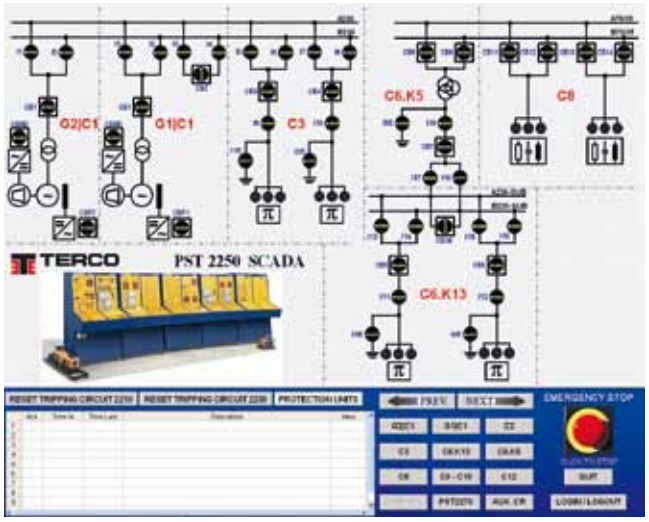
TERCO SCADA System comprises:

- Master computer using Ethernet for communicating with the PST and the PLC's together with the instruments.
- All necessary hardware for communication integrated in the PST.
- SCADA software with development possibilities for the Master computer.
- SCADA client enabler software on the Master computer for enabling clients to login to the SCADA application from Internet Explorer.
- Chosen number of clients for starting sessions with the SCADA application from remote sessions simply by means of Internet Explorer. (Number of simultaneously connected clients depends on Master computer hardware specification. Each client is enabled by a license retreaved in Master computer dongle).
- TERCO SCADA used for the operation of the PST 2200 is built up on the professional GE FANUC iFIX software which is used in power plants across the world.

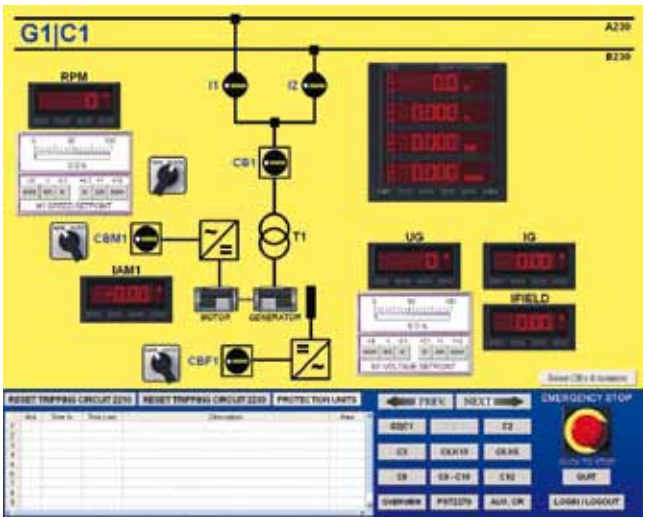
Examples of the TERCO SCADA application

The TERCO SCADA application is constituted by several control views, for instance the Power Plant View (below) where it is possible to control and monitor for example:

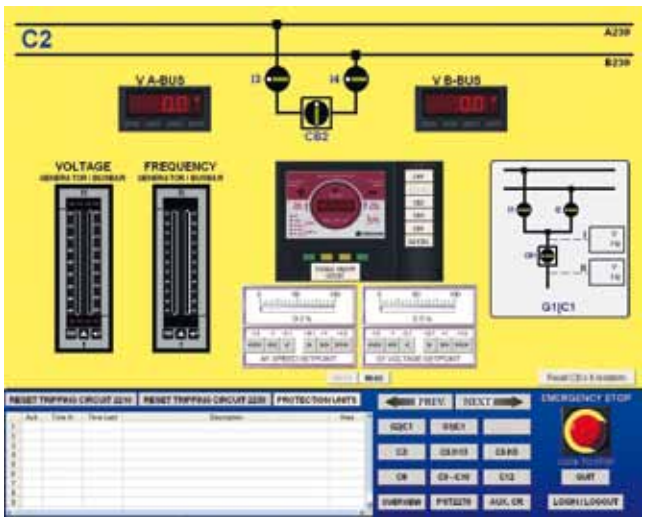
- Motor speed
- Generator voltage
- Control and status of circuit breakers
- Control and status of isolators
- Alarm indication/logging and resetting
- Single parameter instruments
- Three-phase instruments:
  Each displaying 20 parameters distributed over five pages, where current, voltage, active and reactive power in mean values as well as in phase to phase and phase to neutral which makes it possible to study for example non-symmetrical behaviour.



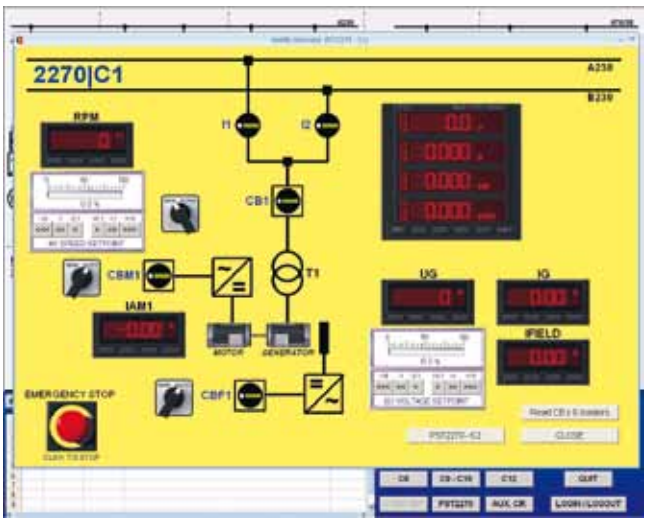
PST Overview Window



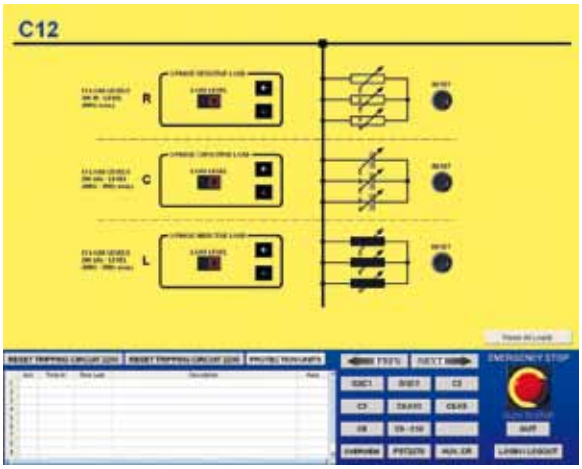
PST Generator Station Window



The Synchroscope Window integrates the view of the bargraphs for frequency and voltage together with the controls for speed/voltage setpoint and the synchroscope.



PST Mobile Generator Window



The PST Load Control Window enables the possibilty to control the three phase loads (R,L and C) independly, each in thirteen different levels.

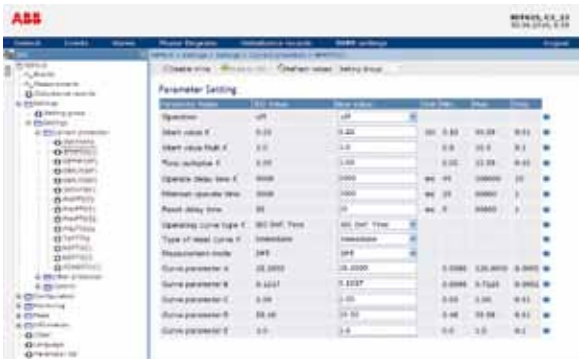
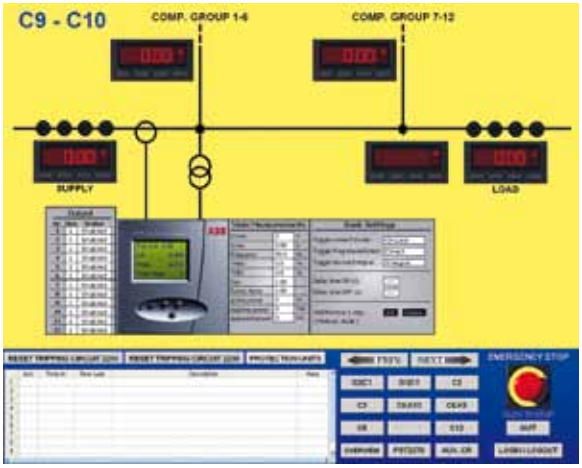
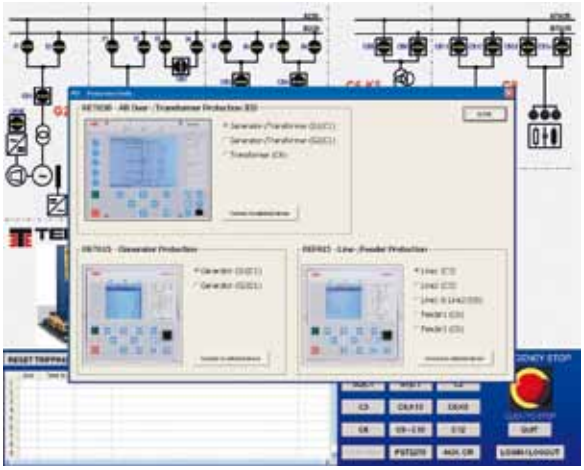


ABB Web HMI enables parameter setting/configuration of the protection units directly from the TERCO SCADA application or by means of Internet Explorer
The protection units can be addressed and configured directly from the TERCO SCADA Application by means of the implemented ABB WHMI application. Also available by means of Internet Explorer. (Example shown in picture above).



PST2280 Power Factor Controller Window including essential configurations and parameter settings of the ABB RVT module.



PST Protection Unit Window where selection of desired unit for parameter setting/configuration can be performed by means of the ABB WHMI.

Technical Specification

SCADA system is fully connected to the measuring system as well as to all PLC's within the PST system including Development Version Licence (not only run time)

Indication Modules:

- Isolator, circuit breaker and flag relays status
- Monitoring of three-phase instruments, each comprising 20 parameters such as:
  - Voltage (ph-ph, ph-N, mean ph-ph, mean ph-N)
  - Current (phase and mean enables the possibility to monitor non-symmetrical - behaviour)
  - Active, reactive and apparent power(phases and mean)
- Monitoring of all single phase instruments including generator voltage and current, generator speed,DC motor current, generator magnetizing current, voltage meters for busbars

Remotely controlled modules:

- Motor turbine speed
- Generator speed
- Synchronization
- Loads
- Circuit breakers
- Isolators
- Alarm resetting

Other features

- Replicates all PST 2200 System main module configurations
- Easily customized monitor images (visualization)
- Easily customized schematics
- Digital virtual instrumentation
- Event logging (alarm history)

Also included:

- Suitabel high specification computer with flat screen
- Colour printer
- Installation/commmissioning and basic teacher training at site by Terco Engineer.

PST 2270 MOBILE TURBINE MODULE WITH GENERATOR SET

This module includes:

- Control panel
- Turbine
- Generator
- Step-up transformer
- A-B-busbars
- Synchronizing- and phasing device
- Current and voltage transformers
- Outgoing lines.
- Power plant with the turbine simulated by a rectifier controlled DC-motor together with a synchronous generator.
- Manual or automatic control both for the frequency (=active power) and the voltage (=reactive power).
- One-line mimic diagrams together with breakers, isolators and groups of digital instruments ar ranged as in real plants.
- Indications as well as interlockings for the operation of breakers and isolators are designed as in existing plants.

Technical specifications

The Turbine / Generator / Step-up Transformer :

- DC-machine 2.0 kW, simulating turbine
- 4-pole synchronous generator, 1.2 kVA, cos phi 0.8
- Static rectifier for speed / W control
- Static rectifier for voltage / VAr control
- Step-up transformer 230 / 400 V, 2.0 kVA

Generator Data :

- Voltage : 3 x 230 V
- Nominal current : 3.5 A
- Frequency : 50 Hz / 60 Hz
- Speed : 1500 rpm / 1800 rpm
- Synchronous reactance 97 %
- Transient reactance 17 %
- Subtransient reactance 8 %

Digital Instruments
(see instrument description page 10):

- Three-phase instruments
- Armature (stator) current
- Armature voltage
- Field current
- Revolutions per minute
- Rotor current for turbine (DC-motor)
- Volt meters for A- and B- busbar with switches for selecting measurements at different points
- Synchroscope
- Bargraphs for voltage and frequency

Cubicle :
Dim.: 1045 x 1060 x 1900 mm
(corresponds in size to PST 2220)
Weight : 280 kg (approx.)

Turbine-Generator Set :
Dim.: 1500 x 300 x 500 mm
Weight : 140 kg

PST 2280 POWER FACTOR CONTROL MODULE

Power Factor Controller (PFC)

With the PFC you can minimize the currents caused by reactive losses of power, thereby optimizing the transfer of energy between generation and loading. This is becoming more and more important today when “Saving energy” is vital in a world with focus on pollution and shortage of energy.

Field of Application

Capacitive, inductive or mixed inductive and resistive networks in need of compensation, for example when starting and running induction motors or for compensating long high voltage power lines.

Principles of Operation

Depending on the power factor of the loading network a microprocessor will connect groups of capacitors.
By measuring phase voltages and current the microprocessor will calculate how many capacitor groups need to be connected and do this in accordance with user configured parameters.

Technical Specifications

Number of 3-ph groups	12 capacitive for control and 2 for inductive default setting.
Power factor setting	0.7 inductive to 0.7 capacitive
Nominal voltage	3 x 400 V 50 – 60 Hz
Nominal power	0 – 2 kVAr cap., 0 - 2 kVAr ind.
PF-Controller	Automatic or manual Adjustable delay times, switching sequences and strategies. Programmable to 12 steps
Monitoring and Measurement	Voltage Current Power factor
Switching modes	Linear and circular
Indication lamps	For the capacitor groups. For default of inductive load compensating banks.

Power supply	1-ph 220 - 240 V AC, 50 - 60 Hz (internally supplied)
Dimensions WxHxD	1045x1800x1060 mm (corresponds in size to PST 2220
Weight	210 kg

Typical Experiments:

- The concept of active power, apparent power and reactive power
- The concept of power factor and “cos ”
- The concept of measuring methods
- Start current settings (C/k)
- Delay times
- Efficiency and losses
- Linear and circular switching modes
- PF-Controller design and schematics
- Configuring the controller
- PF-Controller and resistive/inductive loads
- PF-Controller and induction motor loads
- Control range limits

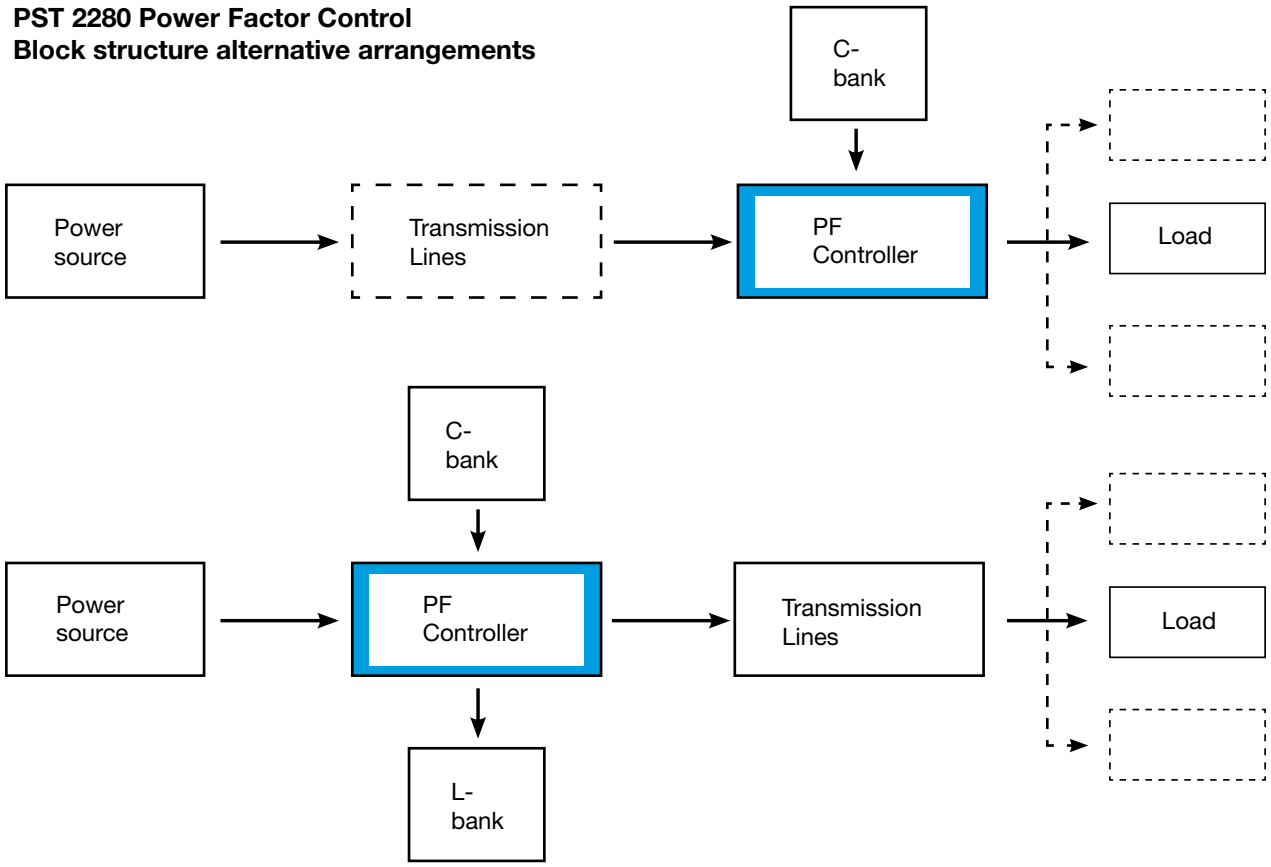
Physical Design

ThePFCismadetoworktogetherwiththeTercoPST2200PowerSimulatorSystembutcanalsobeusedasastandaloneunit.

The PFC is hosed in a PST double cabinet with a clear mimic diagram explaining how to connect the supplying net to the network in need of power factor compensation. Lamps on the front panel indicate which contactor relay is in operation together with the corresponding reactive load bank.

Measured values, parameters and sub-parameters are indicated on the front of the control unit, which can easily be configured to achieve the desired switching behaviour. Contactor relay combinations may be programmed on a terminal board to simulate the methods of optimising the life time for circuit breakers in reality. The electronically displayed quantities are also indicated by classic analogue instruments regarding power factor, voltage and currents.

PST 2280 Power Factor Control
Block structure alternative arrangements



MV 1305 MOBILE MOTOR / GENERATOR UNIT

A standard laboratory for power transmission normally consists of one or two generators, connected to one or more transmission links which finally reach transformers, distribution units and loads.
Energy transfer, load shedding, static and dynamic stability as well as sophisticated protection schemes can be studied under realistic forms. Not to forget compensation possibilities.
Power- and current- paths in grid networks are complicated. The TERCO system will give understanding for these problems.
The mobile generator station / synchronous alternator (compensator) MV 1305 provides a flexible solution for mobile power generation simulation.
The MV 1305 can operate as described or work in parallel with the Power System Simulator PST 2200. In this case mechanical and electrical parameters might be changed by using e.g. flywheel (MV 1010) and different electrical connections.

Technical Specification MV 1305-405

Power Supply	Voltage 380-415 V AC 3-ph	
	Frequency	50 Hz *)
	Max current	16 A
Turbine/DC-machine	Armature Volt	0-240 V DC
	Field Volt	190 V DC
	Armature current	12 A
	Field current	0.8 A
	Power	2.0 kW
	Speed	0-1800 rpm
Synchronous generator	Armature volt 0-240 / 415 V AC	
	Power	1.2 kVA
	Cos φ	0.8
	Field volt	0-230 V DC
	Speed	0-1800 rpm
Speed control/ Active power control	SCR-converter, electronic current limit setting, start- and stop ramps.	
Feedback systems	Manual frequency setting Automatic/Constant setting	
Field current supply	Integrated	
Voltage control/ Reactive power control	PWM min. ripple-converter, electronic current limit setting	
Feedback systems	Manual voltage setting Automatic/Constant setting Separate voltage feedback	
Dimensions	1550 x 800 x 1200 mm	
Weight	200 kg (approx.)	

***)MV 1305-406 for 60 Hz**

Modes of Operation

A. Control of active power (frequency): DC-machine (”turbine”) + synchronous machine (generator) in closed loop connection regarding frequency.
B. Control of active power (frequency) and reactive power (voltage): Two closed loops regarding frequency and voltage.
C. Synchronous compensating: DC-machine (”turbine”) idling, electrically disconnected or mechanically disconnected, synchronous machine in closed loop connection for voltage (=reactive power) control.

Instruments:

DC-machine:
(Turbine simulator)

Armature voltage
Armature current
Indication lamp for field voltage
Speed control potentiometer (=frequency control)
Control method selector

AC-machine:

Armature voltage
Voltage selector switch
Armature current
Voltage control potentiometer
Control method selector
Field current ammeter

Synchronizing devices:

Synchronizing instrument
Double voltmeter
Double frequency meter
Synchronizing switch

MV 1010 Flywheel

The flywheel is dynamically balanced and has a protective casing with 2 couplings.
Moment of inertia:
J = 0.406 kgm2.
Dim: 400 x 300 x 300 mm
Weight: 56 kg

8785 ACCESSORIES

MV 1100 Load Resistor

3-phase 3.3 kW, continuously adjustable.

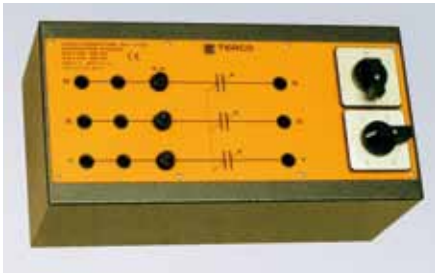
Star connection	400 / 230 V 0.8-5 A
Star connection	230 / 133 V 0.5-5 A
Delta connection	400 / 230 V 2.4-8.7 A
Delta connection	230 / 133 V 1.3-8.7 A
DC parallel connection	220 V 2.3-15 A
Dimensions	630 x 250 x 890 mm
Weight	46 kg

MV 1100-235 Cooling fan supply 230 V AC 50 - 60 Hz
MV 1100-116 Cooling fan supply 110 V AC 60 Hz

MV 1101 Load Reactor

2.5 kVAr, 50-60 Hz. 12 step regulation.

V	Connection	Hz	A
230	star	50	0.2-2.2
230	delta	50	0.6-6.6
400	star	50	0.4-3.8
230	star	60	0.2-1.9
230	delta	60	0.5-5.6
400	star	60	0.3-3.3
Dimensions		510 x 220 x 320 mm	
Weight		40 kg	



MV 1102 Load Capacitor

2.8 kVAr at 50 Hz, 3.3 kVAr at 60 Hz. 6 step regulation.

V	Connection	Hz	A
230	star	50	0.4-2.4
230	delta	50	1.2-7.2
400	star	50	0.7-4.2
230	III	50	2.1-12.6
230	star	60	0.5-2.8
230	delta	60	1.4-8.6
400	star	60	0.8-5.0
230	III	60	2.5-15
Dimensions		185 x 370 x 170 mm	
Weight		7 kg	

MV 1429 Terminal Board

The connection box is equipped with miniature circuit breakers for 20 A.

Dimensions	250 x 240 x 75 mm
Weight	2 kg

MV 1103 Variable Transformer 3-phase

Input	3 x 400 V, 8 A, 50-60 Hz
Output	3 x 0-450 V, 8 A
Dimensions	490 x 275 350 mm
Weight	36.5 kg

MV 1427 Relay Tester

Range of application

Testing of current, voltage, time and power-relays.

Start-up operations where variable current and voltage are required.

Testing of current transformers, ratio tests and plotting of magnetisation curves.

In electrical and measuring departments or in laboratories and technical schools.

Dimensions	280 x 178 x 178 + 63 mm
Weight	15 kg

LABORATORY LAYOUT

The layout is a significant factor to consider when designing a functional laboratory. It is of great importance that equipment and furniture are taken into account early in the planning stage. A preliminary solution for planning a Power System Laboratory for approx. 16 students can be seen below. If the space of the laboratory has been determined already, the standard solution may not be applicable.
Our engineers will be pleased to advise on any individual requirements.
See also our brochures ”Power Distribution System and Furniture for Laboratories” and "Transmission Line, Transformer and Protection Laboratory".

Suggested Laboratory Size: 10 x 10 m^2

1. Power System Simulator PST 2200 - two generators
2. Power Factor Controller PST 2280
3. SCADA PST 2250
4. Universal Relay Trainer MV 1431 with accessories
5. Distance Relay Trainer MV 1434 with accessories
6. Differential Relay Trainer MV 1435 with accessories
7. Line Models
8. Transformers
9. Different loads

Installation and Training

The complete Power System Simulator is normally supplied on turn-key basis with installation, commissioning and on-site training to be performed by Terco engineers.

Further training can be arranged on request in Sweden or on site, subject to a separate agreement.

Individual items specified in this catalogue, can also be delivered on request.

It is our belief that a good result in training power people is only achieved by well trained teachers / instructors, good curricula with sufficient time for hands-on training and relevant equipment.

TECHNICAL INFORMATION

Supply voltage:
3-phase 380 - 415 / 220 - 240 V, 16A, 50 & 60 Hz
Other supply voltages available on request.

Standards
All Protective Relay Units included in the Terco Power System Simulator are fully compliant to IEC 61850 standard.

The Turbine / Generator / Step-up Transformer

- DC-machine 2.0 kW, simulating turbine
- 4-pole synchronous generator, 1.2 kVA, cos phi 0.8
- Static rectifier for speed / W control
- Static rectifier for voltage / VAr control
- Step-up transformer 230 / 400 V, 2.0 kVA

Generator Data

Voltage	3 x 230 V
Nominal current	3.5 A
Frequency	50 Hz/60Hz
Speed	1500 rpm / 1800 rpm
Synchronous reactance	97 %
Transient reactance	17 %
Subtransient reactance	8 %

Transmission Line Data

Type	Voltage	Transmission ability	Length
Two HV pi-links	230 kV	110 MVA	100 km
One MV pi-link	70 kV	50 MVA	50 km
Two MV pi-link	35 kV	20 MVA	20 km
One distribution OH pi-link	11 kV	5 MVA	5 km
One distribution Cable pi-link	11 kV	5 MVA	5 km

Load Module data

Resistive	6x200 W
Capacitive	6x200 VAr
Inductive	6x200 VAr

3-phase Loadbanks

Resistive	2x3-ph 0–900 W
Capacitive	2x3-ph 0–900 VAr
Inductive	2x3-ph 0–900 VAr

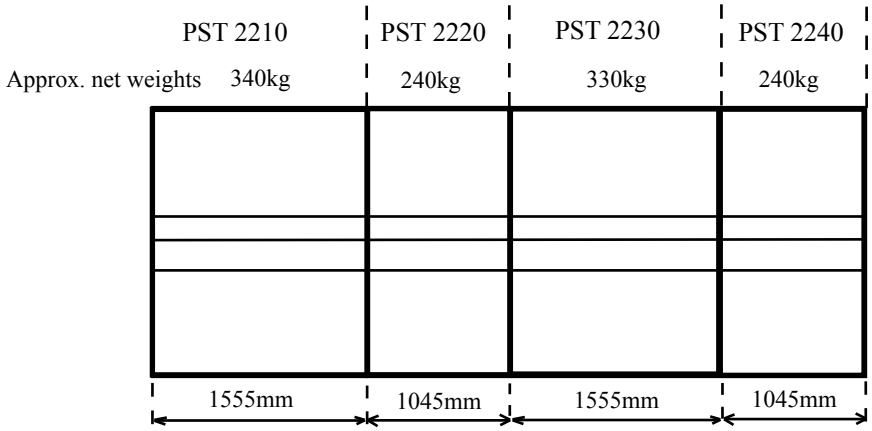
- One induction motor with flywheel and mechanical brake 0.25 kW

Optional

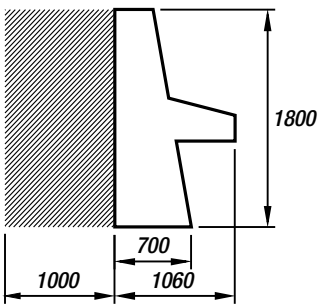
- One induction motor Dahlander with flywheel and mechanical brake 0.25 / 0.12 kW

Weights and Dimensions

Each rack is delivered with a PVC-coated polyester fabric.



Turbine-Generator set: dim 1500 x 300 x 400 mm, netweight 130 kg



PROTECTIVE RELAYS - HOW TO ORDER

Power Plant Module PST 2210
IED Level 1
- All Over Differential Protection
- Generator /HV O/C Protection
- Voltage Protection
- Frequency Protection

IED Level 2
Same as level 1 but also including:
- Three-phase O/C and Directional Earth Fault Protection Line 1
- Three-phase O/C and Directional Earth Fault Protection Line 2

IED Level 3
Same as IED Level 2 but also including:
- Differential Generator Protection
- Rotor Earth Fault Protection
- 95% Stator Earth Fault Protection

Receiving Substation Module PST 2230
IED Level 1
- Transformer Differential Protection
- Voltage Protection
- Frequency Protection
- Neutral Point Earth Fault Protection
- HV / MV Over Current Protection

IED Level 2
Same as Level 1 but also including:
- Busbar Over Current Protection
- Three-phase O/C and Directional Earth Fault Protection Feeder 1
- Three-phase O/C and Directional Earth Fault Protection Feeder 2

IED Level 3
Same as Level 2 but also including:
Line Distance Protection, Multiple Zone Protection with individual settings. The distance protection can be programmed for different HV-levels and characteristics and operates for three-phase short circuits, fault R-S, S-T, T-R, R-earth, S-earth, T-earth and with underimpedance start. There are separate time settings for each zone.

Each or all zones can be programmed for sensing in forward or reverse direction.

Protection of PST Module 2220, 2240, 2270 and 2280 can be equipped independently of each other.

State of the art protections

based on **ABB RELION SERIES** compliant to IEC 61850 standard

ABB IED Protection provides you with a future-proof concept based on application flexibility, which makes them an excellent choice. The integration of the main protection and a wide range of back-up protection functions within these IEDs improve your power system performance. It also reduces engineering and installation time as well as space and spare parts requirements.

ABB REF 615 Line Feeder Protection Relay

Terco reserves the right to make changes in the design and modifications or improvements of the products at any time without incurring any obligations

SOME OF THE WORLDWIDE PST 2200 INSTALLATIONS

LIST OF SOME EXPERIMENTS

Under normal conditions:

- Setting of field control parameters, setting of turbine control rectifier parameters, setting of start- and stop ramps (=intake gate opening and closing).
- Checking AC-supply, DC supply, alarm indications, acknowledge and cancelling procedures, status indications of isolators and breakers. Start order.
- All performance diagrams of the generator can be studied.
- Vector group of system transformer is checked together with no load tests and short circuit tests for both step-up- and substation transformers.
- Differential relays can be tested by resistive faults or trim faults caused inside the protective zones.
- Load distribution can be varied using auxiliary transformers to keep the currents within certain limits. This can also be studied by use of parallel lines where the line parameters are different. (Arranged for example by connectors in the transmission module).
- Generator performance under steady state and dynamic conditions can be studied for different types of loads.
- Difference between manual and automatic control of voltage = reactive power control.
- Difference between manual and automatic control of speed = active power control.
- Rapidity of field control v.s. stability. Optimizing gain and time constants of voltage and current controllers.
- Feedback systems.
- Voltage differences, frequency differences, phase difference, timing, instruments, blockings (synchronising).
- The dynamic characteristics of the controller can be examined.
- All protective relays can be tested separately with or without load by a built-in 18-pole terminal (test unit) which will make individual testing of each protection possible, also when the complete simulator is under normal operation.
- Characteristics of overcurrent and underimpedance starting elements can be obtained by means of loads and system feed provided underimpedance protection is included.
- Impedance maps can be calculated easily to give informa tion for an optimised selectivity plan of protection.
- By means of a ring main feed from one end various methods of protection can be studied, e.g. employing directional overcurrent relays or non-directional relays with instantaneous opening of the main grid.
- The tripping characteristics of a modified impedance relay can be determined by experiment (optional choice).

Under fault conditions:

- The reactances and time constant of the synchronous generator are of decisive importance for its transient behaviour. This can easily be studied in several ways. Also symmetrical and asymmetrical faults can be studied.
- Different types of system earthing methods can be studied: isolated, high resistance, low resistance and Petersen coil.
- Connecting the infinite busbar system in different parts of the network. Influence on fault currents and short circuit currents.
- Influence on fault currents and short circuit currents and relay protections. Settings of relays. Selectivity.
- Transient behaviour of generator can be shown when it is not correctly synchronized with the system.
- Single-phase and three-phase fault interruptions can be demonstrated for different lengths of transmission lines and different values of power transmitted.
- The generator protection scheme is checked under conditions of deliberate maloperation of the generator and especially introduced faults.
- Signalling, indications warnings, trippings, actions in the fault annunciator system.
- Regional fault in a small industrial area and / or domestic living area. A fault is simulated somewhere in the load module and the protection on a feeder from outgoing lines would trip. The fault has to be located, reset and indicated. The energy supply would then normally be transferred back.
- Fault simulation in a section of a medium size city. A fault is simulated somewhere in the substation or on the outgoing lines. The protection relays for the incoming line or transformer or busbar would then trip. The fault has to be located, the relays reset and indicated. The energy supply would then normally be transferred back.
- Fault in a medium city region. A fault is simulated somewhere in the power plant module on the HV side or on the outgoing lines from the power plant. The protection relays for the line should be tripping. Even the protection for the generator may be able to trip. The fault has to be located, the relays reset and indicated. The energy supply would then normaly be transferred back.

- Fault in a region of a country. A fault is simulated somewhere in a part of a country implicating nationwide consequences. Everything is to be disconnected : Generator 1, (possibly Generator 2), infinite bus and other possible sources. A load shedding scheme is to be performed. The fault(s) have to be found and isolated. The generator(s) need to be started, synchronized and connected. Load sharing is to be studied carefully. The energy supply would then normally be transferred back.
- Overcurrent and under-voltage relays for motor protection operating in conjunction with the system relays can also be studied.

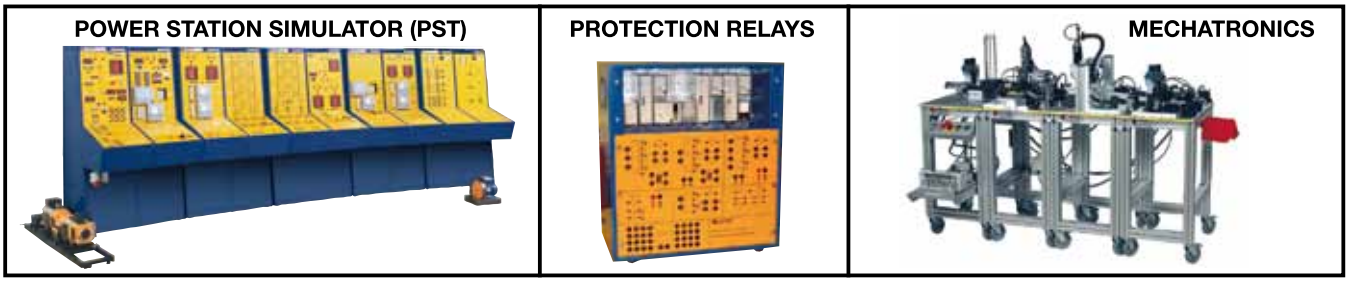
The preceeding experiments are merely a selection from an extensive list of possible experiments.

Protective Relay Functions

- Overcurrent protection
- Overcurrent protection with time lag characteristics relays
- Over and under voltage protections
- Neutral point protection
- Independent time characteristics
- Negative sequential over current protection
- Earth fault protection
- Directional earth fault protection
- Differential protections
- Design principles
- Frequency protection
- A typical feeder protection.

Terco Headoffice

Terco headoffice and factory outside Stockholm, Sweden.



TERCO AB
P.O. Box 5014
SE-141 05 HUDDINGE
SWEDEN

Office/Works: Pyramidbacken 6
SE-141 75 Kungens Kurva
STOCKHOLM

Phone: +46 8 506 855 00
Fax +46 8 506 855 01
e-mail export@terco.se
www.terco.se

worlddidac member

DNV SS-EN ISO 9001

2011.02/2.000/ Östertälje Tryckeri AB, Södertälje