TERCO

PST 2200
Power System Simulator Laboratory

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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.

The Terco Power System Simulator has been designed for practical training of power engineers and technicians in realistic conditions, close to life situations in genuine environment.
A variety of training schemes 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 supplied by ABB and are the same as used in real power installations.

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 prepared to stand human errors, performed by the students during the training.
- The TERCO Power Simulator includes facilities to produce simulated 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 2260 HV-DC Module
- PST 2270 Mobile Turbine - Generator Module
- PST 2280 Power Factor Controller

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 Power System Simulator comprises 5 metallic frame works.
Each frame holds 2 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.

From the rear side of the frames there is full access to the wiring and the components for easy service via lockable doors.

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 or Wind Power.

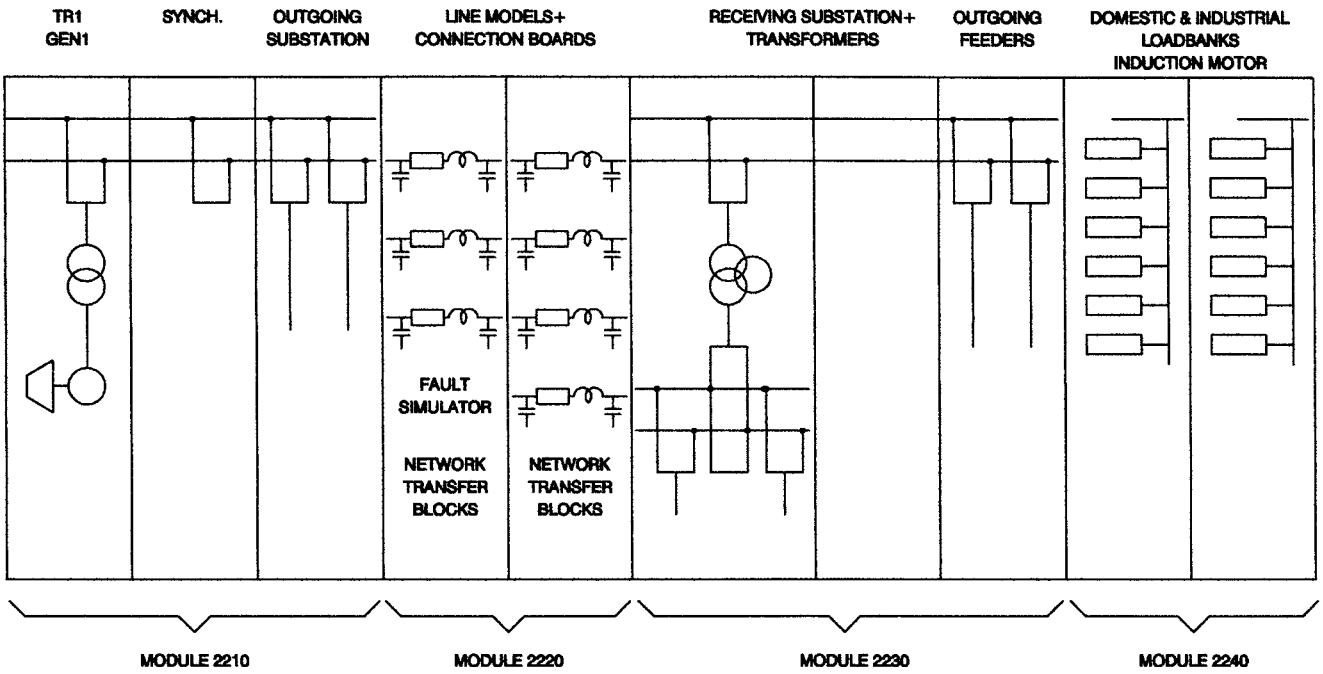
In the Terco Power System Simulator PST 2200 the turbine is simulated by a DC-motor and the generator is a small size real synchronous generator and can be delivered either with cylindrical rotor or salient pole rotor.

GENERAL INFORMATION

The picture above shows a complete standard Power System Simulator level 3 with turbine-generator, power plant section, transmission lines, receiving substation and the load module incl. an induction motor with flywheel.

TERCO POWER SYSTEM SIMULATOR

Standard configuration.



General lay-out of the standard Power System Simulator of 4 Modules

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, synchronising- 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 connected mainly by jumpers. Protective relays etc. may be tested also together with external equipment.

On the transmission lines, the impedance elements can be connected in different ways to design other main characteristics of other transmission links suitable to try different settings of the protections. This possibility of changing the structure of the impedance map is very useful when programming the distance protection.

PROTECTION

Full generator and transformer protection is provided for the simulated power plant and system protection for the artificial lines, when ordering level 2 or level 3 (see page 14).

All protective relays are easily accessible from the control desk where settings can be done easily as well as indications and tripping connections. All protections can be tried individually without interfering with the in-operation simulator because of the test blocks into which test handles can be put. (CT´s are automatically short circuited).
All modules / function blocks in the protective relays can easily be disassembled from the front.
All protective relays are of electronic type (Static and Numerical).

Any protective relay can be exchanged, combined or completed with other relays or relay functions because of the COMBIFLEX connection system. A micro-processor operated 1 + 4 zone distance protection relay can be installed as option on one of the outgoing HV-lines of the HV-substation.

EXPERIMENTS

Experiments may be performed on the complete set-up of modules, or any of the four main modules individually.
By using an external relay tester e.g. MV 1427 (optional) each protective relay can be tested individually.

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.

Most protective relays are operated from individual set-ups of voltage- and current transformers included with terminals accessible from the control pulpit.

PST 2210, The Power Plant Simulator above is a standard version level 3 with one turbine-generator section fully equipped with all protective relays and step-up transformer.

PST 2210 POWER PLANT MODULE

The 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

- 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 2.0 kVA generator has salient poles.

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

More generator data on page 13.

Transformer

A 2 kVA transformer is used as a step-up transformer. The ratio is 1:$\sqrt{3}$. It is wound to withstand voltage surges without saturation (and 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 a contactor relay operation from the control-desk. Tappings on the secondary side of the transformer will make it possible to change the voltage +/- 5 %.

The step-up main transformer is supplying 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 test and short-circuit test on the transformer separately.
Primary as well as secondary voltages and currents can be read on instruments.

Relay Protections for Generator and Transformer

The Electronic Relay Protections for turbine / generator / step-up transformer comprises as a standard the following facilities:

- Differential protection for the generator
- All-over differential relay for generator-transformer
- Three-phase overcurrent relay for the generator
- Over voltage relay
- Rotor Earth-fault relay of injection type
- 95% Stator Earth-fault relay

Optional protection:
- Reverse power relay for the generator
- Negative-sequence protection relay
- Thermal overload relay for the generator

All protections can be connected to 4 mm outlets via a testhandle.

All necessary current transformers are included and the terminals are available from the desk.

More information about protective relays on page 14.

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 instruments:

- Digital volt- and ammeters.
- Digital active and reactive power meters.
- Digital voltmeters for all phases (synch).
- Synchronising instruments including synchronoscope
- Voltage selector switches.

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 the following instruments:

- Digital volt-, ampere- and power meters (P and Q) for both lines
- Voltage selector switches

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.

Electronic Relay Protections for HV outgoing Substation

The Electronic Relay Protections for HV outgoing substation are constituted by:

- One three-phase over current relay with directional earth fault protection for Line 1
- One three-phase over current relay with directional earth fault protection for Line 2.

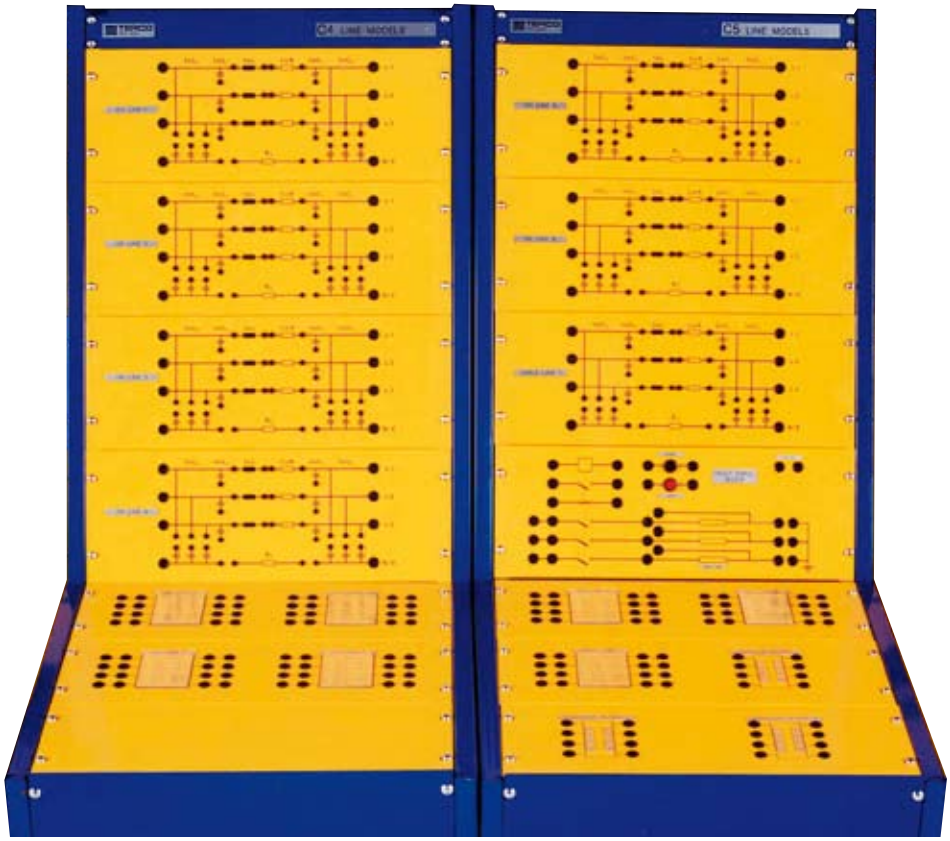
As options are available:

- Static 4+1 zone distance protective relay
- Static impedance protective relay.

All protections are available for connection by 4 mm outlets via a test handle. All necessary current transformers and voltage transformers are included and the connections are available from the desk.

The control elements fitted are mostly of the same industrial type as those 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: The power is generated by a 3-ph synchronous generator driven by a separately excitated DC-motor as turbine. The electrical machines set is electrically fully connected and mechanically mounted on a machine bed.



PST 2220 Transmission Line and Distribution Module.

PST 2220 TRANSMISSION LINE & DISTRIBUTION MODULE

The Transmission Line and Distribution Module comprises:

Type	Voltage	Transmission ability	Length
Two HV pi-links	230 kV	110 MVA	100 km
One MV pi-link	170 kV	150 MVA	150 km
Two MV pi-links	135 kV	1120 MVA	120 km
One Distribution OH pi-link	111 kV	115 MVA	115 km
One Distribution Cable pi-link	111 kV	115 MVA	115 km

All the different voltage levels can be adapted according to customers demands.

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 facilities of connection to Receiving Substation in Module 3 (PST 2230) and the distribution networks with load banks of the Low Voltage Switchgear in Module 4 (PST 2240).
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 above is a standard version level 3 with two incoming lines, HV-busbars, step down transformer, middle voltage busbar and two outgoing lines.

PST 2230 RECEIVING SUBSTATION MODULE

The Receiving Substation comprises of 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

Voltage, current and power meters for incoming power
Voltage between busbars of incoming power
Voltage selector switches for incoming line
Voltage, current and power meters for outgoing power
Voltage between busbars of outgoing power
Voltage selector switches for outgoing lines

Electronic Relay Protections

- Busbar overcurrent protection
- Transformer differential protection
- HV / MV overcurrent protection
- Neutral point voltage earth fault protection
- Overcurrent (three-phase) and directional earth fault protection for outgoing Line 1
- Overcurrent (three-phase) and directional earth fault pro tection for outgoing Line 2
- Multifunction motor protection relay for outgoing Line 2 (optional)
- Auto-reclosing relay in combination with the protection for outgoing Line 1 (optional).

All protections are available by 4 mm outlets via a test handle. All current- and voltage transformers are included and most terminals are available from the desk.

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 front plate.

PST 2240 Load Module.

PST2240 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 optionals to make it possible to study the dynamics of the system as well as the mechanical load sharings between two or more machines. 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.

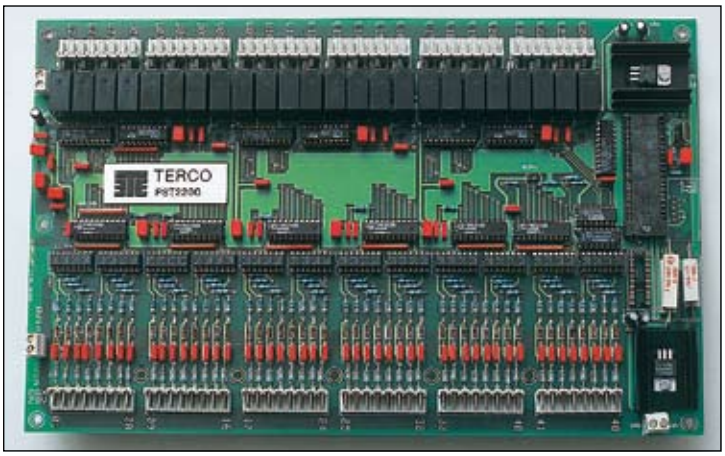
The Load Module comprises

- 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 may be mounted on a metal base or delivered on an external machine bed.

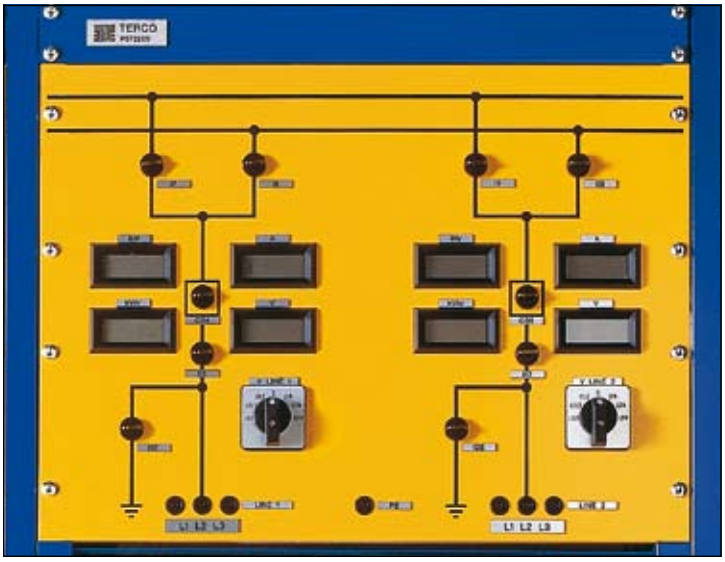
MEASURING DETAILS



Circuits: Logical Blocking Unit with 24 channels.

Logic Blocking Unit

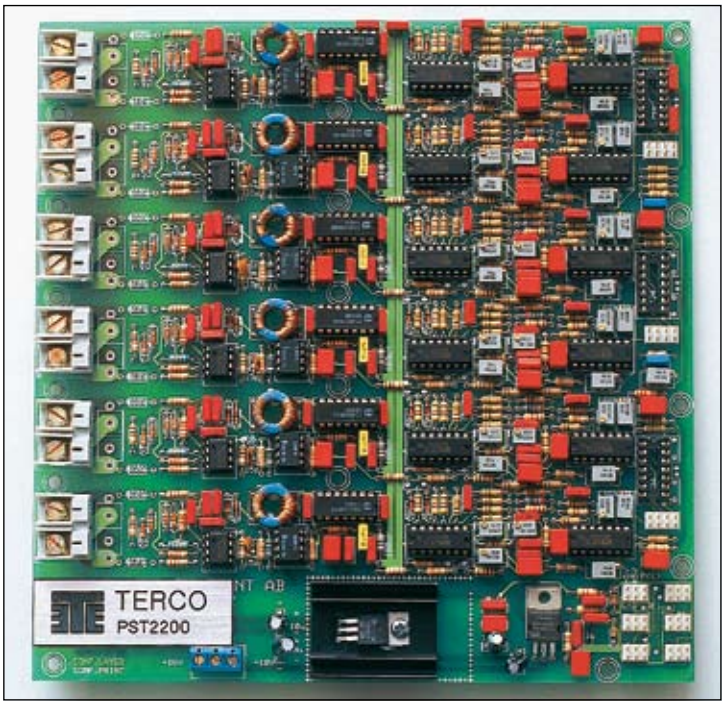
The logical blocking unit uses a microprocessor to determine whether an isolator can be operated or not. All isolators and circuit breakers in the simulator are assigned to a form where the user gives the conditions for operation or not. The corresponding contactor relays give status to the microprocessor which in less than a msec compares all conditions with the demand of the user turning the switch on the front. When upgrading the simulator with more circuit breakers and isolators, the user simply has to reprogramme the microprocessor to fit the new constellation.



Picture showing some of the instruments.

Digital Instruments

The simulator contains, depending on options, normally 60 instrument amplifiers of which 8 are spares for upgrading.
A typical group of instruments will consist of one wattmeter, one VAr – meter, one ammeter and one voltmeter which by means of a selector switch can be connected for measuring line to line voltages or line to neutral voltages.



Circuits: Measuring Unit with 6 channels.

Measuring Unit

Each measuring unit has six signal amplifiers, all of them galvanically isolating the power side from the signal side. All channels are easily adapted for measuring AC or DC or mixed quantities. Calculation of power and reactive power is performed by multipliers and addition circuits. On the output terminals all signals are available as instant values and as buffered mean values within +/-10V. This will simplify future upgrading of the simulator for computer control.

SOME OF THE WORLDWIDE PST 2200 INSTALLATIONS

List of Some Typical Experiments

Under normal conditions

- Settings of field control parameters, settings of turbine control rectifier parameters, settings 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 information 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 synchronised 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 announciator 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) have 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 list of experiments can be made much longer but these are a selection of experiments.

Protective Relay Functions

- Connecting current and voltage transformers in different single- and three-phase configurations.
- Overcurrent protection
- Overcurrent protection with time lag overcurrent relays
- Over- and under voltage relays
- Neutral point protection
- Independent time characteristics
- Directional overcurrent protection
- Earth fault protection
- Directional earth fault protection
- Differential protections
- Design principles
- Instantaneous measuring relay
- Influences of the DC-component
- Directional relay for power
- Signal relays + Auxiliary relays
- A typical feeder protection.

- Microprocessor operated 4 + 1 zones distance protection, programmable for low / high impedance isolated / impedance earthing, under impedance tripping, phase-phase, earth fault etc (optional).
- Auto-reclosing relay with programmable high speed or time delay closing, 1 or several shots, memory functions, counter etc (optional).

Technical Information:

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

Standards
All units included in the Terco Power System Simulator correspond in all significant points to IEC recommendations.

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

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-links	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

Single-phase Load groups

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

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STATIC PROTECTIVE RELAYS

Level 2

POWER PLANT MODULE PST 2210-2

Turbine / Generator / Step-up Transformer:

- All-over Differential Protection
- Three-phase O/C Protection

Power Plant Substation outgoing HV-lines:

- Three-phase O/C and Directional Earth Fault Protection, Line 1
- Three-phase O/C and Directional Earth Fault Protection, Line 2

RECEIVING SUBSTATION MODULE PST 2230-2

- Busbar Overcurrent Protection
- Transformer Differential Protection
- Three-phase O/C and Directional Earth Fault Protection, Line 1
- Three-phase O/C and Directional Earth Fault Protection, Line 2

Level 3

POWER PLANT MODULE PST 2210-3

Turbine / Generator / Step-up Transformer:

- Differential Generator Protection
- All-over Differential Protection
- Three-phase O/C Protection
- Over Voltage Protection
- Rotor Earth Fault Protection
- 95 % Stator Earth Fault Protection

Power Plant Substation outgoing HV-lines:

- Three-phase O/C and Directional Earth Fault Protection, Line 1
- Three-phase O/C and Directional Earth Fault Protection, Line 2

RECEIVING SUBSTATION MODULE PST 2230-3

- Busbar Overcurrent Protection
- Transformer Differential Protection
- HV / MV Overcurrent Protection
- Neutral Point Earth Fault Protection
- Three-phase O/C and Directional Earth Fault Protection, Line 1
- Three-phase O/C and Directional Earth Fault Protection, Line 2

Customer adapted protections

At customers request more sophisticated protections can be chosen in addition to e.g. level 3.

POWER PLANT MODULE

Turbine / Generator / Step-up Transformer:

- Reverse Power Relay for the Generator
- Negative-sequence Protection Relay
- Thermal Overload Relay for the Generator
- Busbar Overcurrent Protection

Power Plant Substation outgoing HV-lines:

- 4 + 1 Zone Digital Line Distance Protection. Separate and independent impedance measuring elements for The General Fault Criteria with advanced characteristic.
  More details of this digital relay below.
- Impedance Relay

RECEIVING SUBSTATION MODULE

- Auto Reclosing Relay
- Distance Protection for Incoming Line
- Busbar Overcurrent Protection (additional)
- Multifunction Motor Protection

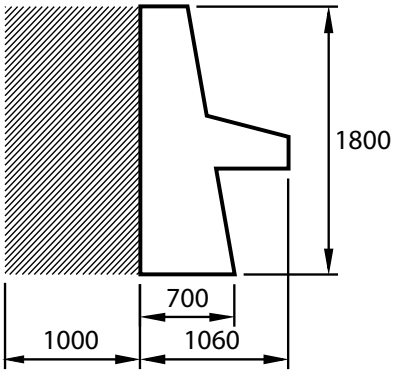
Picture showing some of the Static Protective Relays in the Power Plant Module.

Digital Line Distance Protection, 4 + 1 Zone

Five 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 zone 2, 3 and 4. Each or all zones can be programmed for sensing in forward or reverse direction.

It is possible to add different kinds of options, like Additional Protection Functionality, Control, Monitoring, Metering and Communications.

Weights and Dimensions



	PST 2210	PST 2220	PST 2230	PST 2240
Approx net weights	400 kg	240 kg	400 kg	240 kg
	1045	1045	1045	1045	1045

Turbine-Generator set: dimension 1500 x 400 x 300 mm, weight 130 kg

How to order:

Level	Power Plant Module	Transmission Line & Distribution Module	Receiving Substation Module	Load Module
1	PST 2210-1	PST 2220	PST 2230-1	PST 2240
2	PST 2210-2	PST 2220	PST 2230-2	PST 2240
3	PST 2210-3	PST 2220	PST 2230-3	PST 2240

Level 1. Without static relay protections (normal protection by fusing included).

Level 2. A minimum level when the simulator has a choice of the most important types of static protective relays built-in.

Level 3. Includes a standard set-up of static protective relays typical for small size real power plants and substations.

More sophisticated protections can be chosen as optional and adapted to customers request.

Our Transmission Line Module can easily be adapted in accordance with customer request.
Upgrading of the simulator from a lower level to a higher level or to the customer request can be done at any time.

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

Guarantee & Terms

Turn-Key Delivery and After-Sales Back-Up

The complete Power System Simulator is 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.

Education and training

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.

The Guarantee is valid 12 months from delivery.

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

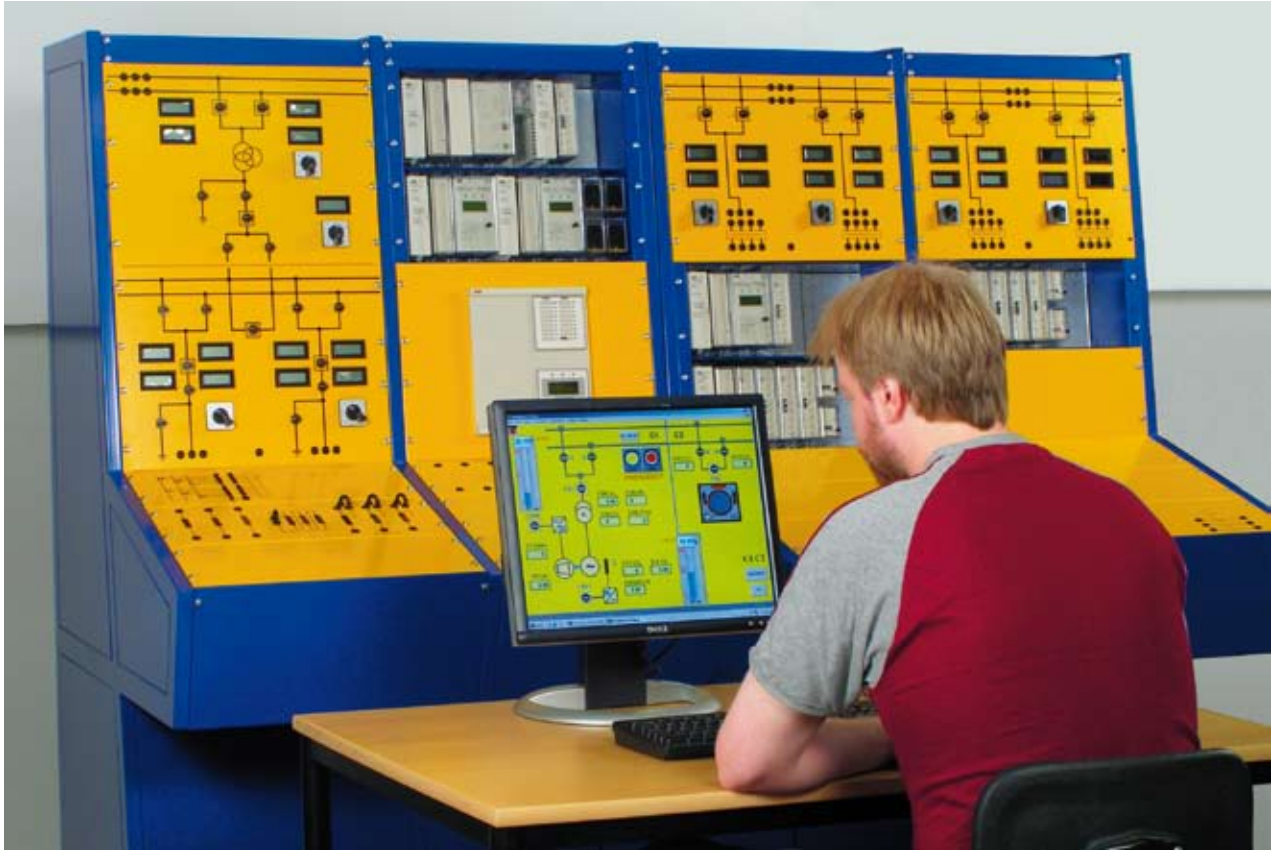
Detailed conditions of guarantee are specified in our Terms of Guarantee.

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

PST 2250 SCADA SYSTEM FOR POWER SYSTEM SIMULATOR



WHAT IS SCADA

SCADA (Supervision Control And Data Acquisition) is the general term for a large group of computer systems with special capabilities.

Typical for SCADA systems is, that they are used in industrial applications to control and to supervise processes in real time.

With process we mean a chain of events with a specific aim e. g. manufacturing paper in the paper industry or transfer of energy in a power transmission network.

HOW DOES SCADA WORK

SCADA gives the personnel the possibility to closely follow and to enter data into the process.

Actual measurements are presented in real time on the computer screen. Control signals may be altered during the process. The SCADA system can also control the process automatically.

During the process a history of values is generated, which is a great help to plan the future and to optimize economics. The system can be controlled remotely through local networks. For 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 has chosen GE Fanuc Fix system and software for the SCADA system. Fix is today world leader in SCADA systems. GE Fanuc Fix operative system was chosen to be the best SCADA system by readers of the Control Magazine 2004.

GE Fanuc Fix is an open system with industrial standard. As such it can be fitted to match any customer made equipment configuration. It can work with any industrial process.

The system can be delivered with up to 16 PC terminals. Consequently 16 students can work simultaneously on the Terco SCADA system with full control or with limited control as chosen by the instructor.

The software system is connected to the PST 2200 Simulator through Profibus.

FEATURES

Indication Modules

- Isolator and Breaker Status
- Status of all Flag Relays
- Current
- Voltage
- Active and Reactive Power
- Generator Speed

Remotely Controlled Modules

- Motor Speed and Torque
- Generator Voltage
- Synchronization
- Loads and Load Values
- Circuit Breakers
- Isolators
- Alarm Resetting

OTHERS

- All isolators and circuit breakers internally interlocked by individually programmed subroutines, to prevent faulty operation orders (TERCO Blocking System).
- Faulty operation attempts are blocked automatically.
- Replicates all PST 2200 System main module configurations.
- Easily customized monitor images and diagrams.
- Easily customized schematics.
- Digital virtual instrumentation.
- Event logging and filing.
- Trending facilities with synoptic diagrams from historically trended data.
- Alarm setting accessible.
- Software for developing / programming different SCADA-applications.
- MANUAL, including Technical Description as well as Users Guide with guided experiments.

Power System Simulator PST 2200 with SCADA

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PST 2270 MOBILE TURBINE - GENERATOR SET

including control panel, turbine, generator, step-up transformer and 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 arranged in the same way as in real plants.
Indications as well as interlockings for the operation of breakers and isolators are designed as in real plants.

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 :
- Armature (stator) current
- Armature voltage
- Field current
- Revolutions per minute
- Rotor current for turbine (DC-motor)
- Active power

- Reactive power
- Volt- and ammeters for busbar
- Voltmeters for all phases (synch.).
- Voltage selector switches

Cubicle :
Dim.: 1045 x 1060 x 1900 mm
Weight : 280 kg (approx.)

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

PST 2260 HV – DC MODULE

The PST 2260 HV-DC Module is designed to operate together with the Terco PST 2200 System Modules.
The basic blocks are housed in two double cabinets like the other modules:

- Cubicle one: Transformers, filters, rectifiers, instruments and controls
- Cubicle two: Line models, fault simulators
- Cubicle three: Line models
- Cubicle four: Receiving plant, inverters, transformers, filters, instruments and controls

The AC side is designed for 3x400 V, 2 A with possibilities to expand to 4 A.
The DC side is designed for 2x350 V, 4 A (centre point earthed).
Power transfer ability is approx. 2.5 kW (3 kVA on the AC-side).

Features:
- Integrated with a power system (PST) or operated as a free-standing unit (optional)
- Signal transducers for all instrument functions to standard buffered outputs +/- 10 V
- Built-in fault simulator
- Selectable power transfer direction
- Necessary protections
- SCR:s individually protected
- Pre-designed for upgrading to SCADA (computer control)

Some typical experiments:
- Main transformer connections
- Current curves in AC-circuits
- Ignition angle control characteristics
- Power control characteristics
- Current control characteristics
- Power flow
- Reversal of power flow

Power supply: 3 x 400 V, 6 A

Dimensions:
Height - 1800 mm
Depth - 1100 mm
Width (total) - 2090 mm total
Weight (app.) - 280 kg total

PST 2280 POWER FACTOR CONTROL MODULE

Power Factor Controller

With the PFC you can minimise the currents caused by reactive losses of power and thereby optimising 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 or inductances.
By measuring phase voltages and current the microprocessor will calculate how many capacitive groups that has to be connected and also in which combinations.

Electrical details	
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.

Typical Experiments:

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

Physical design

The PFC is made to fit together with our PST 2200 Power Simulator System but can also be used as a stand alone unit.

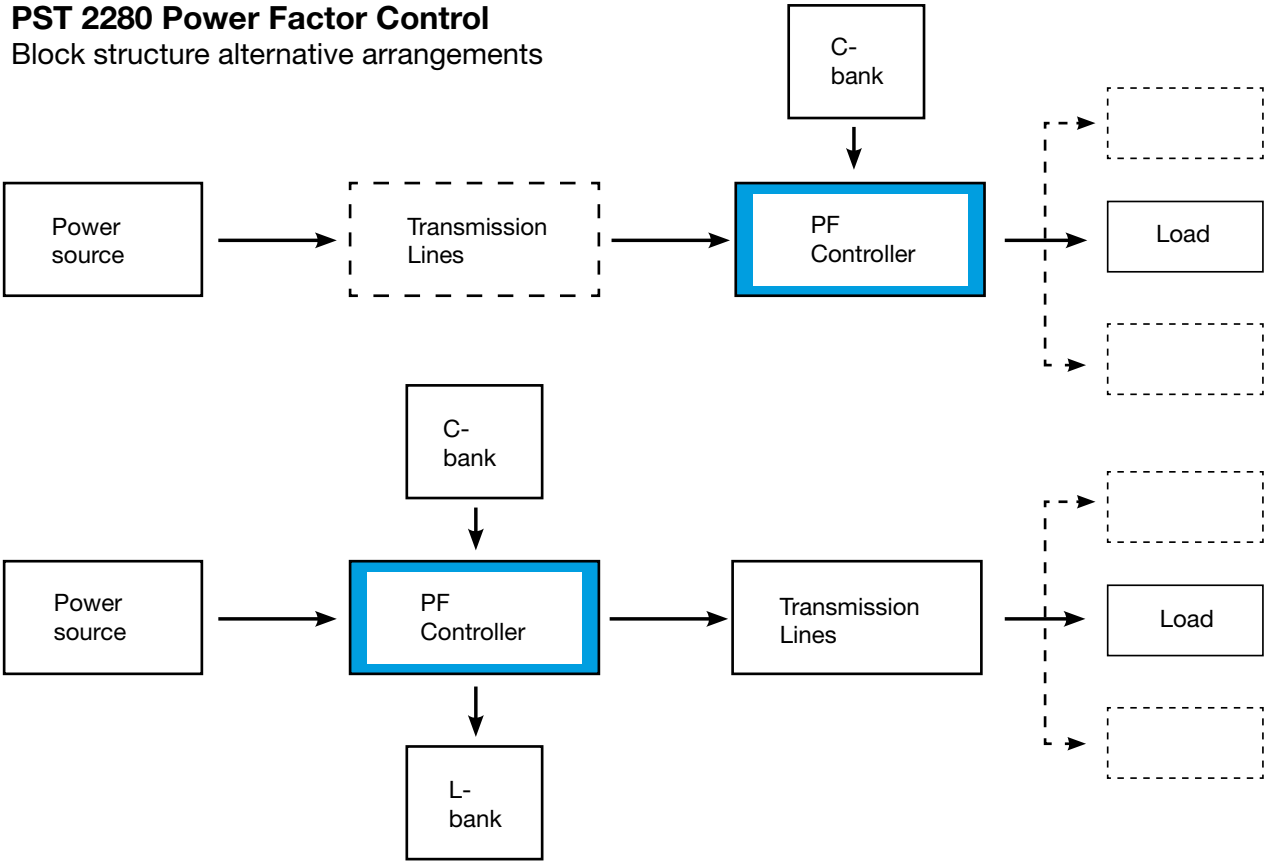
The PFC is hosed in a PST double cabinet with a clear mimic diagram explaining how to connect the supplying net to the network in need of power factor compensation.
Lamps on the front panel indicate which contactor relay is in operation together with the corresponding reactive load bank.

Readings, parameters and sub-parameters are indicated on the front of the controller unit. Other settings and programming than the default may be performed on the controller.
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.

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

PST 2280 Power Factor Control

Block structure alternative arrangements



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MV 1305 MOBILE MOTOR / GENERATOR UNIT

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 at disturbances 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 wide range flexibility will be given by the mobile generator station / synchronous alternator (compensator) MV 1305.
MV 1305 can operate as described or work in parallel with the Power System Simulator PST2200. In this case mechanical and electrical parameters might be changed by using e.g. flywheel (MV 1010) and different electrical connections.

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

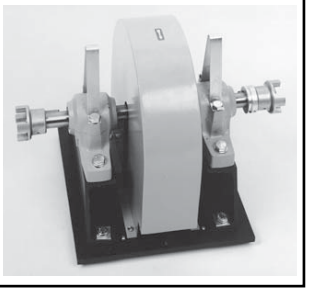
Technical Specification		MV 1305-405
Power Supply	Voltage	380-415 V AC 3-ph
	Frequency	50-60 Hz
	Max current	16 A
Turbine/DC-machine	Armature Volt	0-240 V DC
	Field Volt	190 V DC
	Armature current	12 A
	Field current	0.8 A
	Power	2.0 kW
	Speed	0-1800 rpm
Synchronous generator	Armature volt	0-240 / 415 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 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



ACCESSORIES 8785

MV 1100 Load Resistor

3-phase 3.3 kW, continuously adjustable.

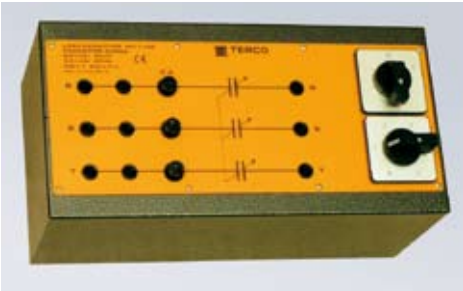
Star connection	400 / 230 V 0.8-5 A
Star connection	230 / 133 V 0.5-5 A
Delta connection	400 / 230 V 2.4-8.7 A
Delta connection	230 / 133 V 1.3-8.7 A
DC parallel connection	220 V 2.3-15 A
Dimensions	630 x 250 x 890 mm
Weight	46 kg

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 - plotting of magnetisation curves.

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

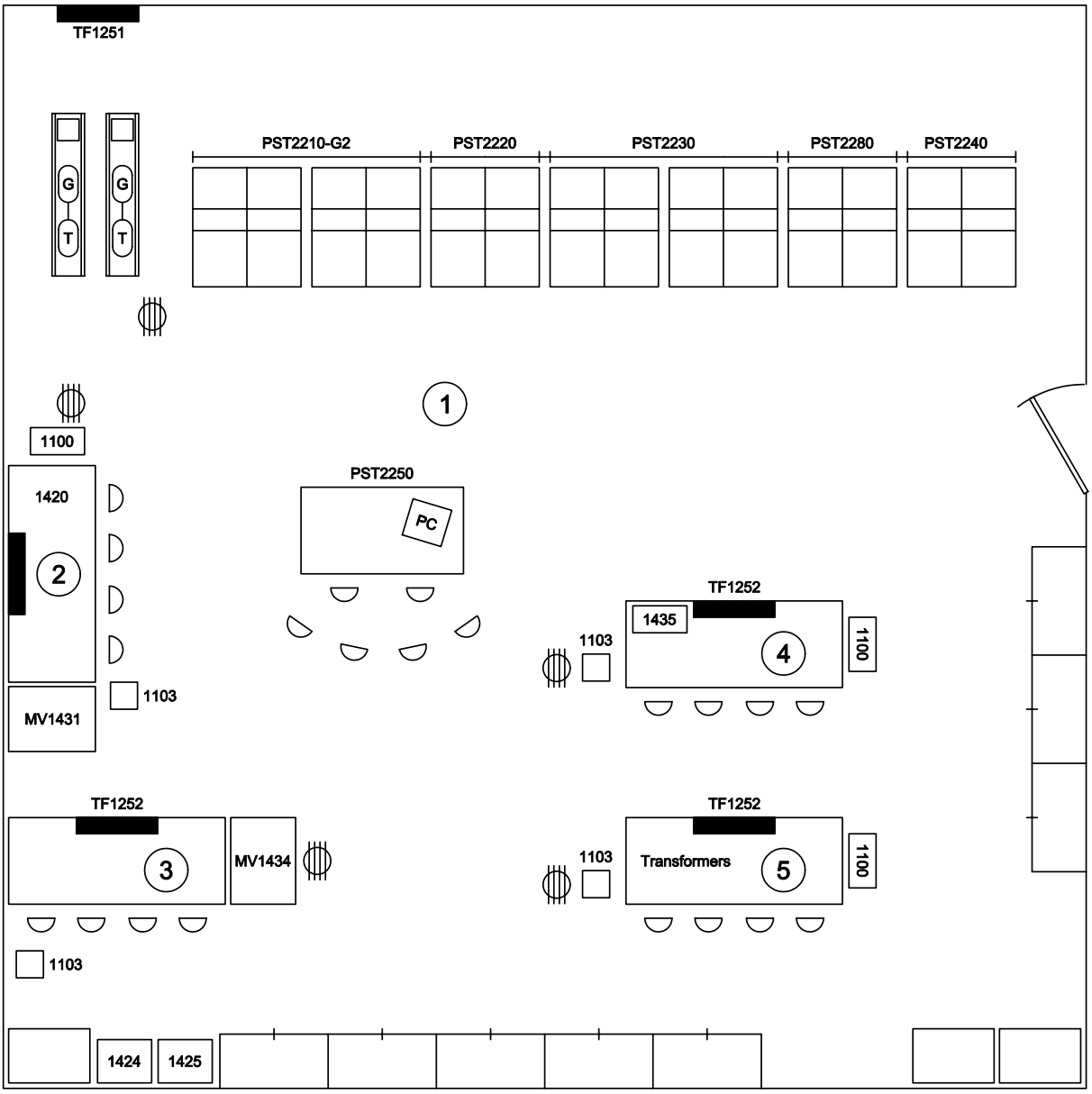
Dimensions	280 x 178 x 178 + 63 mm
Weight	15 kg

LABORATORY LAYOUT

The layout is most important 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".

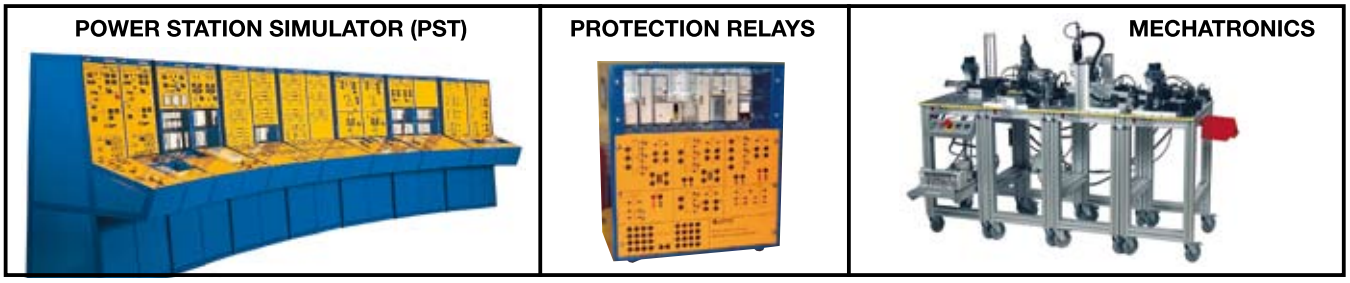
Suggested Laboratory Size: 10 x 10 m²

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



Terco Headoffice

Terco headoffice and factory outside Stockholm, Sweden.



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