Engineering and Technical Teaching Equipment

Low Power Synchronous Generators Application

AEL-LPSG

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PRODUCTS
4.- ELECTRICITY

INTRODUCTION

A generator is defined as a rotary machine able to transform mechanical energy into electrical energy. This mechanical energy comes from what is called driving force, for instance, a turbine, a propeller or a motor. Most generators used in large power plants (except for wind ones) are synchronous type due to the fact that they allow an accurate control of the voltage, active and reactive powers injected into the grid while operating in synchronism (in parallel) with it. The synchronization with the grid and the corresponding process are of great signifcance to avoid serious damages to the generator and the grid itself.

ISO 9001: Quality Management (for Design, Manufacturing, Commercialization and After-sales service)

European Union Certificate (total safety)

Certificates ISO 14001 and ECO-Management and Audit Scheme (environmental management)

"Worlddidac Quality Charter" and Platinum Member of Worlddidac

GENERAL DESCRIPTION

The Low Power Synchronous Generators Application, "AEL-LPSG", has been designed to study the procedure and the maneuvers required for the synchronization of synchronous generators with the grid, with the aim of delivering the generated energy as done in actual power plants.

The "AEL-LPSG" application allows the user to go deeper into the working principles and control of synchronous generators to show the step-by-step synchronization process with the electrical grid. For this, the application includes a synchronous generator coupled to a motor (which will act as driving force, simulating a turbine) along with a series of modules such as a single-phase transformer, an AC/DC converter and a voltage regulator which form the generator excitation circuit. It is also included a motor controller for the turbine-generator speed control, an analog overcurrent relay as grid protection device and a network analyzer to monitor the generation electrical parameters such as the active and reactive powers generated, frequency, voltage, current, power factor, etc.

Generator-Motor Group detail

This application offers two possibilities regarding the generation group control.The first option, the manual control of synchronous generators kit, includes a PWM signal generator module for the control of the synchronous generator excitation current (and therefore the output voltage). This enables the user to carry out the no load, under load and short circuit test aimed to obtain the characteristic curves and the equivalent circuit of the synchronous generator. This kit also includes a synchronization module which will allow the user to monitor and carry out manually the synchronization process. For that, the synchronization module has two analog voltmeters (grid and generation voltage), two frequency meters (grid and generator frequency), a digital synchroscope and two push-buttons for closing and opening the synchronization switch.

Manual Synchronization Circuit Detail

The second option, the synchronous generator automatic control module, offers the possibility to control automatically every electrical and mechanical paremeter of the generator-turbine group. The most signifcant control parameters are the turbine speed, the generator frequency, the excitation current, the voltage at the generator output and the active, reactive and apparent powers. Moreover, this control module is at the same time an advanced protection for generators and turbines. It meets the ANSI standards regarding the protection parameters for generators and turbines (ANSI 81O, ANSI 81U, ANSI 59, ANSI 27, ANSI 50/51, ANSI 32R/F, ANSI IOP 32, ANSI MOP 32, ANSI 46, Voltage Asymmetry, Generator Ground Fault, Phase Rotation, ANSI IEC 255 , Generator Lagging Power Factor, among others). It is required to acquire at least one of the two previously described options to be able to work with the modules included in the base unit.

Automatic Voltage and Speed Controller (AVR, ASC) detail

In order to acquire a greater experience with the study of synchronous generators, it is recommended to acquire a set of resistive and inductive loads with the aim of studying the island operation of synchronous generators (isolated from the national grid). These loads will allow the user to go deeper into the basic concepts about the behaviour of synchronous generators working under load, such as generation and demand in isolated systems, voltage drops or the output voltage control by means of the excitation current regulation.

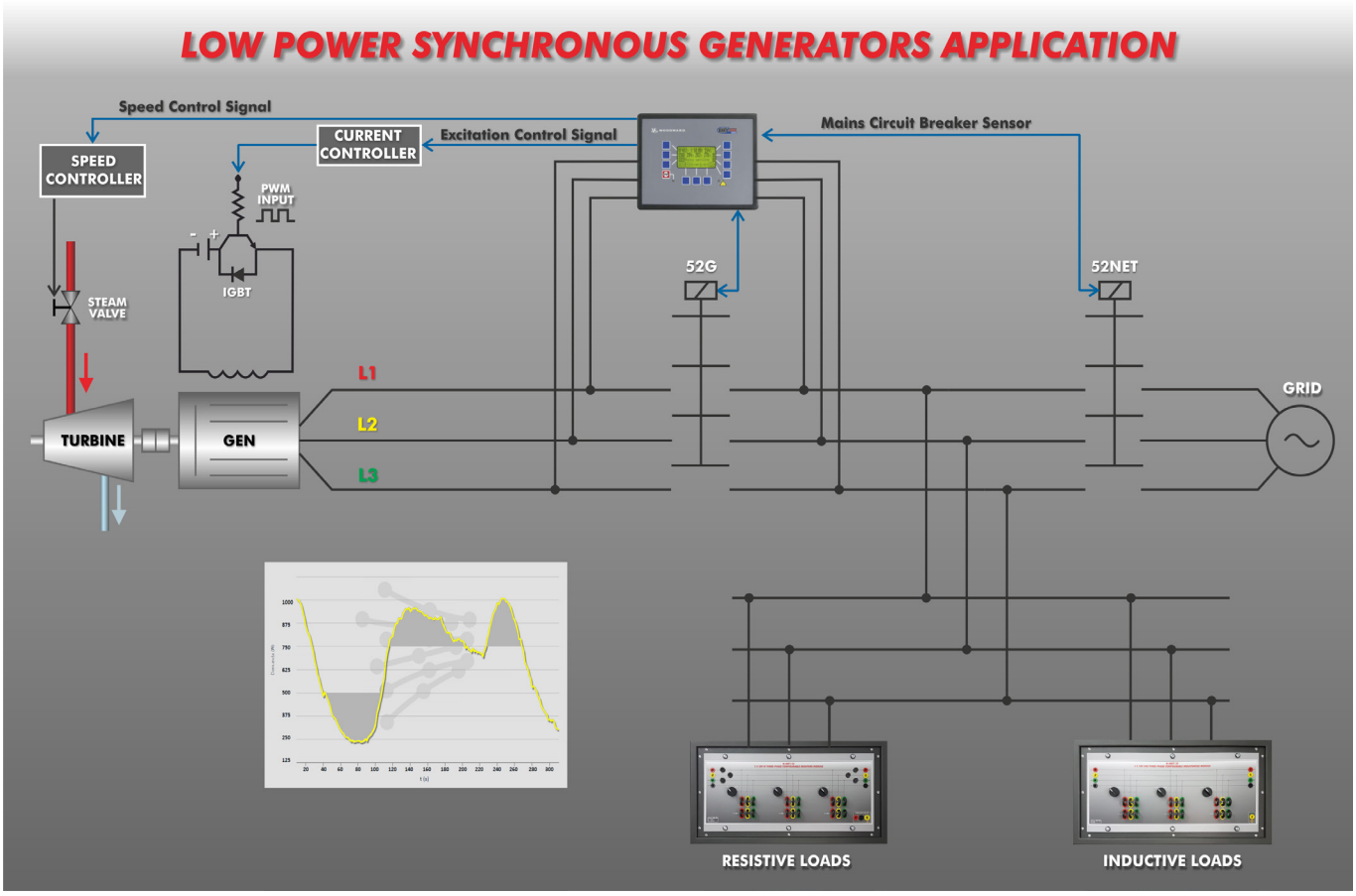
It is also recommended to acquire a kit for the study of faults in synchronous generators, consisting of an advanced differential protection relay with configurable numerical programming which allows showing the features of three-phase differential protection, two power switch modules as interrupting devices, a fault injection module for the injection of single-phase, two-phase or three-phase, to earth, faults and a module with three-phase inductances as buffering element for the faults at the generator induced side.

In addition, it is recommended as well a rotor protection module for the study of faults at the synchronous generator excitation side and a three-phase harmonic filter for the reduction of the harmonics resulting from the regulation of the generator excitation current.

The "AEL-LPSG" is one of the most complete and versatile applications regarding the in-depth study of synchronous generators, both in island and parallel to grid operations. Furthermore, it is compatible with any type of energy transmission line which makes it possible to study the impact of synchronous generators on real grids, analysing events such as power transfer among several machines working in parallel, sudden decouplings and its consequences and endless meanuevers related to electric generators.

Finally, for the most optimal management of the application, it is recommended the Energy Manager and Data Acquisition Software, EMG-SCADA. This awesome tool allows the user to monitor all the curves for the grid and generator electrical parameters, watch the voltage dips, energy losses in transmission lines and voltage drops. in addition, it allows saving all the acquired data to watch and compare it later. It is possible to see clearly and with accuracy the effects of reactive power compensation on the monitored power curves, maximum and minimum energy demand, load unbalances and the variation of the power factor in the nodes of the system.

Example of configuration



The "LPSG-UB" is the base unit of the "AEL-LPSG" application.
The "LPSG-UB" unit includes the following elements:

- N-ALI01. Industrial Main Power Supply Module.
- GEC-KIT-1. Generator Excitation Circuit Kit 1.
  - N-AVR/P. Automatic Voltage Regulator.
  - N-TRANS04. Single-Phase Transformer 230 VAC/2x35 VAC, 300 VA.
  - N-SPAD01. Single-Phase AC/DC Converter 1.
- EMT7/1K. 3 PH Squirrel Cage Motor, 1 kVA.
- EMT6/1K. Independent Excitation 3PH Synchronous Motor-gnerator,1 kVA.
- N-VVCA2K. 2 kW Motor Speed Controller.
- N-EALD. Network Analyzer Module with Oscilloscope and Data Acquisition.
- N-REL10. Time Analog Relay against Overcurrents Module (0 - 16 A).

Required elements for the generator control (at least one is required):

Manual control of the Turbine-Generator group:

- LPSG-K1. Manual Synchronization of 1 kVA Synchronous Generators Kit.
  - N-ASYB. Basic Synchronization Module.
  - N-PWM01. PWM Signal Generator Module 1.

Automatic control of the Turbine-Generator group:

- N-ERP-PGC01. Generator Protection and Control Relay Module.

Recommended elements for a greater functionality of the "LPSG-UB" unit:

- RL-KIT-1. Resistive and Inductive Loads Kit 1.
  - N-REFT/3C. 3 x 300 W Three-Phase Configurable Resistors Module.
  - N-INDT/3C. 3 x 300 VAr Three-Phase Configurable Inductances Module.
- GFS-KIT-1. Study of Faults in Generators Kit 1.
  - N-ERP-PDF01. Differential Protection Relay Module.
  - N-PSM. Power Switch Module. (2 units).
  - N-ERP-MF01. Digital Fault Simulator Module.
  - N-INDT02. Three-Phase Inductances Module 2.
- N-REP. Rotor earth-fault protection module.
- N-THF01. Three-Phase Harmonic Filter Module 1.
- N-REVT/1K. 1kW Three-Phase Variable Resistors Module.
- N-MED11. AC Ammeter (0 - 10 A). (Required to do the generator tests).
- N-MED22. AC Voltmeter (0 - 400 V). (Required to do the generator tests).

Recommended software:

- EMG-SCADA. Energy Manager and Data Acquisition Software.

The application "AEL-LPSG" includes the following elements:

- N-ALI01. Industrial Main Power Supply Module.
- GEC-KIT-1. Generator Excitation Circuit Kit 1.
- EMT7/1K. 3 PH Squirrel Cage Motor, 1 kVA.
- EMT6/1K. Independent Excitation 3PH Synchronous Motor-gnerator,1 kVA.
- N-VVCA2K. 2 kW Motor Speed Controller.
- N-EALD. Network Analyzer Module with Oscilloscope and Data Acquisition.
- N-REL10. Time Analog Relay against Overcurrents Module (0 - 16 A).
- LPSG-K1. Manual Synchronization of 1 kVA Synchronous Generators Kit.
- N-ERP-PGC01. Generator Protection and Control Relay Module.
- RL-KIT-1. Resistive and Inductive Loads Kit 1.
- GFS-KIT-1. Study of Faults in Generators Kit 1.
- N-REP. Rotor earth-fault protection module.
- N-THF01. Three-Phase Harmonic Filter Module 1.
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The application "AEL-LPSG" can be mounted on rack (option A) or on rail (option B):

Option A:

This application needs the following racks:

- N-RACK-A.

Optionally the AEL-WBR. Electrical Workbench (Rack) can be supplied to place the rack/s.

Option B:

This application can be mounted on rail.

Optionally the AEL-WBC. Electrical Workbench (Rail) can be supplied to mount the modules.

SPECIFICATIONS

- N-ALI01. **Industrial Main Power Supply Module.**
  Voltage supply: 400 VAC, 3PH+N+G.
  ON-OFF removable key.
  Emergency stop push-button.
  Output voltage connections:
    Three-Phase + Neutral: 400 VAC.
    Single-Phase: 230 VAC.
  Three-Phase supply wire with IP44 3PN+E 32A 400V connecting plug.
  Differential magnetothermal, 4 poles, 25A, 300mA AC 6KA.


N-ALI01

- N-AVR/P. **Automatic Voltage Regulator.**
  Input voltage: 0 - 100 VDC.
  Input for voltage regulation signal through PWM control.
  Terminals for PWM signals monitoring.
  Output voltage: 0 - 100 VDC.
  DC ammeter for output current measurement, 0 - 4 A.
  3-pin female connector for connection to the excitation input of a generator.
  Fuse 5 A.


N-AVR/P

- N-TRANS04. **Single-Phase Transformer 230 VAC/2x35 VAC, 300 VA.**
  230 VAC single-phase input terminals.
  Terminals for a 70 VAC single-phase output.
  Terminals for two 35 VAC single-phase outputs.
  0 (Opened)/1(Closed) selector switch.
  Fuses:
    Primary side: 5 A.
    Secondary side: 2.5 A.


N-TRANS04

- N-SPAD01. **Single-Phase AC/DC Converter 1.**
  0 - 230 VAC single-phase input terminals.
  AC/DC rectifier.
  DC output terminals.
  Filter capacitor for voltage ripple reduction.
  Bypass terminals for filter capacitor connection.
  5 A fuse.


N-SPAD01

- EMT7/1K. **3 PH Squirrel Cage Motor, 1 kVA.**
  Nominal power: 1100 W.
  Nominal voltage: 3 x 230/400 VAC Δ/Y.
  Frequency: 50/60 Hz.
  Number of poles: 2.
  Nominal speed: 2730 rpm.
  Nominal current: 2,52 / 1,45 A.


EMT7/1K

- EMT6/1K. **Independent Excitation 3PH Synchronous Motor-gnerator,1 kVA.**
  Nominal power: 1000 VA.
  Power factor: 0.8.
  Nominal output voltage: 3x 400 VAC.
  Frequency: 50/60 Hz.
  Speed: 3000 rpm.
  Nominal output current: 0.8 A.
  Nominal excitation current: 5 A.


EMT6/1K

- N-WCA2K. **2 kW Motor Speed Controller.**
  ON/OFF power switch.
  Start/stop switch.
  8-pin micro connector for the speed cotnrol signal.
  Ouput connector.
  Motor speed control potentiometer.


N-WCA2K

- N-EALD. **Network Analyzer Module with Oscilloscope and Data Acquisition.**

N-EALD

The network analyzer module allows fulfilling measurements, displaying and analyzing all the parameters of the AC electrical networks. It has a LCD screen and push-buttons for the navigation through the different menus. It includes specific software for monitoring current and voltage curves, harmonics display, tariffs programming and electrical parameters storage.

Features:

Multifunctional three-phase power meter:

Single and three-phase voltage. Up to 690 VAC L-L.

Phase and line current. Current range up to 200%. Measurement from 0 - 10 A.

Active, reactive and apparent power.

Suitable frequencies: 25 Hz, 50 Hz, 60 Hz y 400 Hz.

Display of the V-I vector diagram.

Supply voltage: 85 - 265 VAC.

Energy quality control:

Current and voltage individual harmonics measurement. Up to the 40 th harmonic.

THD voltage and current, TDD and K-factor.

Maximums and minimums display.

Waveforms display, 128 samples/sec.

Events and data storage.

Harmonics analyzer:

THD voltage and current, TDD current and K-factor, up to the 40 th harmonic.

Current and voltage harmonic spectrum and angles.

Tariff programming:

Class 0.5S IEC 62053 - 22, active and reactive power in four quadrants.

Measurement of the total and per phase three-phase active, reactive and apparent powers.

Usage time, 4 energy/demand records of total tariffs.

8 tariffs, 4 seasons, 4 types of days.

Automatic daily report of energy consumption maximums and minimums.

Communications:

Modbus TCP communication protocol with Ethernet interface.

- N-REL10. **Time Analog Relay against Overcurrents Module (0 - 16 A).**

N-REL10

Three-pole analog overcurrent relay.

Overcurrent, undercurrent and phase loss protection.

Range 0 - 16 A.

Automatic and manual reset functions.

Trip and startup temporization.

2 NO NC auxiliary contacts.

- N-ASYB. **Basic Synchronization Module.**

N-ASYB

Grid three-phase input terminals (L1, L2, L3 and N).

Generator three-phase input terminals (L1, L2, L3 and N).

Measurement terminals for both generator and grid electrical parameters.

Double analog voltmeter for the comparison of the generator and grid busbars voltage.

Digital synchroscope to monitor the synchronization process.

Double frequency meter for the comparison of the generator and grid frequency.

Double push-button for synchronization permission or stop.

400 VAC red, green and yellow lamps to fulfill the lamp methods regarding the synchronization process.

Terminals at the generator and grid busbars for the wiring of the lamps.

ON/OFF power switch.

- N-PWM01. **PWM Signal Generator Module 1.**

N-PWM01

Enable/Disable switch to enable the signal generation.

Potentiometer for the duty cycle control.

Display for the working and maximum duty cycle of the generated signals.

Micro-connector for the transmission of the generated signals.

2 mm terminals to monitor the generated signals through an oscilloscope or any other device.

ON/OFF power switch.

- N-ERP-PGC01. **Generator Protection and Control Relay Module.**

N-ERP-PGC01

Automatic Speed and Voltage Controller: It enables to connect up to 16 electric generators in parallel-island with active and reactive power distribution and start/stop depending on the load demand.

Enables to connect a generator in parallel with the grid.

It allows different switch control modes, such as opening, closing and synchronization.

Three-phase measurement of the grid and the generator voltage.

Three-phase measurement of the generator intensity and power.

Single-phase measurement of the grid intensity.

Protection system:

Generator: Maximum/minimum voltage (59/27), maximum/minimum frequency (81O/U), voltage asymmetry, detection of dead busbars, overvoltage (32), load unbalance (46), negative sequence power/reduced power (32R/F), overcurrent by defined curve (50/51), inverse time overcurrent (IEC255), measured ground fault (50N/51N), phase rotation, switches faults.

Network: Maximum/minimum voltage (59/27), maximum/minimum frequency (81O/U), vector jump, phase rotation.

Measurement terminals.

Output terminals for the connection to the lab grid.

2 mm terminals to monitor the PWM for the excitation circuit and speed signals.

Three control switches to:

Start and stop the turbine.

Give permission to synchronize the generator with the grid.

Give permission to synchronize the generator with the national grid.

Two potentiometers to:

Adjust the set point for the generated active power.

Adjust the set point for the voltage.

Emergency stop push button:

Two circuit breakers for synchronization and island mode operations with state indicator lamps.

- N-REFT/3C. **3 x 300 W Three-Phase Configurable Resistors Module.**

N-REFT/3C

Three three-phase banks with resistors of 1600 Ohms each one.

Configurable Star and Delta connections.

Nominal voltage: 400 VAC.

Nominal power: 3 x (3 x 100) W.

- N-INDT/3C. **3 x 300 VAr Three-Phase Configurable Inductances Module.**

N-INDT/3C

Three three-phase banks with inductances of 5 H each one.

Configurable Star and Delta connection.

Nominal voltage: 400 VAC.

Nominal power: 3 x (3 x 100) Var.

- N-ERP-PDF01. **Differential Protection Relay Module.**

N-ERP-PDF01

Differential protection relay module.

Single-phase supply voltage: 230 VAC.

Light indicator of TRIP.

Differential protection.

DB9 RS - 232 communication connector.

SUB-D signals connector of 62 pins.

ON - OFF switch.

Connection terminals.

Characteristics:

It protects two terminals transformers, generators, reactances and other power devices using a combination of differential, instantaneous and "inverse-time" overcurrent elements. The safety of the differential diagram is obtained by the following actions:

Dual-slope percentage reduction.

Second and forth harmonic blocking.

Fifth harmonic blocking for transformer overexcitation.

CT and transformers connection compensation.

- N-PSM. **Power Switch Module (2 units).**

N-PSM

Power terminals:

Four input terminals (3 PH+N).

Four output terminals (3 PH+N).

Auxiliary contacts:

One NO contact.

One NC contact.

Two push-buttons to open/close the power switch and the auxiliary contacts.

Two 24 VDC control inputs.

Two 24 VDC voltage outputs.

- N-ERP-MF01. **Digital Fault Simulator Module.**

N-ERP-MF01

Enables injecting one, two or three pole different faults at the desired location through fault and line terminals.

Trip time potentiometer.

Ethernet connection: Two communication ports for SCADA remote control.

- N-INDT02. **Three-Phase Inductances Module 2.**

N-INDT02

Nominal voltage: 400 VAC.

Inductance value: 16 mH.

Nominal current: 10 A.

Manual commutator to switch on/off the inductances.

Fuses: 3 x 2 A.

Terminals:

Four input terminals (3PH+N).

Four output terminals (3PH+N).

- N-REP. **Rotor Earth-fault Protection Module.**

  Nominal voltage: 400 VAC.

  Relay voltage: 24 VDC.

  Contacts: 1 NO, 1 NC.

  Contact nomnal current: 10 A.

  Test push-button.

  Reset push-button.

  Two lamps for fault to earth signalling.

N-REP

- N-THF01. **Three-Phase Harmonic Filter Module 1.**

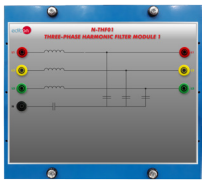
  Passive filter designed for the third harmonic blockage up to the 90%, reducing the currents through the neutral in three-phase installations.

  Phase to neutral voltage: Up to 750 V.

  Frequency: 50/60 Hz.

  Nominal neutral current: 10 A.

  IP00 and IP22 protection.



N-THF01

- N-REVT/1K. **1kW Three-Phase Variable Resistors Module.**

  Three banks with three-phase variable resistances of 150 - 500 Ohms.

  Nominal voltage: 400 VAC.

  Fuses: 3 x 2 A.

N-REVT/1K

- N-MED11. **AC Ammeter (0 – 10 A).**

  Measurement range: 0 - 10 A.

  Terminals:

  Measurement Terminals.

N-MED11

- N-MED22. **AC Voltmeter (0 - 400 VAC).**

  Measurement range: 0 - 400 VAC.

  Terminals:

  Measurement Terminals.

N-MED22

- **All necessary cables to realize the practical exercises are included.**

Cables and accessories, for normal operation.

Manuals:

This unit **is supplied with the following manuals:** Required Services, Assembly and Installation, Starting-up, Safety, Maintenance & Practices Manuals.

Practical possibilities in case of acquiring the kit for the manual control of the Turbine-Generator group, LPSG-K1 :

1.- Manual control of the generator-motor group frequency .
2.- PWM signal generation and duty cycle regulation.
3.- Assembly of the self-excited static excitation circuit.
4.- Manual control of the synchronous generator voltage by means of the excitation current control through PWM signals.
5.- Startup of the synchronous generator under no load.
6.- Manual synchronization of the synchronous generator with the grid.
7.- Synchronization through the dark lamps method.
8.- Synchronization through the bright lamps method.
9.- Synchronization through two dark and one bright lamps method.
10.- Monitoring the power flows injected into the grid.
11.- Active power (P) and reactive power (Q) generation control in synchronism with the grid, by means of the generator frequency and excitation current control respectively.
12.- No load test of the synchronous generator. N-MED11 and N-MED22 modules are required.
13.- Empirical obtaining of the synchronous generator no load characteristic, E= f (Iex). Lineal and saturation zone. N-MED11 and N-MED22 modules are required.
14.- Short-circuit test of the synchronous generator. N-MED11 and N-MED22 modules are required.
15.- Empirical obtaining of the synchronous generator short-circuit characteristic. N-MED11 and N-MED22 modules are required.
16.- Computation of the Poitier's diagram. N-MED11 and N-MED22 modules are required.
17.- Computation of the synchronous generator impedance. N-MED11 and N-MED22 modules are required.
18.- Determining the equivalent circuit of the synchronous generator. N-MED11 and N-MED22 modules are required.
19.- Computation of the synchronous generator capacity limits. N-MED11 and N-MED22 modules are required.
20.- Control logic circuit for the protection of the synchronous generator in synchronism with the grid.
21.- Measurement of the harmonic generation caused by the power elecronic.

Practical possibilities in case of acquiring the module for the automatic control of the Turbine-Generator group, N-ERP-PGC01:

22.- Automatic control of the generator-motor group frequency.
23.- Assembly of the self-excited static excitation circuit.
24.- Adjustable automatic control of the synchronous generator output voltage.
25.- Automatic synchronization of the synchronous generator with the grid.
26.- Monitoring the power flows injected into the grid.
27.- Adjustable automatic control of the active power injected into the grid.
28.- Control logic circuit for the protection of the synchronous generator in synchronism with the grid.

Practical possibilities in case of acquiring the kit for the island operation of the generator, RL-KIT-1:

29.- Island operation with manual/automatic control of the generator-motor group.
30.- Study of the generation and demand in isolated systems.
31.- Study of the votlage drops in sycnhronous generators and compensation through manual/automatic regulation of the generator excitation current.
32.- Test for obtaining the external characteristic of the synchronous generator, V = f (I).

Practical possibilities in case of acquiring the kit for the study of faults in sycnhronous generators, GFS-KIT-1:

33.- Overcurrent protection test with the generator in synchronism with the grid.
34.- Overcurrent protection test with the generator in island operation.
35.- Differential protection relay setting.
36.- Study of the scheme for the differential protection of the synchronous generator in case of fault.
37.- Study of single-phase, two-phase, three-phase, to earth, with and without impedance faults.
38.- Study of the differential protection against instantaneous overcurrent (50P1H).
39.- Study of the differential protection against definite time overcurrent (50P1).
40.- Study of the differential protection against inverse time overcurrent (51P1).
41.- Study of the differential protection against definite time negative sequence current (50Q1).
42.- Study of the differential protection against inverse time negative sequence current (51Q1).
43.- Study of the differential protection against instantaneous residual current (50N1H).
44.- Study of the differential protection against definite time residual current (50N1).
45.- Study of the differential protection against inverse time residual current (51N1).
46.- Transient analysis of fault injection by means of the differential relay manufacturer's software.

Practical possibilities in case of acquiring the rotor earth-fault protection module, N-REP:

47.- Study of the scheme for the rotor protection of a synhcronous generator in case of fault.
48.- Rotor earth-fault protection test.

Practical possibilities in case of acquiring the three-phase harmonic filter, N-THF01:

49.- Study and monitoring the harmonics generation.
50.- Harmonic reduction by means of a three-phase passive filter.

Some practical exercises with the Energy Manager and Data Acquisition Software, EMG-SCADA:

51.- Remote manual control of voltage and frequency of the synchronous generator.
52.- Remote automatic control of voltage and frequency of the synchronous generator.
53.- Remote automatic synchronization operation of the synchronous generator and the grid.
54.- Real time monitoring of the induction generator frequency, current and voltage values and waveforms.
55.- Real time monitoring of the generated active, reactive and apparent powers.
56.- Visualization of the phasor diagrams of the system electrical parameters.
57.- Data saving and storage.
58.- Comparison of the obtained results.

- Several other exercises can be done and designed by the user.

REQUIRED SERVICES

- Electrical supply: Three phase, 380 VAC- 415 VAC/50 Hz o 190 VAC-240/60 Hz, 2 kW.

DIMENSIONS AND WEIGHTS

AEL-LPSG:

- Dimensions: 2000 x 320 x 920 mm approx.
  (78.73x12.59x36.22 inches approx.)
- Weight: 80 Kg approx.
  (176 pounds approx.)

SIMILAR UNITS AVAILABLE

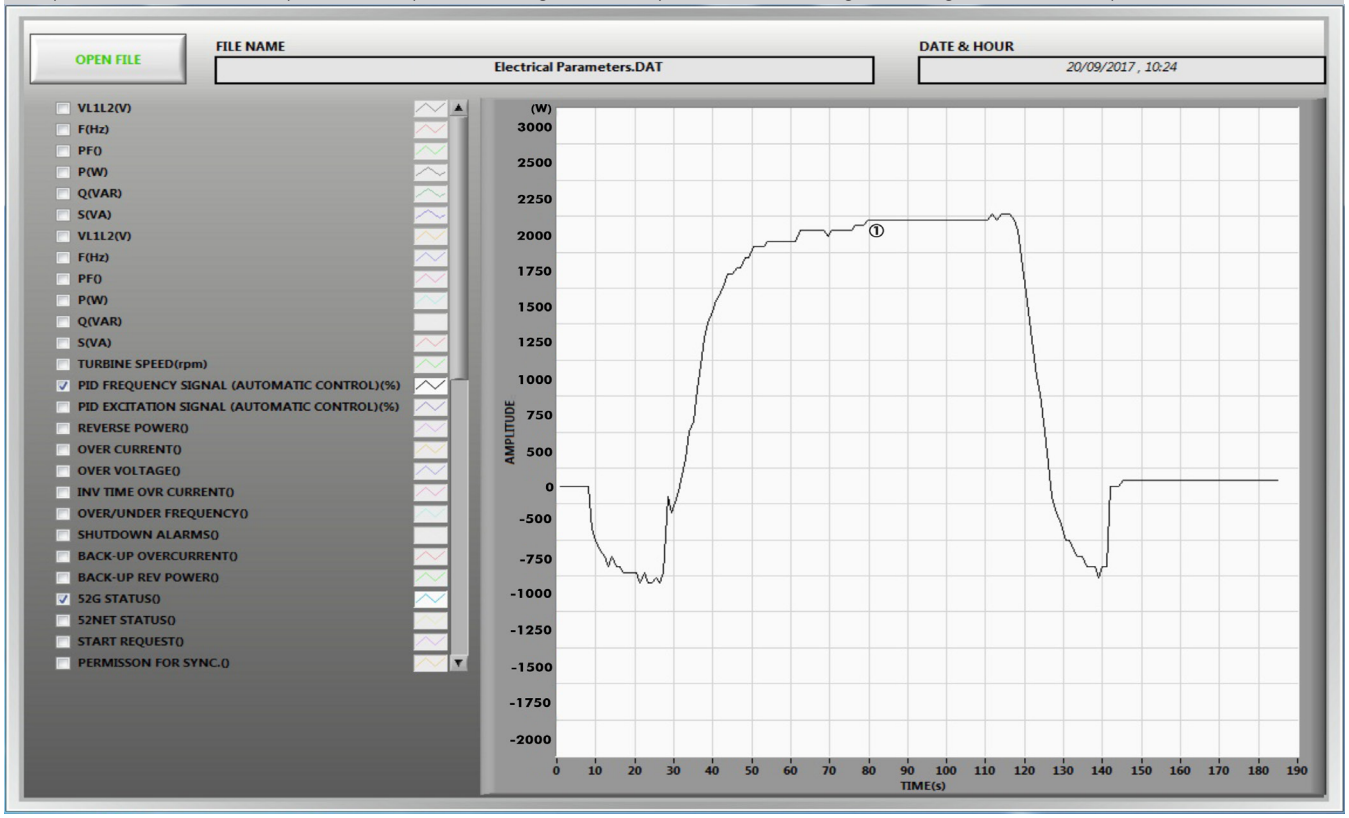
Offered in this catalogue:

- AEL-LPSG. Low Power Synchronous Generators Application.

Offered in other catalogue:

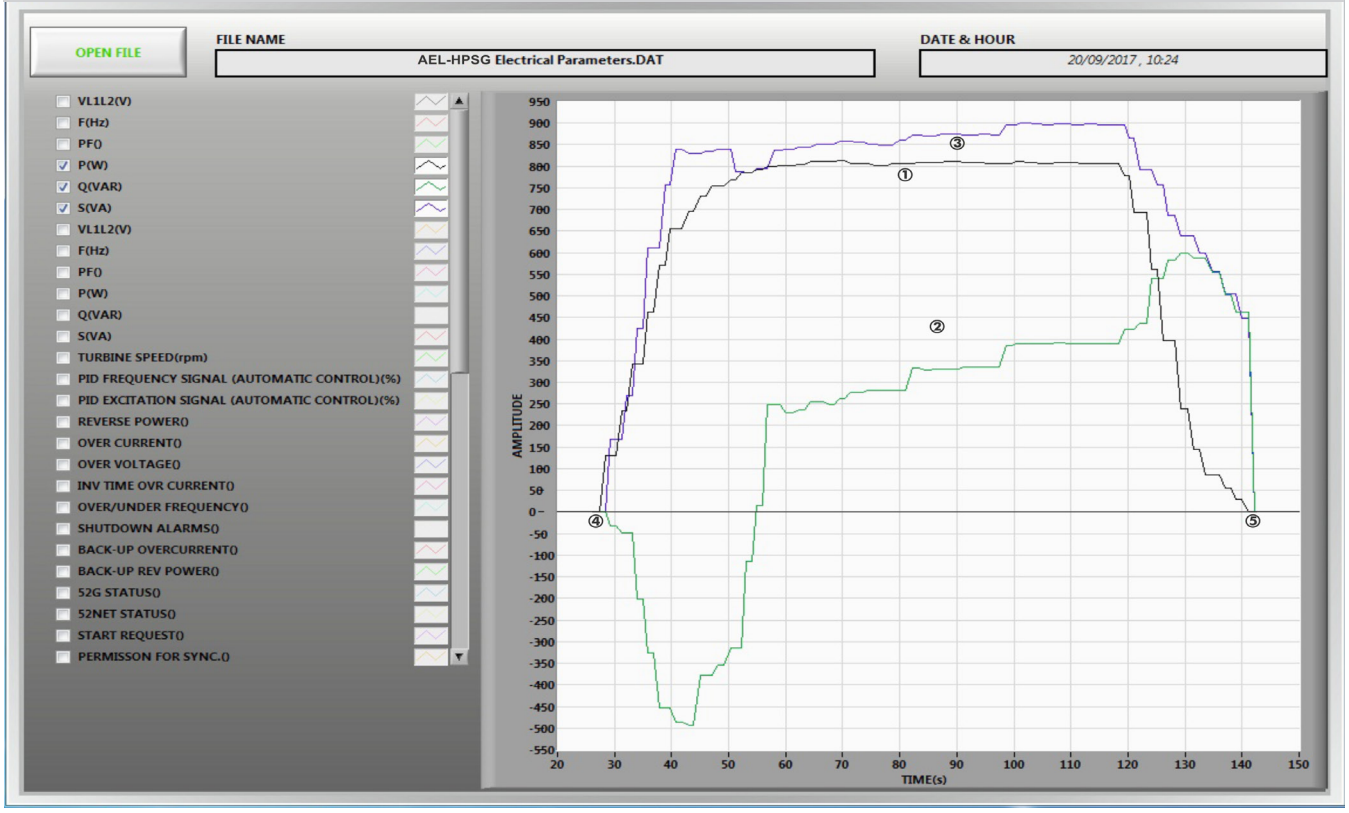
- TDEGC. Computer Controlled Diesel Engine Electrical Generator Application.
- AEL-EPP. Energy Power Plants Application.
- AEL-EEA. Alternators Study Application.
- AEL-HPSG. High Power Synchronous Generators Application.

This picture shows a the active power curvereport since the generator is synchronized with the grid till the generator is uncoupled of it.



① Active power curve Reported.

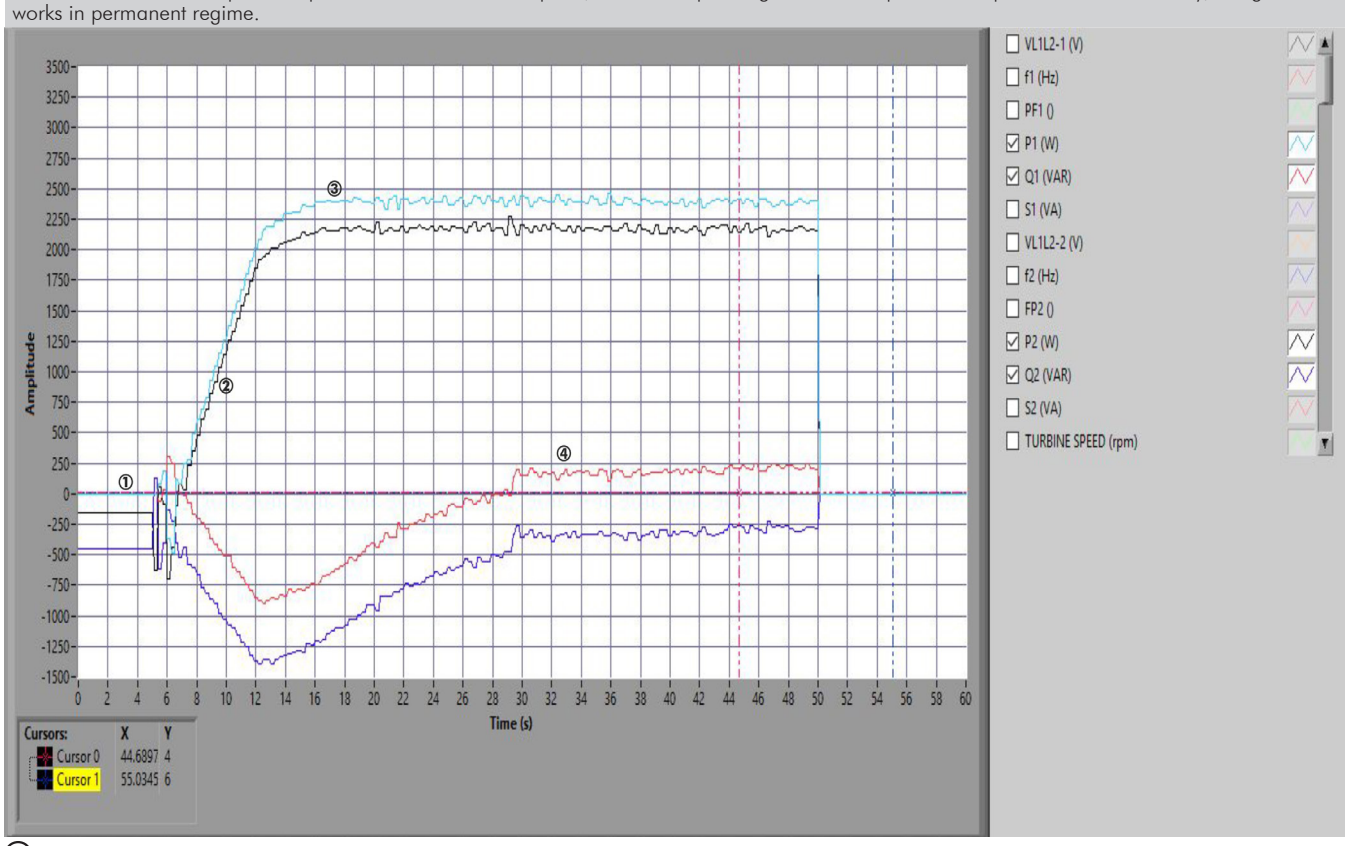
This picture shows the processes of synchronization, active and reactive power generation and uncoupling generator.



① Generator Active Power Wave.
② Generator Reactive Power Wave.
③ Generator Apparent Power Wave.
④ Synchronization.
⑤ Uncoupling generator.

Some **real** results obtained from this unit with the recommended software **EMG-SCADA**

This picture shows the synchronization process between the generator and the grid. In the first stage, the turbine is unstable (0 - 6 sec.) and there are fluctuations in P and Q powers up to 6 seconds. After this point, the active power generator ramp is linear up to 18 seconds. Finaly, the generator works in permanent regime.



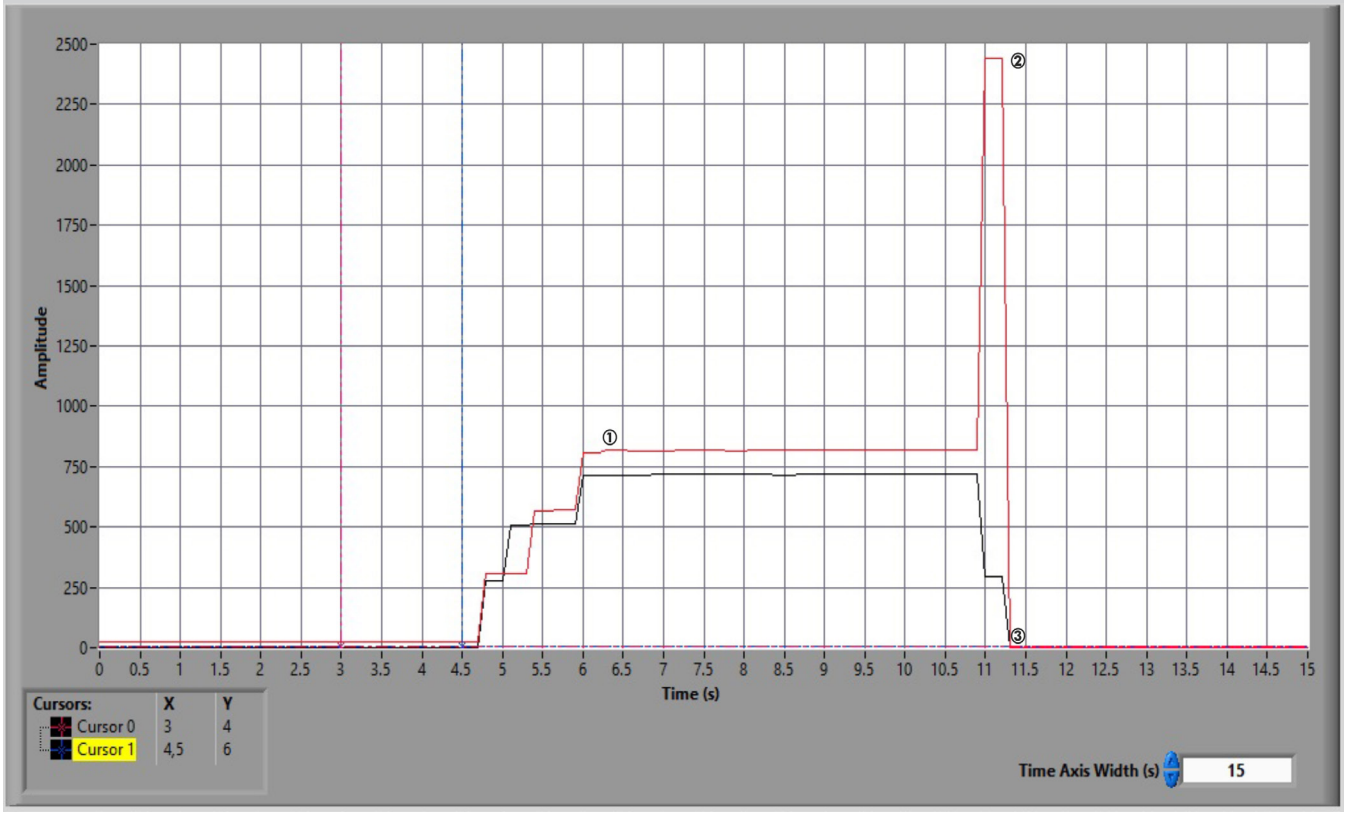
① Generation of active power in permanent regimen in parallel with the grid.

② Generator loading ramp.

③ Reactive power wave during synchronization and loading of generator.

④ Coupling of the generator with the grid.

This picture shows the generation/demand of active power while the injection of a fault and the stopping of the machine after this fault.

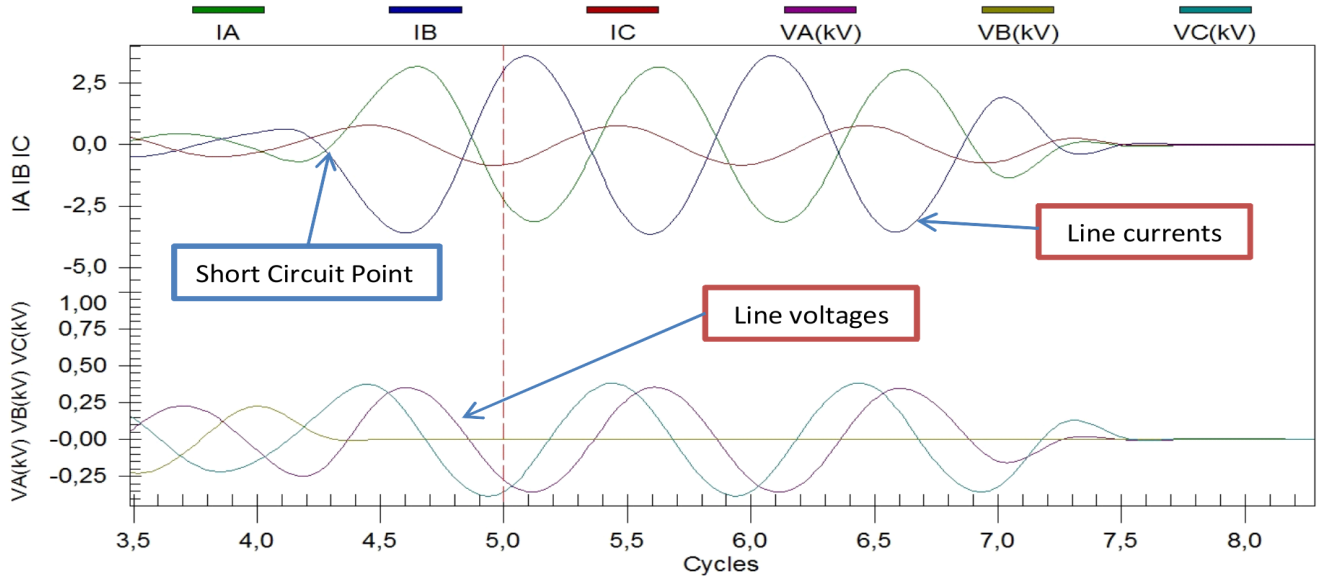


① Active power consumption.

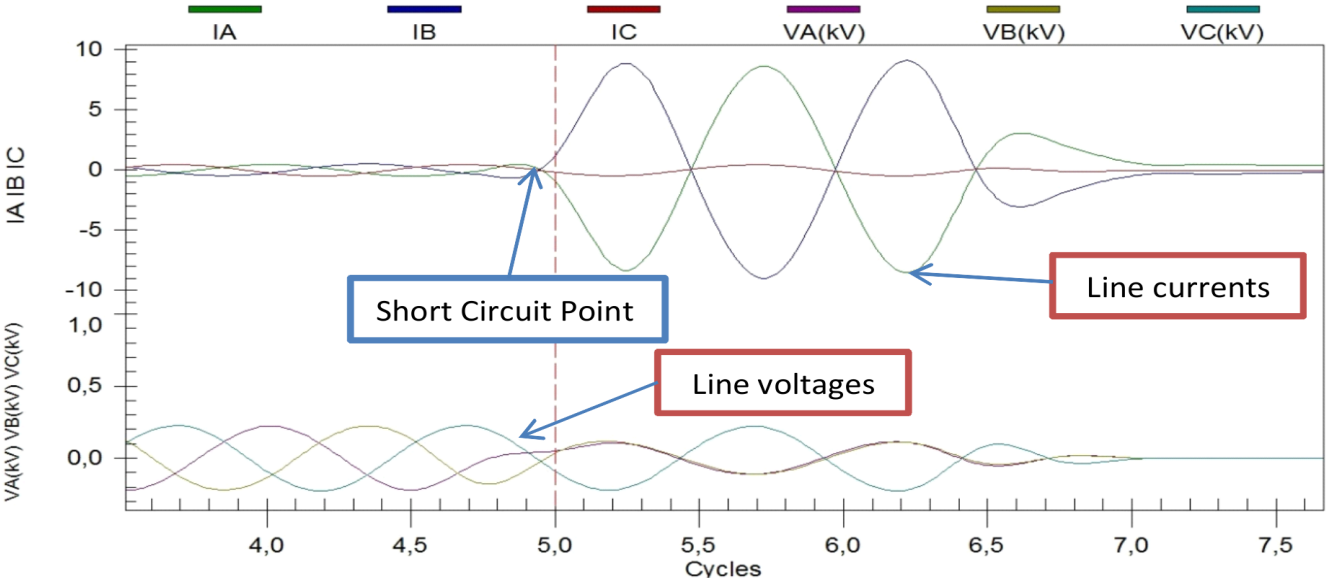
② Fault overcurrent.

③ Turning off the generator.

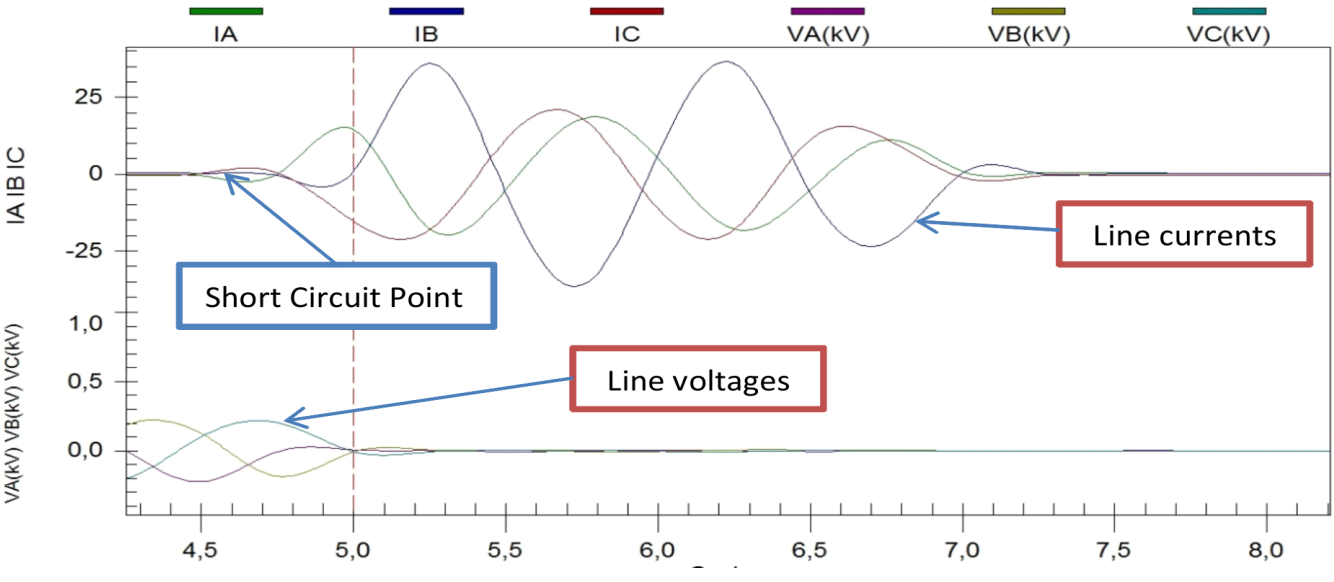
Some **real** results obtained from this unit with the recommended software **EMG-SCADA**



Two-Pole Short Circuit with fault impedance screen

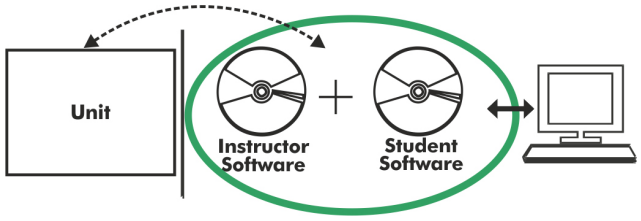


Two-Pole Short Circuit screen



Three-Pole Short Circuit screen

AEL-LPSG/ICAI. Interactive Computer Aided Instruction Software System:



With no physical connection between unit and computer, **this complete software package consists of an Instructor Software (EDIBON Classroom Manager -ECM-SOF) totally integrated with the Student Software (EDIBON Student Labsoft -ESL-SOF)**. Both are interconnected so that the teacher knows at any moment what is the theoretical and practical knowledge of the students.

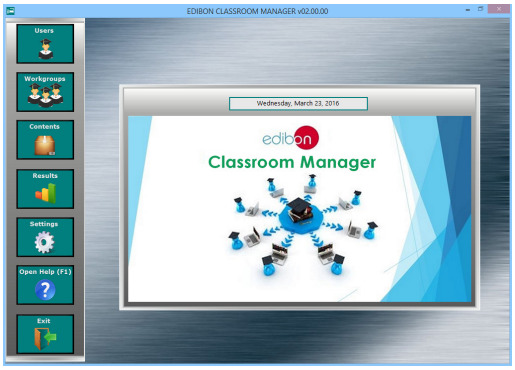
Instructor Software

- ECM-SOF. EDIBON Classroom Manager (Instructor Software).

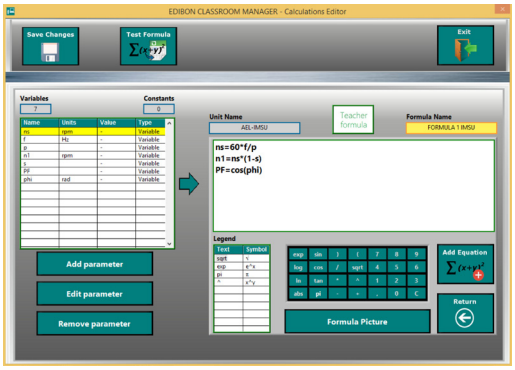
ECM-SOF is the application that allows the Instructor to register students, manage and assign tasks for workgroups, create own content to carry out Practical Exercises, choose one of the evaluation methods to check the Student knowledge and monitor the progression related to the planned tasks for individual students, workgroups, units, etc... so the teacher can know in real time the level of understanding of any student in the classroom.

Innovative features:

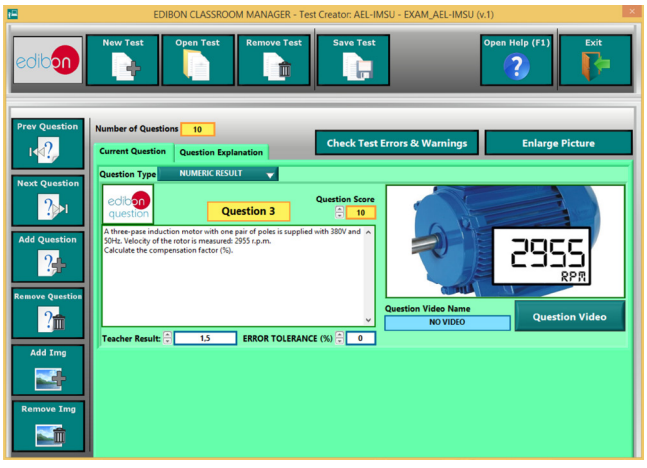
- User Data Base Management.
- Administration and assignment of Workgroup, Task and Training sessions.
- Creation and Integration of Practical Exercises and Multimedia Resources.
- Custom Design of Evaluation Methods.
- Creation and assignment of Formulas & Equations.
- Equation System Solver Engine.
- Updatable Contents.
- Report generation, User Progression Monitoring and Statistics.



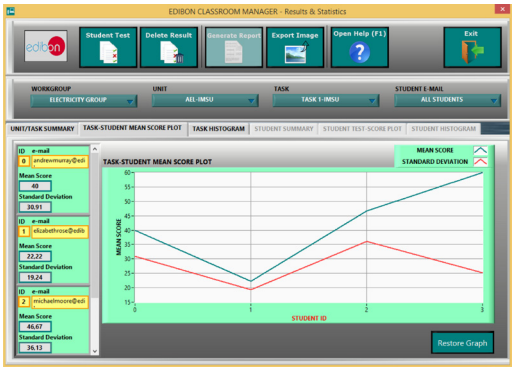
ECM-SOF. EDIBON Classroom Manager (Instructor Software) Application Main Screen



ECAL. EDIBON Calculations Program Package - Formula Editor Screen



ETTE. EDIBON Training Test & Exam Program Package - Main Screen with Numeric Result Question



ERS. EDIBON Results & Statistics Program Package - Student Scores Histogram

Optional

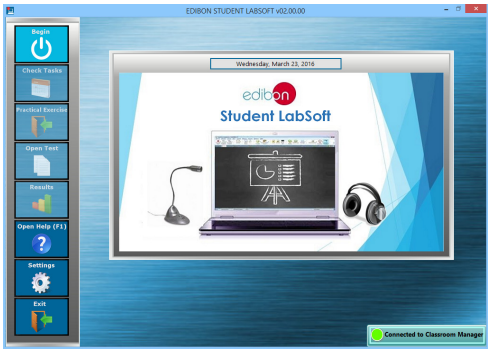
Student Software

- ESL-SOF. EDIBON Student Labsoft (Student Software).

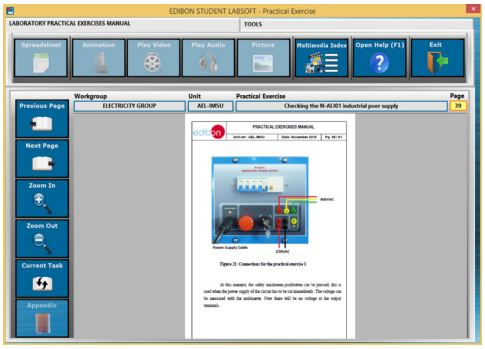
ESL-SOF is the application addressed to the Students that helps them to understand theoretical concepts by means of practical exercises and to prove their knowledge and progression by performing tests and calculations in addition to Multimedia Resources. Default planned tasks and an Open workgroup are provided by EDIBON to allow the students start working from the first session. Reports and statistics are available to know their progression at any time, as well as explanations for every exercise to reinforce the theoretically acquired technical knowledge.

Innovative features:

- **Student Log-In & Self-Registration.**
- **Existing Tasks checking & Monitoring.**
- **Default contents & scheduled tasks available to be used from the first session.**
- **Practical Exercises accomplishment by following the Manual provided by EDIBON.**
- **Evaluation Methods to prove your knowledge and progression.**
- **Test self-correction.**
- **Calculations computing and plotting.**
- **Equation System Solver Engine.**
- **User Monitoring Learning & Printable Reports.**
- **Multimedia-Supported auxiliary resources.**



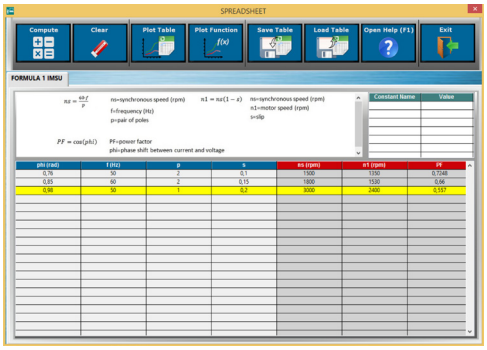
ESL-SOF. EDIBON Student LabSoft (Student Software) Application Main Screen



EPE. EDIBON Practical Exercise Program Package Main Screen

For more information see **ICAI** catalogue. Click on the following link:
www.edibon.com/en/files/expansion/ICAI/catalog

ERS. EDIBON Results & Statistics Program Package - Question Explanation



ECAL. EDIBON Calculations Program Package Main Screen

✱ Specifications subject to change without previous notice, due to the convenience of improvement of the product.

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REPRESENTATIVE: