Engineering and Technical Teaching Equipment

Photovotaic Systems Application in Isolated and Parallel Grids

AEL-PHIP

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PRODUCTS
4.- ELECTRICITY

INTRODUCTION

Energy saving and environmental pollution are crucial global issues. The use of renewable energies as alternative sources to fossil fuels can solve both problems, with great benefits particularly for countries where conventional energy sources are scarce. In the last two decades, photovoltaic energy has evolved from small-scale applications to become a dominant energy source.

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 Photovoltaic Systems Application in Isolated and Parallel Grids, "AEL-PHIP", has been designed to study the operations carried out in photovoltaic power systems which operate isolated from the national energy grid (island operation) or connected to it (parallel operation). This application allows studying the electricity generation by means of photovoltaic panels, through the simulation of different configurations and irradiance conditions, as well as its working in island and parallel to grid operation. To that end, the application also allows proving and understanding the working principles of the different control, regulation and energy storage devices used in real photovoltaic systems. For these purposes, the "AEL-PHIP" application consists of different kits that allow studying several aspects of photovoltaic power plants:

- PHIP-K1. Analysis of Series and Parallel Photovoltaic Modules Kit.
- PHIP-K2. Off-Grid Single-Phase Photovoltaic Systems Kit.
- PHIP-K3. Single-Phase Photovoltaic Systems for Parallel to Grid Operation Kit.

Each kit's didactic purpose is detailed below:

- **PHIP-K1. Analysis of Series and Parallel Photovoltaic Modules Kit.**

  This kit consists of a photovoltaic module assembled on a wheeled structure that allows varying the solar module tilt angle. Thus, different roof tilts or typical structures can be simulated, above which these photovoltaic modules are installed. A halogen lamp mounted on an articulated arm is coupled to the mentioned structure for the sun's path simulation. The lamp has a current regulator which allows controlling the incident irradiance on the photovoltaic panel. In order to simulate the solar panel load, the kit includes a variable resistive load.

  This kit also includes a solar simulation module consisting of three photovoltaic panel simulators, which allow working without the halogen lamp lighting. Each panel simulator has a regulator for the adjustment of solar irradiance and an analog voltmeter and ammeter for measuring the generation electrical parameters.

  With this kit, the user will be able to achieve the following learning: daily and yearly curves display, calculation of the photovoltaic modules optimal position, characteristic curves display and photovoltaic modules analysis in parallel, series and other configurations.

- **PHIP-K2. Off-Grid Single-Phase Photovoltaic Systems Kit.**

  This kit consists of all the industrial elements needed to study and understand the operation of a real photovoltaic system which operates in island mode. Firstly, it includes an electronic regulator whose purpose is to control the battery charge flow and the inverter input power flow. In addition, this kit includes a sinusoidal wave inverter which transforms the DC current coming from the regulator into single-phase AC current. Both at the regulator and inverter outputs, AC and DC loads are connected respectively, whose purpose is to consume the generated energy. These loads are AC and DC lamps with different power consumption. This kit also includes a network analyzer for monitoring the system electrical parameters and an analog voltmeter and ammeter with the goal of connecting them to the battery terminals for measuring its operating current and voltage.

  With this kit the user will be able to achieve the following learning: installation of photovoltaic systems, measurement of the plant electrical parameters and design and operation of photovoltaic systems isolated from the grid in direct or storage operation.

- **PHIP-K3. Single-Phase Photovoltaic Systems for Grid-Parallel Operation Kit.**

  This kit consists of the industrial elements needed to study and understand the operation of the photovoltaic systems which operate in parallel to the grid mode. To that end, it includes an industrial inverter which provides the grid with the generated power. The grid is represented by the power supply included in the base unit. The grid inverter monitors voltage, current and grid impedance for an emergency disconnection in case of deviations or faults that may be dangerous. This kit also includes a network analyzer for monitoring the electrical parameters of the power flux supplied to the grid.

  The "PHIP-UB" is the base unit of the "AEL-PHIP" application.

  The "PHIP-UB" unit includes the following elements:

  - N-ALI02. Domestic Main Power Supply.

  At least one of the following kits is required to work with the "PHIP-UB" unit:

  - PHIP-K1. Analysis of Series and Parallel Photovoltaic Modules Kit.
    - PESS. Photovoltaic Module with Solar Path Simulation.
    - N-EAL-DC. DC Network Analyzer Unit.
    - N-REV01. Single-Phase Variable Resistor Module 0-1 kOhm.
    - N-SSM. Solar Simulation Module.
  - PHIP-K2. Off-grid Single-Phase Photovoltaic Systems Kit.
    - BAT6. Lead-Acid Battery 6.
    - N-MED85. DC Ammeter (-6+6 A).
    - N-MED86. DC Voltmeter (0-15 V).
    - N-REG02. Current Electronic Regulator Module 2.
    - N-SWIN. Sine Wave Inverter.
    - N-EALD. Network Analyzer Unit with Data Acquisition.
    - N-LAM34. 3 AC Lamps Module.
    - N-LAM35. 2 DC Lamps Module.
  - PHIP-K3. Single-Phase Photovoltaic Systems for Grid-Parallel Operation Kit.
    - N-EALD. Network Analyzer Unit with Data Acquisition.
    - N-INV04. Single-Phase Grid Inverter Module 4.

The application AEL-PHIP 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-ALI02. **Domestic Main Power Supply.**
  Supply voltage: 230 VAC (single-phase), PH+N+G.
  ON-OFF removable key.
  Output voltage connections:
  Single-Phase: 230 VAC, PH+N+G.
  Single-phase supply hose with plug connection.
  Differential magnetothermal, 2 poles, 25 A, 30 mA AC 6KA.


N-ALI02

- PESS. **Photovoltaic Module with Solar Path Simulation.**
  Photovoltaic panel:
  Maximum power : 15 W.
  Open circuit voltage: 1,96 V.
  DC current: 1 A.
  Nominal current: 0,83 A.
  Nominal voltage: 18 V.
  Halogen lamp: 500 W.
  Voltage supply: 230 VAC.


PESS

- N-EAL-DC. **DC Network Analyzer Unit.**
  DC analyzer module for measuring DC current and voltages.
  Characteristics:
  Phase voltage, phase current, active power, mean power, active energy, bidirectional measurement.
  Communications: Modbus RS-485.


N-EAL-DC

- N-REV01. **Single-Phase Variable Resistor Module 0-1 kOhm.**
  0-1 kOhm variable resistor.
  Maximum Power: 500 W.
  Potentiometer.
  Terminals:
  Three terminals for taking the maximum resistance or a variable value.


N-REV01

- N-SSM. **Solar Simulation Module.**
  3 photovoltaic panel simulators.
  No load voltage: 24 V.
  3 potentiometers for the adjustment of the simulated irradiance.
  3 DC ammeters.
  3 DC voltmeters.
  Bypass diodes.
  Short circuit protection.


N-SSM

- BAT6. **Lead-Acid Battery 6.**
  Battery voltage: 12 V.
  Charge and discharge current: 23 A.
  Battery capacity: 7Ah.


BAT6

- N-MED85. **DC Ammeter (-6+6A).**
  Measurement range: - 6 A +6 A.
  Terminals:
  Measuring terminals.
  Ground terminals.


N-MED85

- N-MED86. **DC Voltmeter (0-15 V)**
  Measurement range: 0-15 V.
  Terminals:
  Measuring terminals.
  Ground terminal.


N-MED86

- N-REG02. **Current Electronic Regulator Module 2.**
  Automatic detection of operating voltage of 12V or 24V.
  Monitoring of parameters:
    Voltage.
    Current.
    Charge level of the battery.
    Charging current.
    State.
    Devices with self-protection, battery and loads.


N-REG02

- N-SWIN. **Sine Wave Inverter.**
  Nominal Power: 375 VA.
  Input Voltage: 12 VDC.
  Output voltage range: 210-245 VAC.


N-SWIN

- N-EALD. **Network Analyzer Unit with Data Acquisition.**
  The network analyzer module allows fulfilling measurements, displaying and analyzing all the parameters of the AC electrical networks. It has an 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, alarms 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 40th 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 40th 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-EALD

- N-LAM34. **3 AC Lamps Module.**
  Lamps voltage: 230 VAC (PH+N).
  Conventional lamp: 25 W.
  Low consumption lamp: 4 W.
  LED lamp: 2 W.
  Three switches.


N-LAM34

- N-LAMP35. **2 DC Lamps Module.**
  Lamps voltage: 12 VDC.
  Halogen lamp: 25 W.
  LED lamp: 2 W.
  Two switches.


N-LAM35

- N-INV04. **Single-Phase Grid Inverter Module 4.**
  Input voltage: 40-80 V.
  Power: 350 W.
  Output voltage: 230 VAC/50 Hz.
  Maximum Input current : 9 A.
  Efficiency: 95 %.
  Emergency disconnection for grid protection.


N-INV04

- **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.

EXERCISES AND PRACTICAL POSSIBILITIES

Practical possibilities with the PHIP-K1 kit:

1.- Daily and yearly curves display.

2.- Calculation of the photovoltaic modules optimal position.

3.- Display of the photovoltaic modules characteristic curves.

4.- Working of bypass diodes.

5.- Series and parallel configuration of the photovoltaic modules.

6.- Analysis of the simulated generation with different configurations of the photovoltaic modules and different solar irradiation conditions.

Practical possibilities with the PHIP-K2 kit:

7.- Installation of photovoltaic plants.

8.- Measuring the electrical parameters of the photovoltaic generation system.

9.- Designing and testing a photovoltaic system isolated from the grid in direct operation.

10.- Designing and testing a photovoltaic system isolated from the grid in storage operation.

11.- Designing and testing a photovoltaic system isolated from the grid with AC voltage supply and energy storage.

Practical possibilities with the PHIP-K3 kit:

12.- Installation of photovoltaic plants.

13.- Measuring the electrical parameters of the photovoltaic generation system.

14.- Designing and testing grid-connected (or parallel) photovoltaic systems.

15.- Determining the industrial inverter efficiency.

16.- Analysis of the photovoltaic system response to a grid black-out.

REQUIRED SERVICES

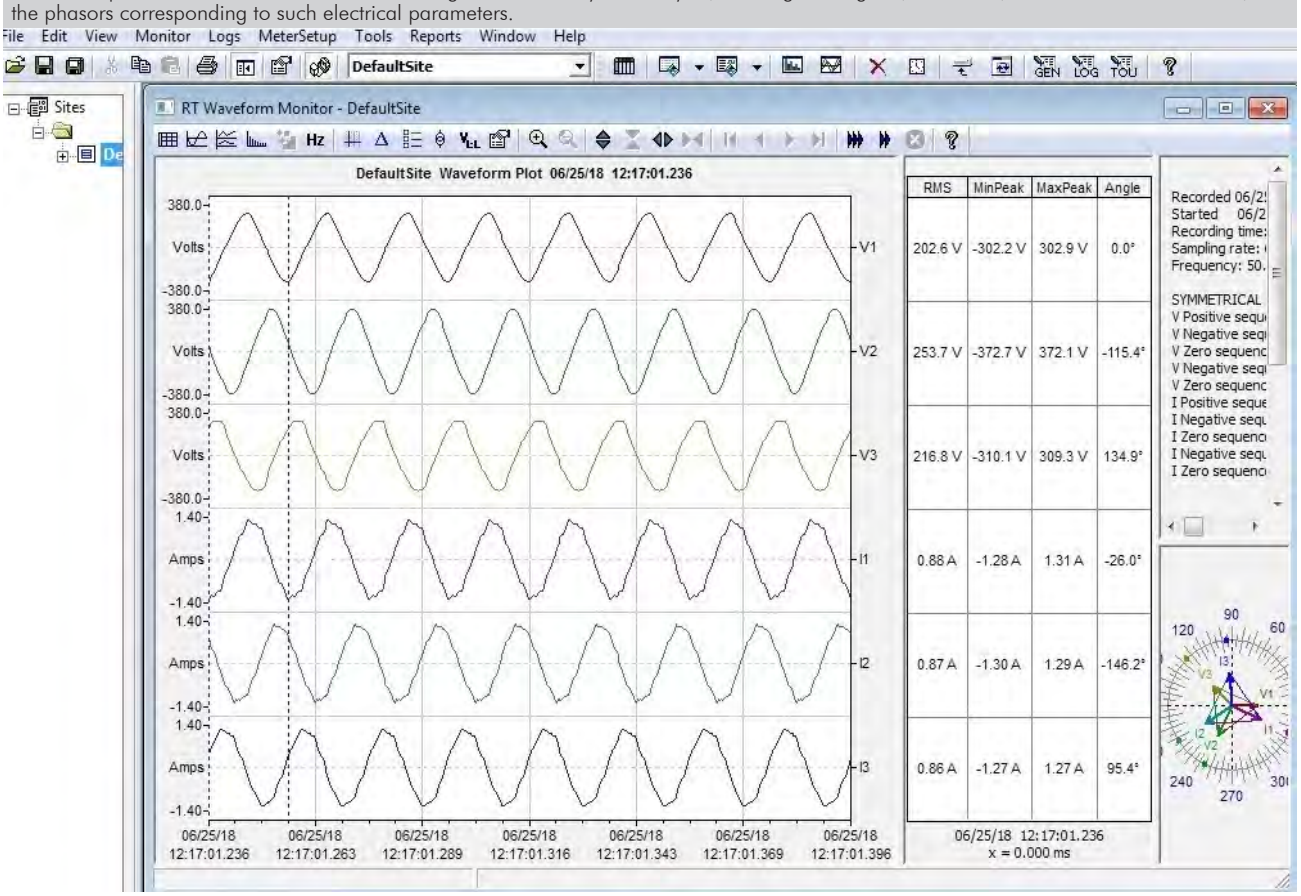
- Electrical supply: Single-Phase, 220 V/50 Hz or 110 V/60 Hz, 1 kW.

DIMENSIONS AND WEIGHTS

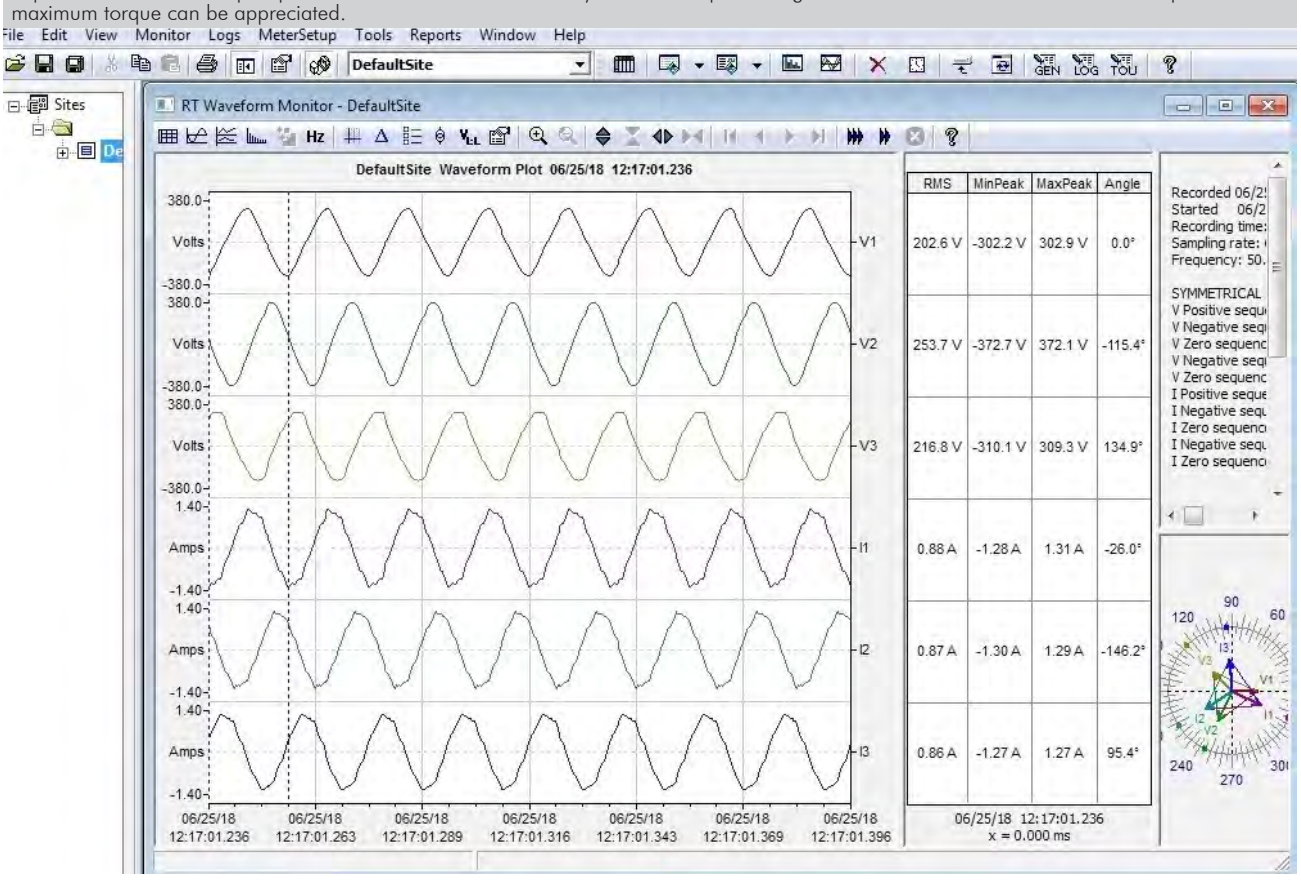
AEL-PHIP:

- Dimensions: 640 x 320 x 670 mm approx.
  (25,19 x 12,59 x 26,37 inches approx).
- Weight: 35 Kg approx.
  (77,16 pounds approx).

Waveform plot of the real time currents and voltages measured by the analyzer, showing the angular, maximum, minimum and RMS values, and the phasors corresponding to such electrical parameters.

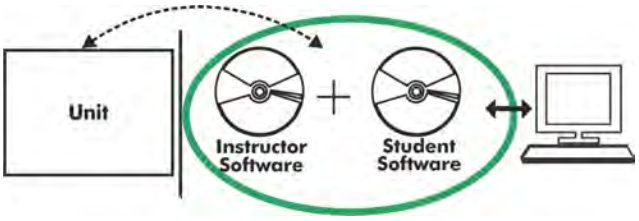


Representation of the torque-speed curve for the Three-Phase Asynchronous Squirrel Cage Motor. Notice that the motor nominal speed and the maximum torque can be appreciated.



Optional

AEL-PHIP/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.

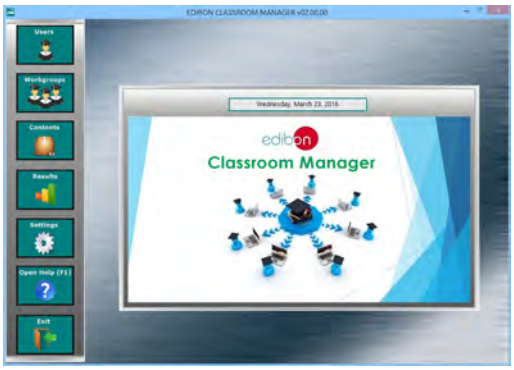
Instructor Software

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

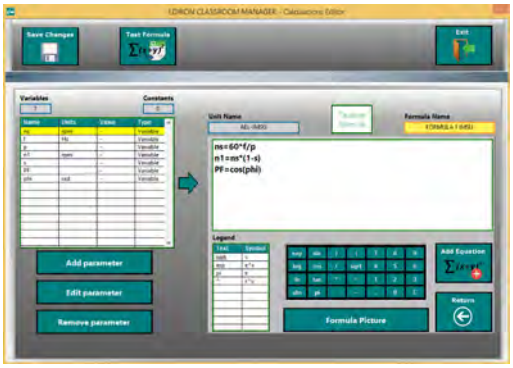
ECM-SOF is the application that allows the Instructor to register students, manage and assign tasks for workgroups, create own content to carry out Practical Exercises, choose one of the evaluation methods to check the Student knowledge and monitor the progression related to the planned tasks for individual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

Innovative features:

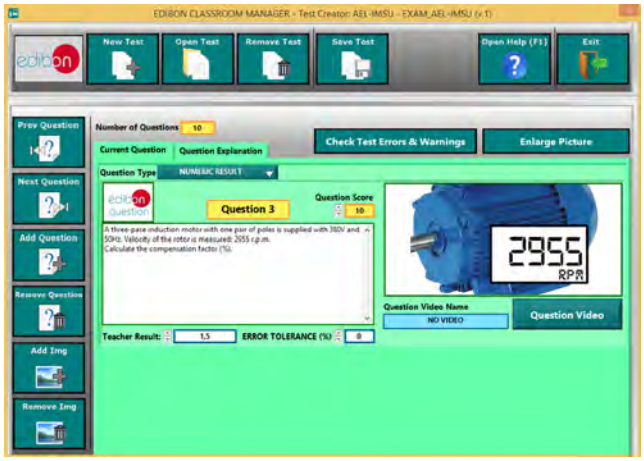
- **User Data Base Management.**
- **Administration and assignment of Workgroup, Task and Training sessions.**
- **Creation and Integration of Practical Exercises and Multimedia Resources.**
- **Custom Design of Evaluation Methods.**
- **Creation and assignment of Formulas & Equations.**
- **Equation 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:

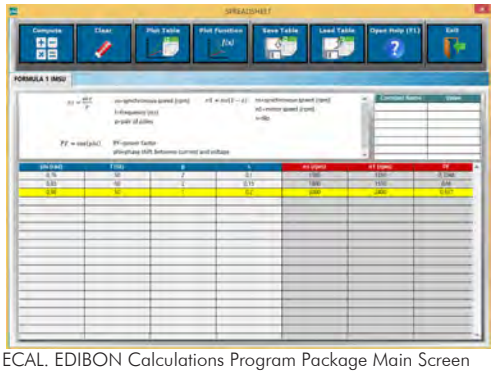
- **Student Log-In & Self-Registration.**
- **Existing Tasks checking & Monitoring.**
- **Default contents & scheduled tasks available to be used from the first session.**
- **Practical Exercises accomplishment by following the Manual provided by EDIBON.**
- **Evaluation Methods to prove your knowledge 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: