INTRODUCTION

WHY A SMART GRID?

Since the early 21st century, opportunities to take advantage of improvements in electronic communication technology to resolve the limitations and costs of the electrical grid have become apparent.

Technological limitations on metering no longer force peak power prices to be averaged out and passed on to all consumers equally.

In parallel, growing concerns over environmental damage from fossil-fired power stations has led to a desire to use large amounts of renewable energy.

Dominant forms such as wind power and solar power are highly variable, and so the need for more sophisticated control systems became apparent, to facilitate the connection of sources to the otherwise highly controllable grid. Power from photovoltaic cells (and to a lesser extent wind turbines) has also, significantly, called into question the imperative for large, centralised power stations.

The rapidly falling costs point to a major change from the centralised grid topology to one that is highly distributed, with power being both generated and consumed right at the limits of the grid.

Finally, growing concern over terrorist attack in some countries has led to calls for a more robust energy grid that is less dependent on centralised power stations that were perceived to be potential attack targets.

SMART GRID

WHAT IS A SMART GRID?

The Smart Grid is a system for an "intelligent distribution" of electricity, able to know the consumption of the various end users and to manage the generation and distribution of electricity according to demand.

Simply put, if in a given area we have a potential overload of energy, the excess energy can be redistributed to other areas that need it, based on the actual requests from end users.

Furthermore, the software that runs the Smart Grid monitors the electrical flow of the system, integrates renewable energy into the network and activates / suspends the industrial or domestic processes during periods when electricity costs less / more.

The smart grid knows our requirement of power consumption. When the demand for electricity is at its maximum, the smart grid automatically adapts to the demand by picking up excess energy from many sources to avoid overload problems or interruptions of power.

It has, therefore, the function of sharing the electricity that is generated from various sources, both public and private, traditional and renewable, and ensuring that electrical devices use electricity as efficiently as possible.

WHAT IS A SCADA SOFTWARE?

The **SCADA** (Supervisory Control And Data Acquisition) is an industrial control system that performs the following functions:

- acquisition of the physical quantities that are needed for the control and the supervision of the system;
- control, by means of actuators, of its operation;
- supervision, to visually monitor, through the so termed synoptic diagrams, the operating status of the system, the alarms, etc., also in remote control.

SCADA systems supervise, control, optimize and manage the systems for the generation and transmission of electrical energy as well as the distribution networks.
They allow to collect, store and analyze data from hundreds of thousands of data points in national or regional networks, to model networks, to simulate operations, highlight faults, prevent them and finally participate in the energy markets.
They are a vital part of modern networks and enable the development of the smart grids that must handle enormous amounts of energy from renewable sources produced by generators of large and small scale, to maintain stability in the network despite the intermittency of these sources and the bidirectionality of the energy flow.

SMART GRID

DE LORENZO SOLUTION

The smart grid system developed by De Lorenzo can be organized in **eight subsystems**, each comprised of several modules. The first four subsystems are simulations of energy sources; the first one is the main power supply of the grid with a three-phase supply unit that represents a coal plant.

The other three subsystems correspond to alternative sources of energy: wind, hydroelectric and solar. The wind plant simulation is made with a three-phase induction motor acting as a generator while the hydroelectric plant simulation is made with a three-phase synchronous machine, additionally with a generator synchronizing relay module to make possible the connection to the grid. Finally, the solar energy part of the system is generated with a solar panel and four dimmable lamps simulating the sun, which is connected to an inverter module that allows the energy generated to be transferred to the grid.

A fifth subsystem in the smart grid consists of modules for fault protection; the modules are a feeder manager relay that measures in real time voltages and currents to detect faults in the grid and four power circuit breakers controlled by the previous module to disconnect faulty lines.

The sixth subsystem refers to modules for measuring; it has three maximum demand meters that measure AC voltages, currents, frequencies, active power, reactive power, apparent power, power factor and THD for each of the three available phases in the grid and two electrical power digital measuring units that, besides measuring the same as the previous module, make measurements of DC voltage, current, power and energy.

The seventh subsystem is for power factor control with 2 modules, the first one is a switchable capacitor battery with four different values of capacitors and the second one is a reactive power controller that activates the capacitors of the previous module to make a power factor correction.

The last subsystem is composed of passive elements; three modules with different kind of loads (capacitive, inductive, resistive) that simulate the loads in a house or factory and two modules with impedances simulating the losses generated in transmission lines, specifically in lines of 10 and 100 km length.

A **SCADA** software provides to the acquisition and storage of the data coming from the measurement instruments and to the control of the actuators for an “intelligent” management of the whole electrical system. The SCADA software can also be supplied on request in an OPEN version, so that the teacher can implement his own project and select modes and procedure for visualizing the parameters and controlling the actuators.

The system described above represents the basic configuration of our laboratory (DL SGWD).

Optionally, it is also possible to add an additional wind energy small scale generation system, with a real wind turbine connected to an inverter module to make possible the connection to the grid.

SMART GRID

Special configuration prepared for the Worlddidac Exhibition

TRAINING OBJECTIVES

The Smart Grid trainer can be considered a **multidisciplinary laboratory**, because it allows studying and exercising different technical subjects, that are then integrated in a full Smart Grid system setup.

Actually, the Smart Grid trainer is an integrated laboratory that can be useful for a huge number of undergraduate and graduate courses in the engineering school. The laboratory equipment can be configured to create different exercises, which reinforce basic and advanced concepts in electric energy. The equipment can be interconnected to form **a full smart grid system**. However, as you can see from the list of experiments in the next paragraph, conventional topics, such as electric machines, distribution systems and so on could be covered by the Smart Grid trainer; this innovative laboratory can include class demonstrations and laboratory experiments under regular laboratory classes.

There are fundamental topics that are needed for understanding the smart grid concept and they have to be connected with real life situations, yet a set of different topics could be added in order to get a special curricula. The **core topics** include: electric circuits, electric machinery, hydroelectricity, wind energy, photovoltaic solar energy, renewable energies, power transmission, power distribution.

Furthermore, **additional courses** can benefit from the smart grid trainer, such as, for example: power system engineering & analysis, electric machines, linear control systems, electrical distribution engineering and smart grids automation, power generation operation and control, power electronics, cost and construction of electrical supply, power system stability, optimization methods, stochastic processes, embedded systems.

The smart grid system can be used by mechanical and electrical engineering students as a longtime project as it comprises enough elements to cover most of the topics listed above.

Electric circuits' particular subjects can be studied through load modules, enabling the full understanding of resistive, capacitive and inductive loads, fed by AC or DC supply. A protected equipment permits the application of domestic and industrial rated electric magnitudes as well as their instrumentation. Particular effects of inductive loads and power factor correction are issues which can also be addressed.

The study of AC electric machinery can also be complemented with the practical insight provided by the induction and synchronous generators used to emulate a wind and a hydro-electrical power plant respectively.

Synchronization methods, power and instrumentation transformers, and the inner physical phenomena can be measured and studied as individual elements or as part of the whole power distribution system.

The entire system can be tested under many considerations as it is configurable, so different experiments can be driven based on the same principles. When analyzing distribution systems and fault schemes, the instrumentation and logical equipment can provide enough flexibility to understand the process between power generation and usage, together with abnormal events and their respective protective relaying issues. In this way, the topics added in the curricula which regard power management and distribution can also find room in the integrated long-term smart grid project, which can be also evaluated under efficiency concerns depending on load conditions or particular generators' states.

In this way, the smart grid as a set of individual modules or as a whole, enables the student to move towards a single objective necessarily going through each individual area, making possible the full understanding of smart grid theory, application, and capabilities, as well as the concerning steps of its integration.

The Smart Grid trainer also allows to understand **advanced topics** like energy production in wind plants that are connected to the main electric grid or they can be isolated as micro-grids, so the students can comprehend real problems in engineering which are imperative in the energy progress; thus, the basic and advanced courses can be combined in the wind turbine system. For example, wind generators include a pitch controller that increases the energy efficiency and the energy generated is sent to the central electric grid; hence, the students have to use several topics such as control systems, digital control, electric machines, and so on.

As an additional example, a combination of 3 energy sources can be studied when they are providing energy to the load. If the conventional source is combined with a wind and hydro energy, the student will be able to understand in a clear manner the process of providing energy to the load by alternative energy. Moreover, environmental questions can be included in the exercise (carbon footprint).

The number of exercises and topics can be expanded and the student is able to propose novel ideas about how to solve problems that affect the society; hence, the motivation of student can be increased.

In conclusion, engineering courses need to cover experimental concepts that increment the engineering knowledge of students but it is not easy to find experimental systems that allow to combine those concepts.

SMART GRID

Although Smart Grid is a quite complex problem that is impacting electrical energy, it could be used for leaning basic concepts like electric circuits; hence, this system includes all the elements for providing a real experience in the mechanical and electrical engineering curricula and impact the advanced and basic topics in the curricula. Smart Grid is a perfect system for teaching and involving students in experimental engineering problems. Besides, the student can deal with ecological and economical problems. The experimental use of solar and wind energy provides information about how the alternative sources of electrical energy can be used in large scale and low scale.

Our proposal includes exercises with the Smart Grid in different topics; thus, this system is the conductor for connecting theoretical and practical concepts.

LIST OF EXPERIMENTS

PHOTOVOLTAIC SYSTEM
Characterization of a photovoltaic panel without a load
Characterization of a photovoltaic panel with a load
Connecting a photovoltaic system to the real network by using a single-phase inverter grid system

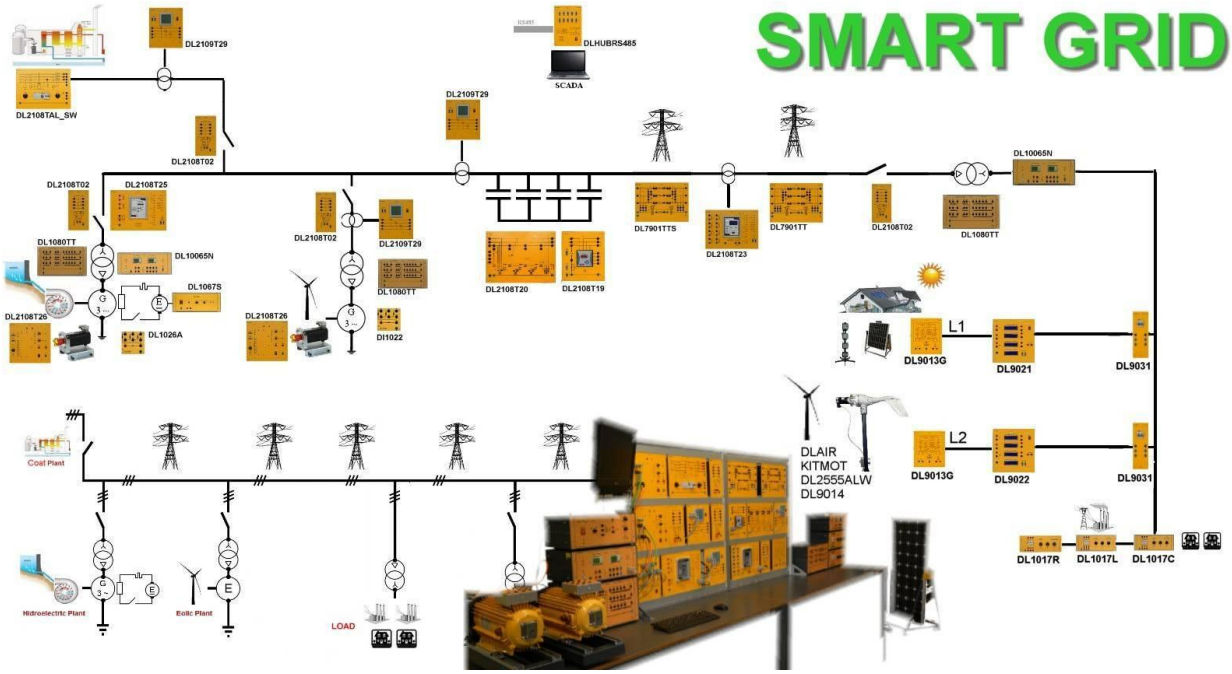
TRANSFORMER
Vector group
No load performance
Load performance
Asymmetrical performance
Regulation performance

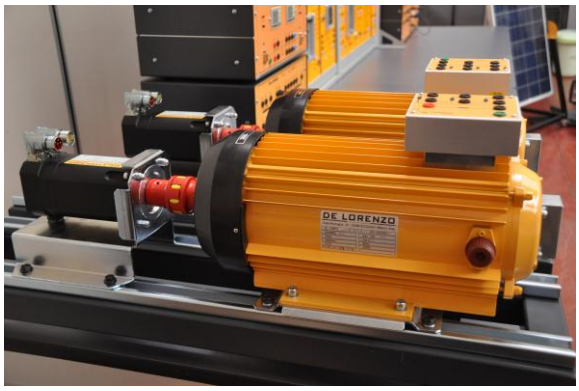
TRANSMISSION
No-load performance
Matched-load performance
Ohmic-inductive load
Ohmic-capacitive load
Automatic compensator
Transmission line radial network
Transmission line meshed network
Transmission line: fault-to-earth and protection
Transmission line earth fault protection
Transmission line under voltage protection
Transmission line over voltage protection

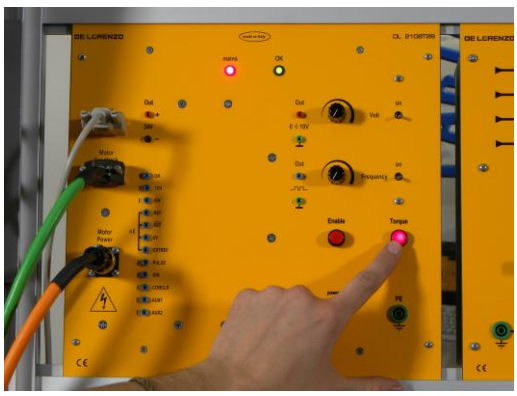
SMART GRID
Contribution of solar energy
Contribution of hydropower
Contribution of wind plant

SMART GRID

SMART GRID DIAGRAM







MANUALS

The system includes an experiment manual with a detailed description of the 22 experiments that we suggest for the system.

Furthermore, the system is supplied complete with the 300 page book "EXPERIMENTAL CONCEPTS OF SMART GRID TECHNOLOGY BASED ON DELORENZO SMART GRID", written by Dr. Pedro Ponce and Dr. Arturo Molina, from the Tecnológico de Monterrey (Mexico).
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10 APPENDIX 1: Smart grid components

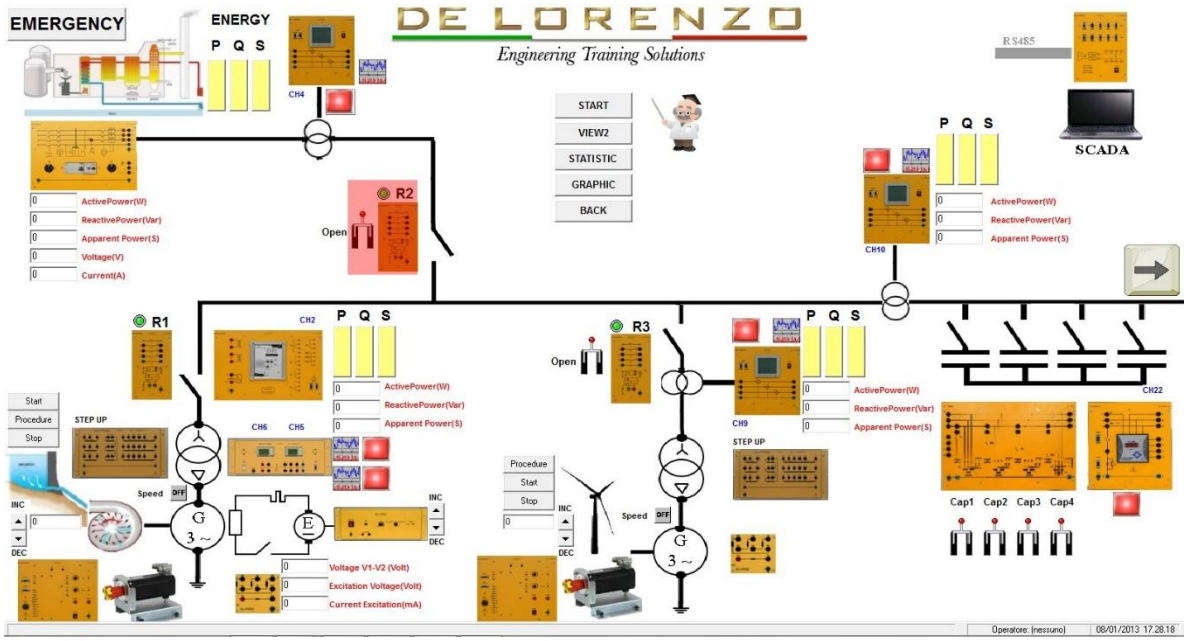
SAMPLE EXERCISE

CONTRIBUTION OF SOLAR ENERGY

Assume that there is demand for energy from a distant point and there is solar energy to be able to be exploited. In this exercise, the student will intervene by reducing the consumption of energy from a plant of old generation, using the surplus energy produced by solar photovoltaic systems.

The reduction of even a minimum absorbed energy will certainly have an impact on the environmental pollution produced by a plant of the old generation.

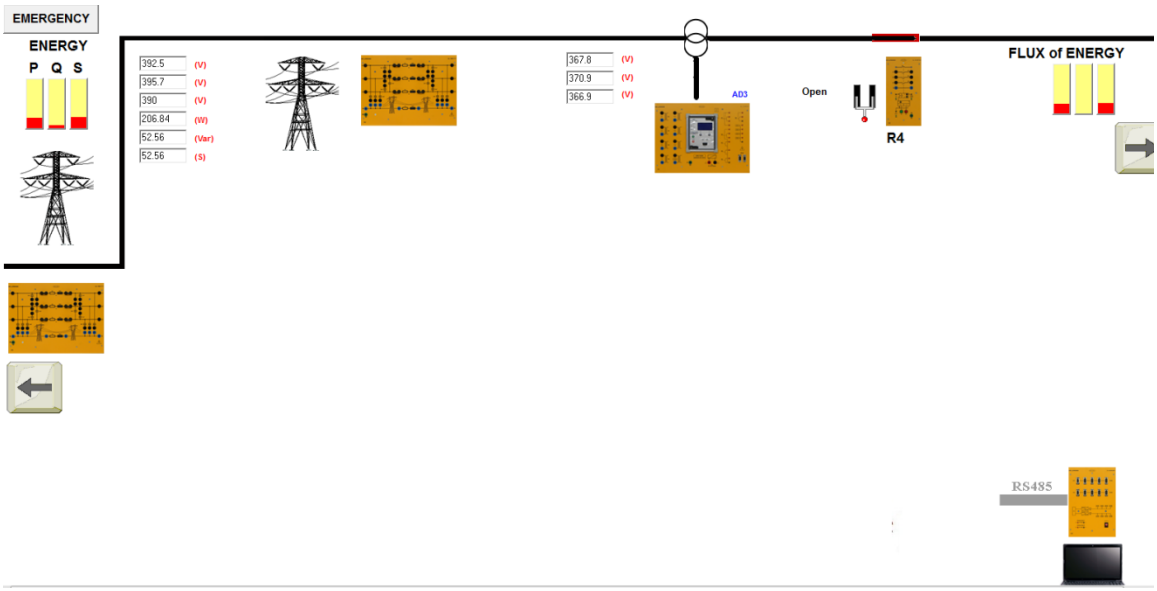
1. Set the load DL 1017R to position 2 and close the relay R2 to supply energy coming from the coal plant.



2. Close the relay R4 to transfer energy coming from the plant to the load and observe the power consumption on the module DL 2109T29.

DL 1017R Position	Active power [W]	Reactive power [VAR]
2	207.64	52.32
3	310.00	101.00

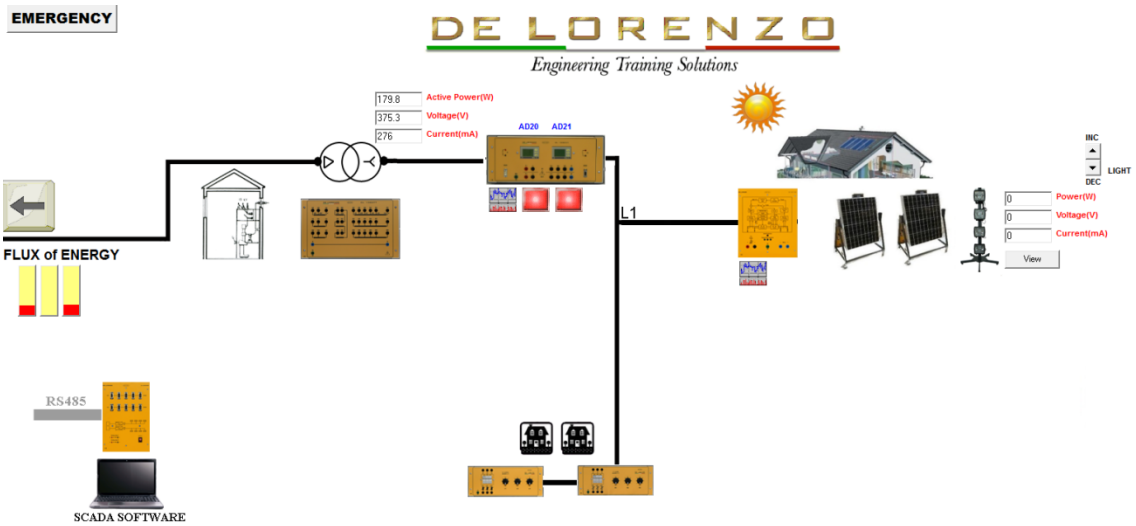
In this situation you can see the active power required from the resistive load (DL 1017R) and a few of reactive power required from the primary of the step down transformer.



3. Observe the active power consumption indicated by the red arrow after the step down secondary transformer.

DL 1017R Position	Active power [W]
2	179.9
3	275.1

In this situation, the total energy coming from the coal plant and directed to the load, crossing the long distance, produces a power loss in the transmission line.



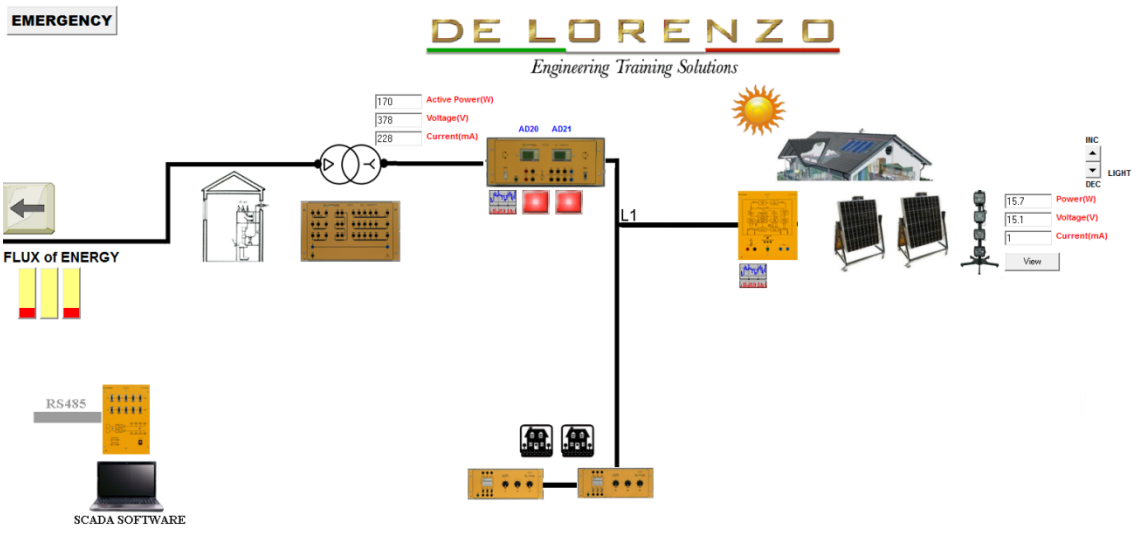
4. Increment the sun energy and check the contribution of energy coming from the photovoltaic system plant.

DL 1017R Position	Active power [W]
2	15.7
3	12.3

(with light at 100% and panel in 90°)

The active power coming from the coal plant is going to be reduced and as well then the reduction of pollution in terms of CO_2. If you convert the reduction of power in reduction of pollution in large scale, we can give a big contribution to environment.

The reduction of the power energy is less if you use the artificial lights, but if you orient the photovoltaic panel to the real sun the contribution would be higher.



SMART GRID

LIST OF MODULES

DL 2108T26	BRUSHLESS CONTROLLER WITH MOTOR	2
DL 1021/4	THREE-PHASE ASYNCHRONOUS MOTOR	1
DL 1013A	BASE	2
DL 1026P4	THREE-PHASE SYNCHRONOUS MACHINE	1
DL 1017R	RESISTIVE LOAD	1
DL 1017L	INDUCTIVE LOAD	1
DL 1017C	CAPACITIVE LOAD	1
DL 2108TAL-CP	THREE PHASE SUPPLY UNIT	1
DL 1067S	MOTOR DRIVEN POWER SUPPLY	1
DL 7901TT	OVERHEAD LINE MODEL – 360 KM	1
DL 7901TTS	OVERHEAD LINE MODEL – 110 KM	1
DL 10065N	ELECTRICAL POWER DIGITAL MEASURING UNIT	2
DL 2109T29	THREE-PHASE POWER METER	3
DL 2108T25	GENERATOR SYNCHRONIZING RELAY	1
DL 2108T23	FEEDER MANAGER RELAY	1
DL 2108T02	POWER CIRCUIT BREAKER	3
DL 2108T02A	POWER CIRCUIT BREAKER	1
DL 2108T19	REACTIVE POWER CONTROLLER	1
DL 2108T20	SWITCHABLE CAPACITOR BATTERY	1
DL 9031	CIRCUIT BREAKER	1
DL 9013G	INVERTER GRID	1
PFS-85	PHOTOVOLTAIC SOLAR PANEL	1
DL SIMSUN	LAMPS FOR THE PHOTOVOLTAIC SOLAR PANEL	1
DL WINDSIM	WIND SIMULATOR	1
DL HUBRS485F	MODBUS COMMUNICATION HUB	1
DL SCADA-WEB	SOFTWARE SCADA	1
DL 1080TT	THREE-PHASE TRANSFORMER	3
DL 1155SGWD	KIT OF CONNECTING LEADS	1
DL 1001-1-AS	WORKBENCH	2
DL 2100-3M-AS2	FRAME	1
DL PCGRID	ALL-IN-ONE PERSONAL COMPUTER	1
SOCKET-MAIN	MAIN SOCKETS	1
SOCKET-EXT	SOCKET EXTENSION	1
DL 2100TT	THREE-PHASE TRANSFORMER	1

If you want to order all the above, you must use the ordering code: DL SGWD

Options:

- **Wind energy grid connection.** It allows adding a wind energy system in parallel to the photovoltaic solar system in the utilization section of the system **– ordering code:**
  DL SGWD-W (which includes the DL SGWD and the DL WIND-A1G option).
- **Back to back inverter (DL 2108T29)**, that integrates in the Smart Grid system the Wind Power Plant trainer DL WPP. With this option, the three-phase squirrel cage motor (DL 1021/4) is substituted by the three-phase slip ring motor (DL 1022P4).
- **Wireless LAN.** It allows a wireless connection with laptops and tablets (not included) – **ordering code: DL TC78** (in addition to the DL SGWD)

THE MODULES

THREE PHASE SUPPLY UNIT

Power supply unit for three-phase connection with 4-pole cam mains switch.
25A current operated earth leakage circuit breaker, sensitivity 30 mA.
Three-phase indicator lamps.
Output through 5 safety terminals:
L1, L2, L3, N and PE.
Switch for simulation of wind or photovoltaic energy power source.

DL 2108TAL-CP

THREE-PHASE TRANSFORMER

Three-phase transformer for feeding a transmission line model 380 kV with scale factor 1:1000

Primary

- 3 x 380 V windings with tap at 220 V
- Star or delta connection

Secondary

- 3 x 220 V windings with taps at +5%,-5%,-10%,-15%
- Star connection for 3 x 380 V
- Various star connections possible
- Rated power: 800 VA

DL 1080TT

SMART GRID

FEEDER MANAGER RELAY

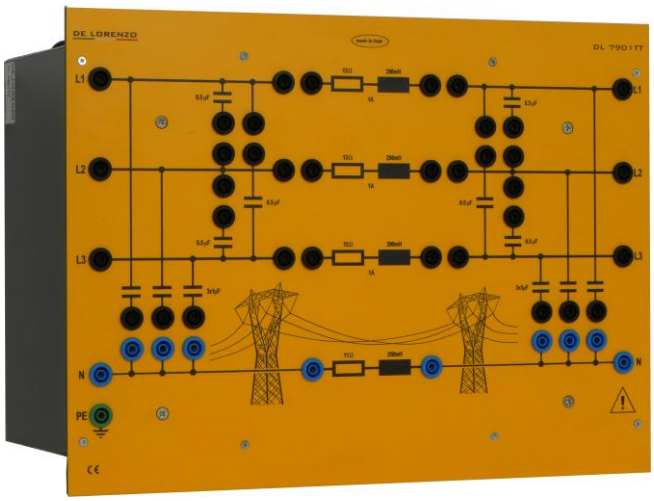
DL 2108T23

Three-phase Current, Voltage and Earth Fault multifunction relay for protection and management of MV/HV distribution lines.
Real time measurement of the primary value of the input quantities are continuously available from relay's display and from the serial communication port.
Relay's programming and setting can be made directly by the front face keyboard or via the serial communication ports.

Setting, event recording and oscillography are stored into non volatile memory (E2prom). The relay is fitted with a multivoltage, auto ranging power supply unit self protected and transformer isolated.

- Three levels for phase current independently programmable as directional or non directional
- Three levels for Earth Fault independently programmable as directional or non directional
- Selectable Time current curves according to IEC and IEEE standards
- Two over/under voltage levels
- Two over/under frequency levels
- Zero sequence overvoltage level
- Two Negative Sequence current levels
- One Positive Sequence overvoltage level
- One Negative Sequence under voltage level
- Two Reactive Power (VAR) control levels (optional)
- Trip circuit supervision
- Associated Circuit Breaker control (OPEN / CLOSE)
- Breaker failure protection
- RS232 serial communication port on Front Face
- RS485
- Output relays totally user programmable
- Digital inputs user programmable

LINE MODEL



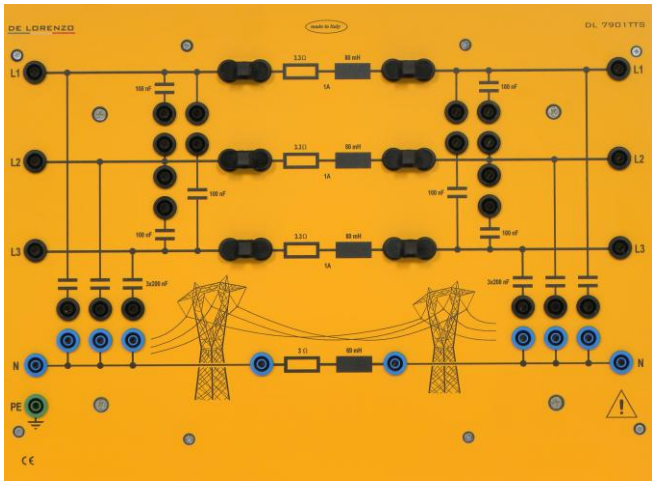
DL 7901TT

Three-phase model of an overhead power transmission line 360 km long, voltage 380 kV and current 1000 A.

- Scale factor: 1:1000

SMART GRID

LINE MODEL

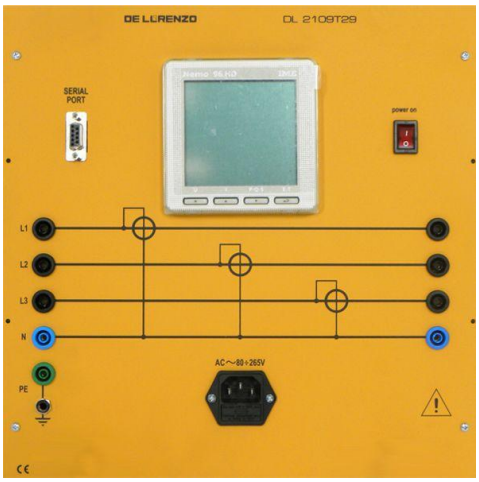


DL 7901TTS

Three-phase model of an overhead power transmission line 110 km long, voltage 380 kV and current 1000 A.

- Scale factor: 1:1000

MAXIMUM DEMAND METER

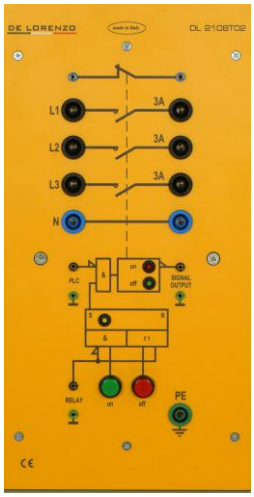


DL 2109T29

Microprocessor controlled three-phase power analyzer.
Measurement of voltages, currents, frequencies, active power, reactive power, apparent power.

- Input voltage: 500 V (max 800 Vrms)
- Input current: 5 A (max 20 Arms)
- Operating frequency: 47 ÷ 63 Hz
- Auxiliary supply: single-phase from mains

POWER CIRCUIT BREAKER



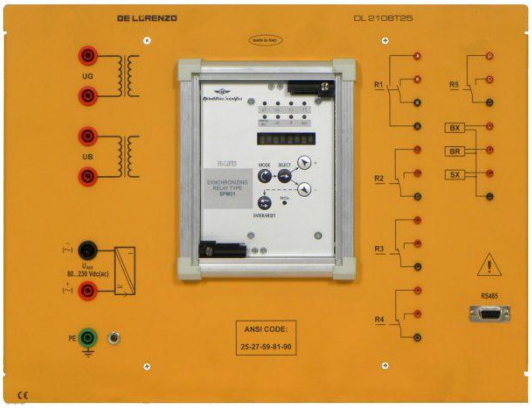
DL 2108T02 and DL 2108T02A

Three-phase power circuit breaker with normally closed (DL 2108T02) or normally open (DL 2108T02A) auxiliary contact.

- Contact load capability: 400 Vac, 3 A
- Supply voltage: single-phase from mains

SMART GRID

GENERATOR SYNCHRONISING RELAY



DL 2108T25

It is a numerical synchronising relay which measures voltage and frequency of two inputs; the voltage, frequency and phase angle of the Generator input (G) are individually compared with those of the Bus input (B) considered as reference.

Functions:

- Automatic Synchronization and Synchro-check
- Fast proportional Voltage and Frequency regulation
- Phase displacement checking with circuit breaker closing time control
- Anti-motoring
- Kicker pulse
- Event Recording
- Modbus Communication Protocol

Synchronising of the generator with the reference bus

- Normal/Dead Bus operation modes Adjustable Operate time delay
- Adjustable Max Voltage difference Anti-motoring control
- Automatic Adjusting of phase angle for circuit breaker close
- Adjustable Max Frequency difference
- Adjustable Max Phase displacement
- Adjustable Increase/Decrease pulses to speed regulator
- Adjustable Increase/Decrease pulses to voltage regulator
- Adjustable Min/Max Bus voltage for synchronising operation
- Adjustable Min/Max Bus frequency for synchronising operation
- Kicker pulse control on steady phase displacement
- Fast synchronisation with control pulses proportional to speed and voltage difference
- 3 Digital Inputs optically isolated 2kV

MOTOR-DRIVEN POWER SUPPLY

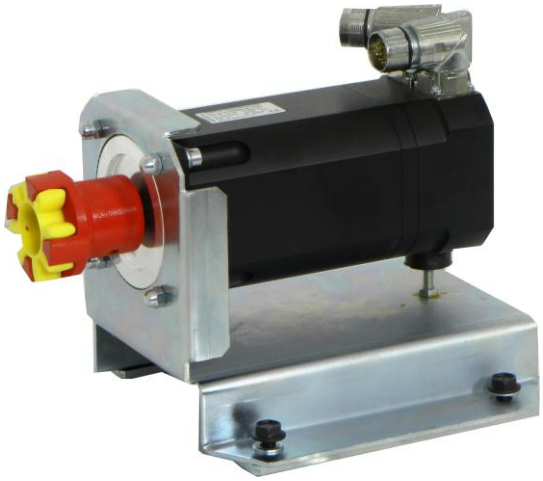
DL 1067S

Suitable for power supplying with variable voltage the braking systems and the excitation of the machines through manual or automatic operation.

- DC output: 0 to 210 V, 2 A
- Automatic regulation of excitation to keep a constant voltage
- Power supply: 220 V, 50/60 Hz

SMART GRID

BRUSHLESS MOTOR WITH CONTROLLER



DL 2108T26

Study of automatic control for a brushless motor.

- Control and operation of a brushless motor in voltage

The system allows the study of the operation of a brushless motor of a typical industrial process automation.

The student has the opportunity to learn to control and parameterize an automatic operation.

The control and monitoring system can be done through a software that can:

- Set system parameters
- Draw graphic curves
- Monitor real-time system (torque, speed, ...)

Specifications

- 1kW power brushless motor with electronic encoder
- Control of the system in frequency and voltage
- Mechanical braking system for the analysis of the torque
- Encoder outputs for the analysis of speed
- Display system for controlling and monitoring events
- Button start and stop action and automatic stop intervention in case of alarm
- Complete software for PC interfaced to the system via RS485

THREE-PHASE SYNCHRONOUS MACHINE

DL 1026P4

Machine with smooth inductor and three-phase stator armature winding for operation either as alternator or synchronous motor.

- Power: 1 kVA
- Voltage: 220/380 V Δ/Y
- Current: 2.6/1.5 A Δ/Y
- Rated speed: 1500 rpm, 50 Hz
- Rated speed: 1800 rpm, 60 Hz

Excitation winding on the rotor.

SMART GRID

RESISTIVE LOAD

DL 1017R

Single or three-phase resistive step-variable load.

- Max. power: 3 x 400 W
- Max. voltage: 220/380 V Δ/Y

INDUCTIVE LOAD

DL 1017L

Single or three-phase inductive step-variable load.

- Max. power: 3 x 300 VAR
- Max. voltage: 220/380 V Δ/Y

CAPACITIVE LOAD

DL 1017C

Single or three-phase capacitive step-variable load.

- Max. power: 3 x 275 VAR
- Max. voltage: 220/380 V Δ/Y

SMART GRID

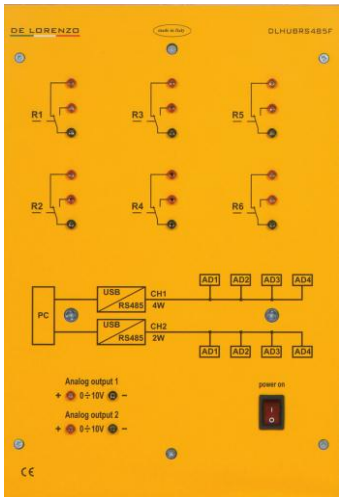
SQUIRREL CAGE THREE PHASE ASYNCHRONOUS MOTOR

DL 1021/4

Induction motor with three-phase stator winding and squirrel cage buried in the rotor.

- Power: 1.5 kW
- Voltage: 220/380 V Δ/Y
- 4 poles
- Rated speed: 1500 rpm, 50 Hz
- Rated speed: 1800 rpm, 60 Hz

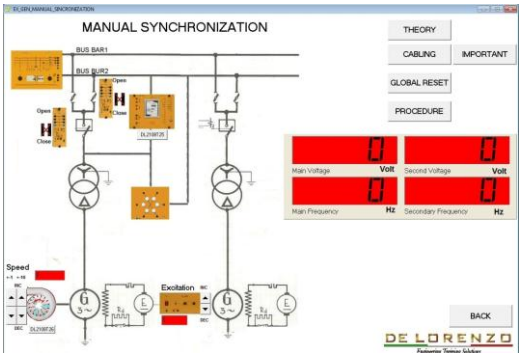
COMMUNICATION MODBUS



DL HUBRS485F

HUB that allows communication and control via PC of the measurement modules and brushless motors.

SCADA

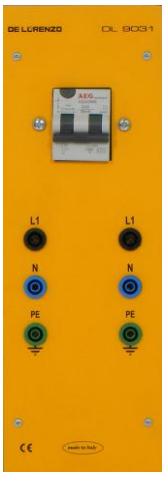


DL SCADA-WEB

SCADA software for control and monitoring.
With the possibility to show the application to different devices connected in the same network.

SMART GRID

CIRCUIT BREAKER



DL 9031

- Current Max.: 10A
- Intervention threshold differential: 30mA

ELECTRICAL POWER DIGITAL MEASURING UNIT

DL 10065N

Measurement of dc voltage, current, power and energy.

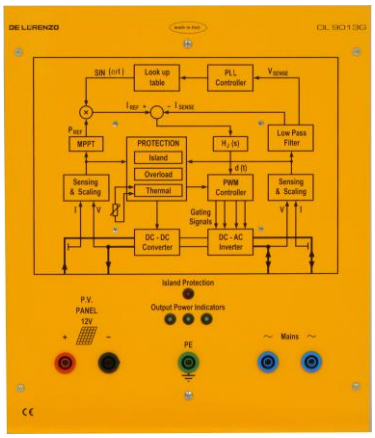
Measurement of AC voltage, current, power, active energy, reactive energy, apparent energy, power factor and frequency.

- Direct voltage: 300 V
- Direct current: 20 A
- Alternate voltage: 450 V
- Alternate current: 20 A
- Power: 9000 W

Single phase power supply: 90-260 V, 50/60 Hz

Communication: RS485 with protocol MODBUS RTU

INVERTER GRID



DL 9013G

- Current max.: 30A
- Voltage: 12V
- Power: 360W

SMART GRID

PHOTOVOLTAIC INCLINABLE MODULE

PFS-85

90W, 12V, complete with a cell for measuring the solar radiation and with a panel temperature sensor.

LAMPS FOR THE PHOTOVOLTAIC MODULE

DL SIMSUN

The light intensity can be manually adjusted through a potentiometer or automatically controlled through a 0-10 V input, to allow performing experiments with different light intensities, therefore simulating the light conditions from dawn to twilight.
It includes the following main components:

- 4 off halogen lamps, 300 W each
- Dimmer for controlling the light intensity
- Magneto-thermal switch, differential 10 A
- Potentiometer, 10k

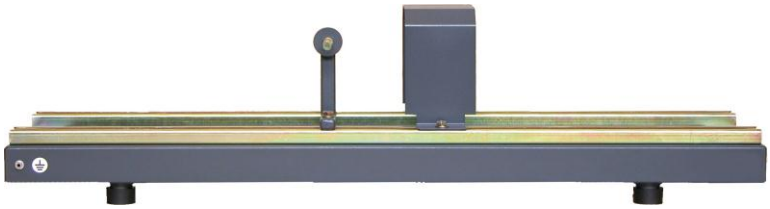
WIND SIMULATOR

DL WINDSIM

System composed of: wind speed and direction sensor, power supply, fan, potentiometer, measurement circuit, RJ45 and RS485 port.

It allows simulating the wind force and direction.

BASE

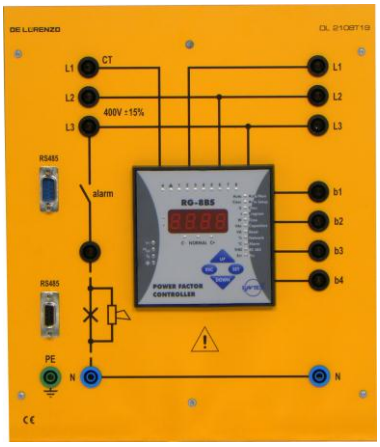


DL 1013A

Duralumin alloy varnished structure mounted on anti-vibration rubber feet, provided with slide guides to fix one or two machines and with coupling guard.

SMART GRID

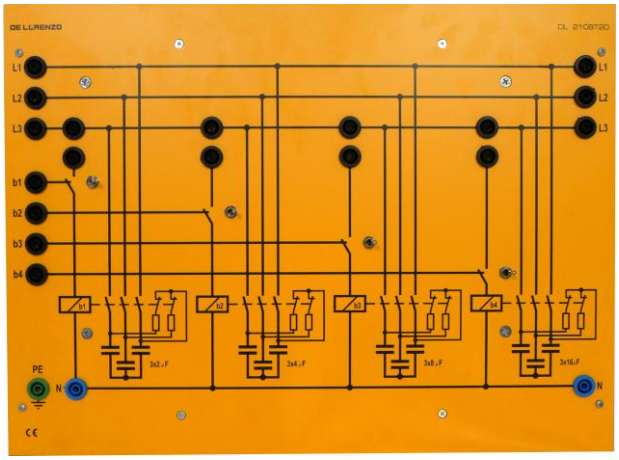
REACTIVE POWER CONTROLLER



DL 2108T19

Relay for automatic adjustment of the power factor in systems with inductive load.
Power factor adjustment range: 0.9 ... 0.98 ind
Sensitivity: 0.2 ... 1.2 K
2 decimal digit display
Output relay for batteries connection: 4 NO contacts with LED indication
Output relay contact: 400 Vac, 5 A
Supply voltage: three-phase from mains
Ammetric input circuit: 5 A (250 mA min.)
Automatic detection of the frequency.

SWITCHABLE CAPACITOR BATTERY



DL 2108T20

Switching system with which different capacitance values can be connected to the mains for reactive power compensation.
Four switching levels each consisting of 3 capacitors in star connection with discharging resistors:
level 1 (b1 coil): 3 x 2 µF/450 V
level 2 (b2 coil): 3 x 4 µF/450 V
level 3 (b3 coil): 3 x 8 µF/450 V
level 4 (b4 coil): 3 x 16 µF/450 V
Compensation power: max 1360 VAr at 50 Hz, 380 V
Each switching level can be controlled separately: internally, through 4 toggle switches, externally, through 4 control inputs
Coil operating voltage: 220 Vac

CONNECTING LEADS

DL 1155SGWD

Set of connecting leads.

WORKING BENCH WITH FRAME

DL 1001-1-AS + DL 2100-3M-AS2

Workbench with double three-level frame (stools not included).

The system includes an All-In-One Personal Computer.

DIMENSIONS OF THE TRAINER

All the panel modules of the trainer are mounted on two three-level frames that, in turn, are assembled on two work benches. Each work bench dimensions are: 2000 x 1000 x 800 (h) mm. On top of the bench, besides the frames, more bench top modules are placed, such as electrical machines, loads, transformers, etc.

Furthermore, more space is needed for the photovoltaic panel with the light stand and for the wind turbine (optional). The **total space required** in the classroom for the installation and the operation of the system is approximately 6 m. x 2 m. = 12 m^2.

Packing for shipping is in two wooden cases as follows:

	Case 1		Case 2
dimensions:	212 x 112 x 113 (h) cm.	dimensions:	212 x 112 x 113 (h) cm.
volume:	2.68 m^3	volume:	2.68 m^3
gross weight:	437 kg.	gross weight:	390 kg.
net weight:	322 kg.	net weight:	275 kg.

SMART GRID

OPTION 1: DL WIND-A1G

WIND ENERGY MODULAR TRAINER WITH CONNECTION TO MAINS

Didactic system for the study of the generation of electric energy from a wind turbine and its inlet in the mains network.
The device includes a set of control modules, measures and applications, a wind turbine, a stepper motor to drive the wind generator in absence of wind and descriptive and practical manuals.

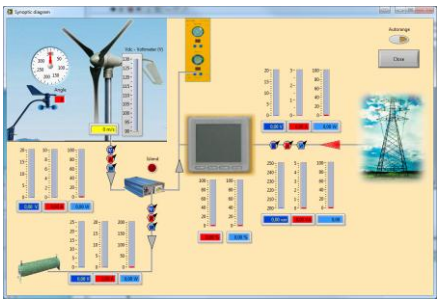
The system is composed of the following modules:

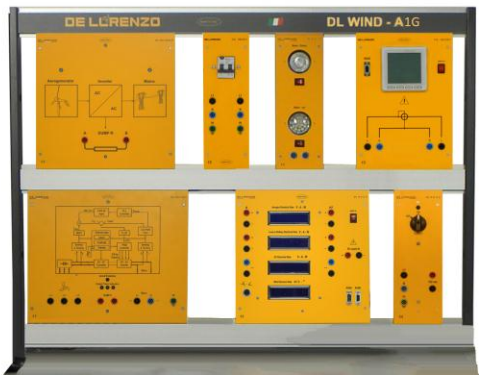
- Module for measuring electric and wind parameters
- DC/AC conversion module
- Braking resistance, 250 W, 3 Ohm
- Mains lamps module
- Energy measurement module
- Differential magneto-thermal switch
- Network distributor
- Motor kit for driving the wind turbine, composed of a stepper motor and a 300 W power supply
- Wind generator: 400W, 12Vac
- Wind sensor: Anemometer and wind direction sensor mounted on a stand

It also includes:

- Two level frame
- Set of interconnecting wires
- Descriptive and practical manual
- Wind turbine instruction manual

The trainer includes a software for data acquisition and processing.

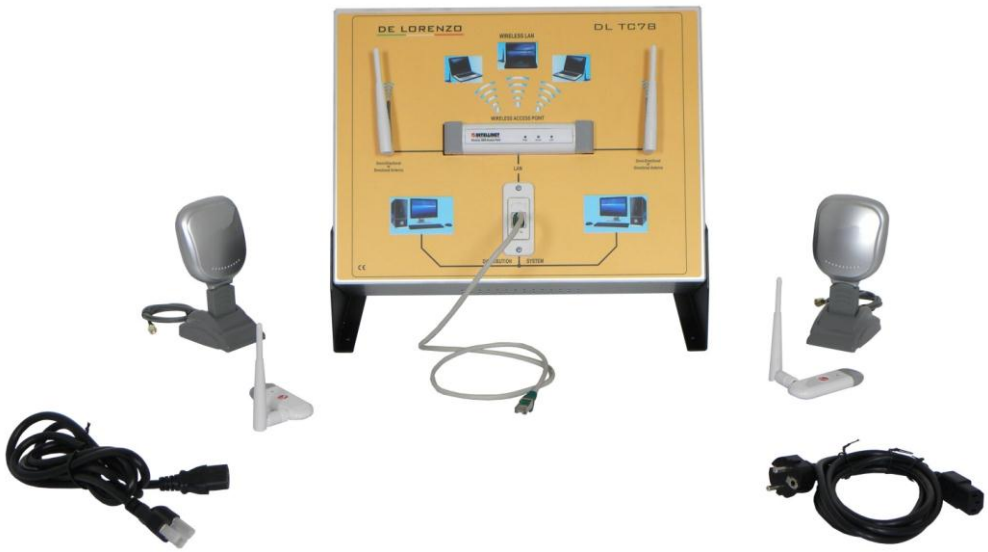




OPTION 2: DL TC78

Wireless LAN (WLAN)

The purpose of this option is twofold. First of all, the trainer is used to provide wireless connection to the IT section of the Smart Grid system, giving the possibility to teacher and students to access the SCADA software by means of a wireless laptop computer or a tablet.
Secondly, the trainer allows studying all the components and technical features of a wireless LAN network, as detailed in the following. In fact, modern communication systems are fundamental for the monitoring of the behavior of SCADA installations.



The system has been designed for the training of an installation and maintenance technician for wireless local networks, able to:

- know the principles, the standards and the devices normally used in WLAN,
- install and configure wireless networks,
- perform the maintenance, the troubleshooting, the tests on WLAN.

Composed of:

- Wireless LAN Access Point (DL TC78-AP)
- Wireless LAN USB Adapter (Quantity two - DL TC78-WA)
- Software with theory, questions, exercises, support programs (DL TC78-SW)

Training objectives:

The Training Package covers the following subjects:

- Introduction to the wireless local networks
- Structure of the MAC level (Media Access Control)
- Structure of the PHY level (Physical layer)
- The devices for the WLAN
- WLAN, exercises

List of lessons

- Introduction to wireless networks
  What is a wireless network
  Wireless networks and the IEEE 802.11 standard
  Other wireless network technologies
  RF transmission/reception system components
  RF modulation
  RF signal propagation and interference
  Wireless networks and security
- The IEEE 802.11 standard
  The importance of the standard
  The IEEE 802 family
  The components of a wireless network
  Types of wireless network
  Network services
- IEEE 802.11: the MAC sublayer
  The main functions of the MAC layer
  Data transmission
  Connectivity
  Timing and synchronisation
  Consumption management
- IEEE 802.11: the physical layer
  The structure of the physical layer
  The functions of the physical layer
  The 802.11 standard
  The 802.11a standard
  The 802.11b standard
  The 802.11g standard
  The 802.11n standard
- Types of wireless networks and devices
  Types of wireless network
  Client devices
  Access points
  Antennas
  Amplifiers
- Access points and applications
  The Wireless 300N Access Point
  Operating modes
  Security: WEP
  Security: WPA
  Security: RADIUS Server
  Security: MAC Filtering
- Antennas
  RF signal propagation
  Characteristics of antennas
  Types of antennas