# Training in Solar Photovoltaic Energy at the Universidad Politécnica de Valencia

**Salvador Segui Chilet [1], Francisco J. Gimeno Sales [1], Fernando Ibañez Escobar [1], Carlos Sánchez Díaz [1], Miguel Alcañiz Fillol [1], Salvador Año Villalba [2], Juan Angel Saiz Jimenez [2], Jose Vicente Catala Villar [2], David Rodriguez Lopez [2], Pilar Molina Palomares [2], Bernardo Alvarez Valenzuela [2]**

*[1]Departamento de Ingenierí a Electrónica, Universidad Politécnica de Valencia, Spain, http://www.upv.es*
*Tel:(+34)96 3877600, Fax:(34)96 3877609, ssegui@eln.upv.es*
*[2]Departamento de Ingenierí a Eléctrica, Universidad Politécnica de Valencia, Spain, http://www.upv.es*
*Tel:(+34)96 3877590, Fax:(34)96 3877599, jasaiz@die.upv.es*

**Abstract:** The installation of a solar photovoltaic station at the Universidad Politécnica de Valencia (UPV) in 1999 was an important step in bringing the UPV closer to the increasingly important alternative energy sources such as solar and wind. The solar photovoltaic station can produce 17.5 kWh and contains 234 solar panels, six monophase inverters supplying power to the electrical grid, a data acquisition system, and a weather station.

Various objectives have been established at the university to encourage the wider use of these energies. The first one is the familiarisation of students with alternative technologies and will be achieved by the inclusion of solar photovoltaic concepts in related subjects, visits to solar stations and windmills, student work experience in sector companies and preparation of student final-year projects on alternative energies.

Technical specialist training courses will be organised for UPV students and other professionals interested in the sector. These courses will offer both theoretical and practical experience, and include visits to relevant companies and installations. At the end of the course, students will be able to design a solar photovoltaic station and select the most adequate components. Students may be able to study solar energy applications in foreign universities.

An additional objective is the research and development of improved solar systems. This will involve teachers and students working together with companies in the sector.

The University plans to increase the size of its solar station in the near future and widen its co-operation with companies in the sector. It also plans to encourage the wider use of alternative technologies by creating multi-disciplinary groups to study the use of photovoltaic energy for independently-powered sewage treatment plants and water desalination.

**Keywords:** solar photovoltaic energy, education.

## 1. Introduction

The production of alternative, or clean, energy is becoming increasingly important in the electrical energy sector. Observers can find groups of windmills, some very large, throughout Spain. However, other energy sources, such as photovoltaic solar energy, have not experienced such dramatic growth. One of the reasons is that photovoltaic energy is expensive and unprofitable when compared with other renewable sources.

This situation may change with the introduction of policies that encourage greater use. These policies are now emerging from various European Union (EU) organisations and from the member states themselves.

A recent EU white book on energy suggests that by the year 2010 some 12 per cent of electrical energy will come from renewable sources. To achieve this the EU will make investments totalling Euros 2.125m between 1999-2003 for project research and new technology demonstrations. Photovoltaic solar energy is seen as a key area and is given a special section inside the framework plan.

Spanish legislation has been recently changed in order to encourage alternative energies. Specifically, electrical energy supplied to the national grid from photovoltaic installations with less than 5 kWp can receive financing of € 0.397/kWh – and larger installations can receive € 0.198/kWh. It is probable that more of these installations will be installed and residential areas, as they do not acoustically pollute the environment.

It is likely that in urban a growth in this market will create an increasing demand for technical specialists able to develop, manufacture, and install systems connected to the electrical grid. We believe that it is the role of the universities to train these specialists, and publicise the advantages of using this type of energy. With these objectives in mind, the Universidad Politécnica de Valencia (UPV) installed a solar photovoltaic station in 1999.

This photovoltaic installation can produce 17.5 kWp and consists of: 234 solar panels; six monophase inverters supplying low voltage energy to the three-phase supply grid; a data acquisition system; and a weather station. A computer stores data every five minutes, so we can produce graphics of all the measured parameters and obtain the performance of the whole system.

## 2. Objectives

The plan has the following objectives to encourage the more widespread use of renewable energy:

- Familiarise UPV students with photovoltaic and other alternative technologies.
- Offer training for technical specialists.
- Co-operate with Spanish energy sector companies.

The familiarisation of students with alternative technologies will be achieved by the following actions:

- Inclusion of the following material in related subjects:
  - An introduction to solar photovoltaic energy
  - Components of a solar photovoltaic station
  - Characteristics of stations – both isolated and those connected to the electrical grid
- Work experience and preparation of student final-year projects on alternative energies
- Visits to solar stations and windmills

## 3. Teaching solar photovoltaic energy

This paper proposes introducing solar photovoltaic studies in the current course topics for the Bachelor Degrees in Industrial Electronics Engineering and Electrical Engineering. Both degrees are taught at the Escuela Universitaria de Ingeniería Técnica Industrial (E.U.I.T.I) of the U.P.V.

Below we detail solar photovoltaic concepts to be included in the various study-plans. They are grouped into blocks with similar content.

ELECTRONIC POWER CONVERTERS.

- Monophase and three-phase inverters connected to the grid or operating in island mode for electrical energy generation.
- Pulse width modulation (PWM) and quasi-resonant converters.
- Quality improvements to supplied energy.
- Security and safety.

ELECTRONIC POWER CONVERTER CONTROL.

- Generation of digital/analogue PWM signals.
- Control algorithms.
- Maximum power point tracking (MPPT).
- Synchronisation with the electrical grid.

CHARGING/DISCHARGING BATTERIES / BATTERY STATE MONITORING.

- Battery types / performance.
- Battery chargers.
- Battery state monitoring.

DATA ACQUISITION SYSTEMS.

- Measuring DC and AC voltage and current.
- Measuring quality of the AC energy supplied.
- Measuring parameters that influence system performance: radiation, temperature, wind speed, etc.
- Communication (RS-232 / RS-485 / fibre optic).
- Database management.

SOLAR PANELS / ENERGY SOURCES.

?? Solar cells: photovoltaic effect .
?? Types of solar cells / characteristics.
?? Manufacturing solar cells.
?? Serial-parallel connections.
?? Performance of commercial solar cells .

LEGISLATION (technical).

✍ Low voltage regulations.
✍ Regulations for connecting photovoltaic installations to the supply network.

During the theoretical part of the course the studies will focus on the general characteristics of each section. Students will be visiting the UPV installation and so technical documentation from the various component manufacturers and installers of this station will be used in the teaching material.

Students will be set problems based on the real characteristics of the UPV solar station; in addition, real measurements taken from the data acquisition system will also be used.

Photovoltaic and other alternative energies have already been introduced in two subjects. In Circuit Theory, first year students learn and apply the Fourier transformation. In one of the examples, students study the current waveform of one inverter and obtain and view the harmonics contained in the signal.

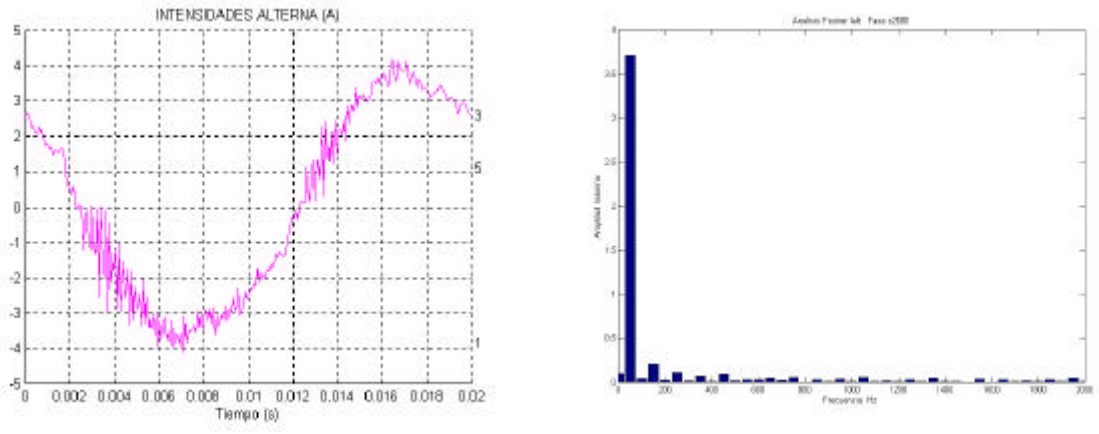


Fig. 1: Example of the current waveform and analysis of the harmonics.

The second example is Technical English, which now includes a module on alternative energies and photovoltaic systems.

When the final subjects are reached the student will already know the basic elements of a photovoltaic solar system, and so the course will go on to include visits to the UPV solar station, as well as other nearby installations.

Part of the UPV solar station is re-configurable and various panels, and groups of panels, can be addressed individually. As a result, some final-term laboratory practices will be organised in the Department of Electronic Engineering's Power Electronics laboratory – located in the E.U.I.T.I. The participating subjects will be Advanced Industrial Electronic Systems, Industrial Electronic Experimentation, and Industrial Electronic Laboratory. These practical sessions will focus on: measuring AC/DC voltage and current; controlling DC/AC converters; determining a panel's maximum power point, etc.

## 4. Work experience and degree final projects

Students will be able to use information acquired in their studies during work experience periods with those energy sector companies maintaining relations with the university. Students can gain credits for these work experience periods by including them as either; optional subjects, or part of their final year projects.

Many student final-year projects can be prepared using the solar station. These projects will help students gain greater experience in the field of solar energy development and implementation. At the same time, the installation can be used to experimentally prove developed systems.

Some of the proposed subjects include:

- New topologies for inverters connected to the grid, or operating in island mode. Once the inverter is designed and assembled, the student can test it in a real installation using continuous voltage supplied by the solar panels. The data acquisition system can be used to monitor the quality of the generated signal and the performance of the system. The added advantage is the ability to work with real and proven systems, meaning that a given design, once refined, will be valid for industrial application.
- The development of new data acquisition systems. It will be possible to design new equipment for measuring: atmospheric pressure; continuous and alternating electrical parameters, power quality, etc. Students will be able to obtain measurements using a real system and then compare results with those obtained from the data acquisition system of the solar station – and so obtaining a bench mark for evaluating the reliability of their design.
- The design of complete solar installations. By using as a base the structure of the existing installation and the results obtained, students can go on to design complete solar stations. In addition, the data generated by the UPV solar station (energy generated, performance, dependence on climatic conditions, etc) can be extrapolated to size solar stations with different characteristics.

Other possible final projects related to the UPV solar station include:

- Solar station web page. This project could integrate aspects such as the use of web design tools, and the acquisition of an understanding about photovoltaic solar energy.
- Solar station database. This project would involve preparing a database of the measurements obtained by the data acquisition system. This database would be updated in real-time and could be consulted from anywhere via Internet. Part of this information could be displayed on panels in the entrance-hall of the E.U.I.T.I.

## 5. International Relations

Relations are currently being established with those European and South American universities interested in solar power. Exchanges of students working in these areas will be arranged, and international working groups will be organised to participate in the many programs being put forward by the EU. These universities include:

- TEI Tesalonica (Greece)
- Fachhochschule Osnabruck (Germany)
- Fachhochschule Gelsenkirchen (Germany)
- University of Southampton (United Kingdom)
- Engineering College of Copenhagen (Denmark)

## 6. Training courses

Specialists in solar energy installations will be trained as part of an effort to encourage the use of solar photovoltaic energy. Short courses with both theoretical and practical content will be aimed at UPV students and other interested professionals. By the end of the course students will be able to design a complete solar photovoltaic installation and select the most adequate components.

These courses will include the following areas:

- Current state of solar photovoltaic energy
- Solar cells: introduction; characteristics; types; manufacturing; and interconnection
- Sources of conventional electrical energy
- Potential converters for photovoltaic solar energy
- Description of a solar photovoltaic installation; performance evaluation; electrical parameter measurements; atmospherics; solar radiation; etc.
- Safety and regulations
- Design and sizing an installation
- Other sources of alternative energy

The course will finish with technical visits to the UPV solar station, the "Los Pajaricos" windmill centre, and other installations.

In recent years, some of the authors have been teaching a 20 hour course on "Windmill and solar energy applications in electrical installations".

## 7. Technological innovation

Technological innovation and research objectives are also included in the plan. These objectives involve energy sector companies and their employees, teachers, and students. The aim is to improve existing solar systems.

Within the framework of co-operation with companies it will be possible test and verify industrial photovoltaic equipment using the UPV solar installation.

In addition, it will be possible to agree plans with companies for the joint development of new photovoltaic systems.

These agreements will enable:

?? The development of new techniques in the renewable energy sector
?? The updating and improvement of teaching subject content

Some examples of these agreements include:

- Description of a low power solar photovoltaic installation connected to the grid (IBERDROLA).
- Battery chargers for an isolated solar photovoltaic system (ATERSA).

As a result of these agreements, solar energy will be more widely used, qualified workers will be more in demand, and more graduates with training in renewable energy sources will find jobs.

## 8. Conclusions

The UPV is studying the possibility of enlarging its photovoltaic installation. The aims are: to encourage greater use of solar energy; secure further co-operation from companies; widen the use of solar energy by creating multi-disciplinary groups for applying the energy in other fields such as sewage treatment and water desalinisation.