How to Get Students Involved Learning Photovoltaics

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Abstract – *Photovoltaics has a good image among students, who associate it to a clean and renewable source of energy, helping to build-up the motivation to enroll and follow a formal course on PV. In our experience this, however necessary, is not sufficient to get full return from the effort invested: the students need to get, besides motivated, involved in the subject. In this paper we will show that an excellent tool for involvment is to get students working hands-on, individually, on a PV project of their choice.*

Index Terms —*Education, Photovoltaics*

INTRODUCTION

Teaching photovoltaics started at the Universidad Politécnica de Cataluña back in 1975 and has been part of the degree of Telecommunication and electronic Engineer since then . This paper describes the experience of the author teaching an elective course entitled ´ Photovoltaic solar energy´ in the Telecommunication Engineering School of the UPC.

Educating engineers has become increasingly challenging in general, and, specially the education in photovoltaics has had to evolve continuously as the last 25 years have witnessed the emergence of a strong photovoltaics industry for terrestrial applications. We have also seen the preferences of students in engineering schools drifting towards computer science and more recently the overall number of students enrolling in engineering studies decreasing in Spain.

There is also a trend in engineering education promoting the team work, which is of course fundamental to understand the complexity of the engineering projects, but has also some side effects on the full competence of all students in the fundamentals.

Motivation of students is still of paramout importance in their education ; once they are engaged in an engineering degree , we have to assume that, the average student has a broad motivation for technical matters and still has to discover the specific subject where to specialize or even to plan a professional career.

Phtovoltaics has several characterisitics that shine in front of the students ando f the general public. It is about a renewable source of energy which is an important issue for many students having environmental concerns. Moreover it is about solar energy which is perceived as clean, long lasting, and available everywhere. It is also perceived as modern or fancy, in the way it is exploited today, and most of the students have been exposed to documents, web pages or media productions covering highlights of solar energy deployment. Some students see it also as an opportunity for career development and a field where jobs can be available for them. All this facts make the students to have an initial positive motivation to enroll in the course.

However, the technical contents of the course deals with important physical fundamentals going from semiconductor physics and astronomy to more applied topics in system design. It is key to keep the motivation alive during the duration of the course.

And this is the goal of this paper: show one method to keep and increase the motivation of the students. We have found that the development of a PV project, individually, during the length of the course is a powerful educational instrument because every student in the class commits himself to a personal goal. The students are asked to identify, define, conceive, plan and draw an execution plan of a PV installation, answering to a student personal wish or interest. This has several advantages: (a) involvement of the student in a personal project, (b) every student is the chief engineer of his/ her project and cannot rely on the work of others (c) can compare with the approaches taken by the fellow students (d) are exposed to the same information environment than a professional engineer (f) has to support the technical decisions.

This paper will describe the details of the approach and provide some of the results.

COURSE OUTLINE

The course contents is organized in 15 weeks covering a semester, two lecture hours per week and a third hour per week which is devoted to numerical exercises and problem solving and to provide guidance and get feedback from the student personal PVcourse project. This third hour also serves to make the students aware of the PV world by discussing hot topics, news and to clarify doubts . Finally a fourth hour per week is devoted to practice with software simulators.

The contents of the course starts covering solar radiation basics, PV history, standard spectrum of the sun and black body radiation model. Besides, a broad review of solar energy availability in the world as a function of the geometric coordinates is provided by means of graphs. This introduction provides the basics of the PV terms and vocabulary
Next, the solar cell physics is described, mainly oriented to the spectral response and short circuit current , by means of a simple 1D solar cell model based on the semiconductor equations. Absorption and reflectance data are used to compared about real device properties. Concepts of spectral current density, quantum efficiency and spectral response are described. As students come from many different countries, both from Europe and South America, the contents of the description of the solar cell is self contained. The contents of this chapter are further extended in laboratory simulations based in PC1D.
Next, the electrical characteristics and the equivalent circuit model of solar cells are covered. Main fundamental parameters as open circuit voltage, maximum power point and efficiency are introduced. The sensitivity of these operational parameters to irradiance, temperature and space radiation are described. A Pspice model of solar cell is introduced here and the students have to work with it in the laboratory.
It follows the description of solar cell associations in arrays, modules and PV generators. Problems such as hot points, shadow effects and bypass diodes are covered. The solar cell model is extended to arbitrary series-parallel association of cells, and PV plants and this is converted into a Pspice model which includes temperature and irradiance effects.
The PV system operating point and interface problems with battery and electronics are described. The focus is put into the several losses that appear in the configuration of a PV system, and interface properties. The main components of the PV system such as charge regulators and inverters, are described. Design of stand alone systems with the calculation of the battery size and PV plant size is described and extended to grid connected systems ad pumping systems
Sizing issues, both for stand alone and grid connected. Simulation of PV systems under synthetic radiation series helps understanding the long term operation of PV systems.
Finally the several PV technologies now in the market are described: from low cost or thin film devices up to high efficiency concentrating solar cells.

PERSONAL PROJECT

As described above, students are asked, from the very first day, to think on a PV system they would like to build and, every week, they have assignations to do, covering the various phases of the project:
The students are asked in a weekly basis to :

- Identify a location where to build a PV plant or system and the nature of it: stand-alone, grid connected, irrigation
- Find solar energy radiation data in average dayly values for several inclination angles. Students have to find solar energy handbooks or they can use Meteoneorm or PVSYST software which is made available to them by means of a Campus Licence
- Define the power demand profile of the system
- Find suitable components for PV modules, battery, inverter and BOS components, and understand their technical characteristics
- Interpret the technical data available for the system components
- Compute the system size and the energy produced in a yearly basis
- Find appropiate regulation and legislation on PV energy subsidies or green energy benefits
- Compute the system costs and return of investment
- The final assignement they have, is to write down a paper describing the work they have done in a scientific paper format such a IEEE Transactions template The lecturers act as reviewers of the papers and of the presentations, providing feedback to the students.
- Write and give a presentation summarizing the system aims, design and performance.

The points described above are meant to guide the personal work of the students during 10 weeks of the course in parallel to the lectures, exercises and laboratory work. Our experience tells us that this approach has several benefits:

- Makes the students have a clear knowledge of the solar energy input in a location of interest to them
- Makes them to build their own ¨PV world awareness¨ as they have to find module characteristics, prices, delivery delays, etc.
- They have to match the characteristics of the several components
- They have to be aware of the regulations ruling PV installations in a given country
- Makes them to have a deeper knowledge on the economic issues of PV

As the course has many students coming from other european and southamerican countries, the course community is largely international creating, thereby, a forum where different country policies for PV can be compared in terms of feed-in tariff or subsidies. This also gives the student the opportunity to extend the presentation of the work to contry framework for renewables and they can share different implementation policies and deployment status.

RESULTS AND CONCLUSIONS

In our experience all of the students (exception made of few cases) enrolled follow the course up the the end with a high level of course attendance. The fact that the students have to start thinking in terms of a PV system from the very beginning, makes them raise questions very soon and the challenge for the instructors is to make sure that the students find the right answers in the course timeline. The approach in this course is technical, no room for activism, and the student are advised so the first day. This makes them to fell free from prejudgments and approach objectively the issue of the PV solar energy in general and they see that some of the applications selected by the fellow students are not economically sound and some other are. In the experience of this course, the choices of student's project has been quite broad, related to the students own circumstances, geographical origin or professional intuition or will and, generally, they end up with the feeling to have grasped the main technical problems related to PV concepts and to be aware of the PV world.

The use of software is very adequate for this course. The most important one is a software tool for system design such as PVSYST. In our experience the students get very fast aquainted of the tool and the work of the instructors is twofold: make the students aware of the technical PV terms and clarifiy the meaning of them and to understand the results and put them into prospective. The software also allows to peform economic analysis bringing the side of bussiness to the topic. The software to simulate the PV solar cells is also very well appreciated by the students and some of them are more interested in the solar cell physics and development rather than the system itself. Finally there is a extensive support for sustem in depthe modelling using Pspice which is familiar for most of the students[1].

REFERENCES

[1] Castaner, L.M. and Silvestre S., "Modelling PV systems using PSpice", *Wiley*, 2002.