A photovoltaic electric vehicle as an experiment-based platform to integrate knowledge in an Electronics program

Robinson Pizzio; Clovis A. Petry; and Flabio A. B. Batista
Federal Institute of Santa Catarina: Department of Electronics
Florianópolis, SC, Brazil
{robinson.pizzio;petry;flabio}@ifsc.edu.br

***Abstract* — This work presents the development of a generic platform, a photovoltaic electric vehicle, used as a base structure by students from an Electronics undergrad program to integrate knowledge. The main goal of the project is the development of some special characteristics over an unmanned photovoltaic electric vehicle. The results of three semesters using the platform are presented and discussed in this paper.**

Keywords* — *photovoltaic electric vehicle, integrate knowledge, teaching strategies.

I. Introduction

Teaching of electronics is basically formed by theoretical classes, homework, simulation and lab experiments [1]. In this way, many efforts have been done in order to turn the teaching of electronics more dynamic, challenging the students with different problems, focusing on motivation and ways to get their interest [1 – 4]. Therefore, either using remote labs [1, 5 – 6] or other teaching strategy [2 – 4, 11], professors have been searching for ways to improve electronics teaching and make it more interesting. In [8] the authors emphasize the teaching problems in a learning by doing approach.

They work with basic elements and instruments in electronics in a group of students. Another work that brings the idea of knowledge integration is [9].

They have developed a method for the integration of power electronics with other studies like environment, mechanical, civil engineering, and project management.

Bauer and Kolar discuss in [7] the use of a web-based learning tool for power electronics, and point out the benefits of the problem-based learning (PBL) methodology for first year students and the design-oriented practical (DOP) for the fourth year students. In [12], the authors compares the benefits of virtual labs with remote labs.

They argue that those two platforms offer different advantages for students but both are very important parts of the curriculum of engineering education. In addition, in [13] the authors describe their experience of using a remote lab to improve their computer networks classes.

After describe the experiments explored by the students, they conclude that the experience of using a remote lab was a success from both, the instructor and the student point of view. Another very interesting work is from [14] where the authors describe their experience of working with remote and hands-on labs. Their results suggest that both labs are comparable in terms of teaching.

In [10], the authors present a very interesting platform called Solar Climber used to introduce students to power electronics. They describe the motivations for the project, the model of the climber, the learning outcomes and the experiences from the project.

Our work presents the development of a generic platform, a photovoltaic electric vehicle, used as a base structure by students from an Electronics undergrad program to integrate knowledge. The main goal of the project is the development of some special characteristics over an unmanned photovoltaic electric vehicle.

II. Working Plataform

Before the first offer of the class called "*Projeto Integrador*" we have mounted eight basic platforms to be used in class. The mechanical structure and some basic electrical items were mounted and tested on the vehicle.

The block diagram of the solar vehicle structure can be seen in Figure 1. There, solid line represents items from the basic platform mounted by teachers, and dashed line represents items that the students should design. We have opted for prototypes with standard mechanical structure, where the students cannot change it, in order to give equal conditions to all groups to develop the project.

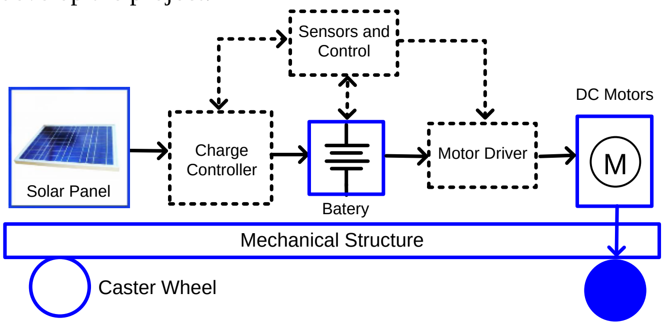

Fig 1. Block diagram of the solar vehicle.

An advance of a single and standard platform is its low cost, where cost is approximately $ 200.00 for the basic platform. Also, the time to develop the Project can be shortened.

In this way, the groups can dedicate their whole time to the development of the energy systems processing, the motor drives and the control of the vehicle.

Figure 2 shows the basic platform. The main components of the platform are described in the following.

A. Mechanical Structure

The mechanical structure of the solar vehicle was mounted in a wood base with 50 cm x 30 cm where aluminum bars were fixed to support the solar panel and other items of the system.

The motors were fixed in this structure with rectangular aluminum bars and the wheels coupled directly to this axis. In Figure 3 we show a draft with the vehicle dimensions.

Fig 2. Basic platform.

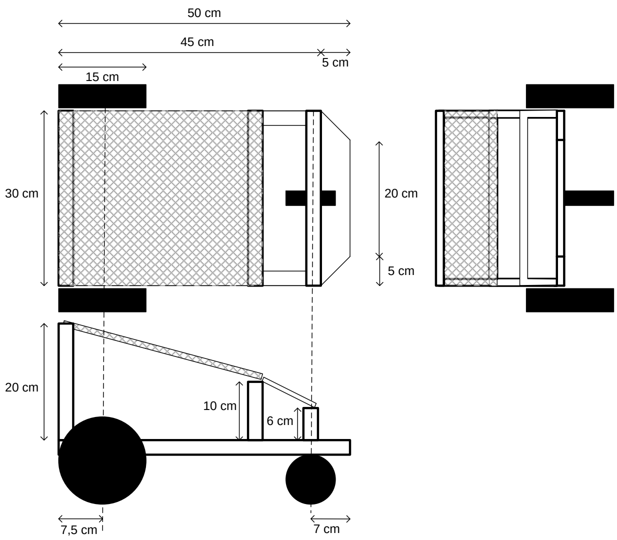

Fig 3. Dimensions of the mechanical structure.

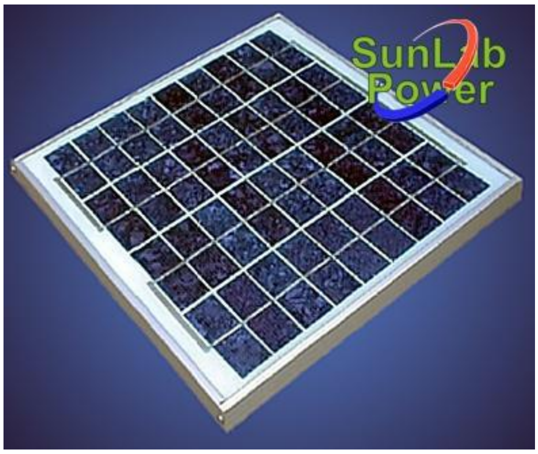

Fig 4. Photovoltaic panel SL-10.

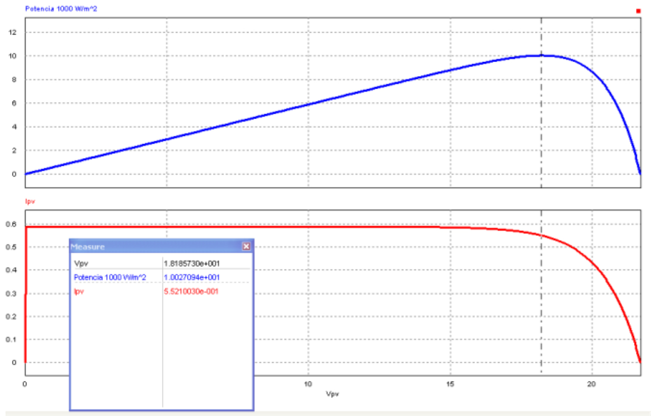

Fig 5. Power curve of SL-10 Photovoltaic panel.

B. Photovoltaic panel

The photovoltaic panel has the function of providing energy to the motor drives system and control. Also to be the source of energy to recharge the batteries.

In Figure 4 it is shown the panel model SL-10, from Sunlab Power. Theses panels have open circuit voltage of 21.7 V and short circuit current of 0.63 A.

The maximum power is 10 W for 17.4 V and 0.58 A. This point can be verified in Figure 5.

Various information on photovoltaic panels are available to students, such as electrical and mechanical characteristics and thermal coefficients through the data sheets provided by the manufacturer.

C. DC Motors

Each vehicle has two DC motors model AK380/24-R35E with gearbox of 1:260 from Akiama Automação. The DC motor is shown in Figure 6.

Theses motors were coupled to rubberized metal wheels with 15 cm diameter. This allows the vehicle to move with variable speed and change direction.

Table 1 presents the main characteristics of the motors.

Fig 6. DC Motor.

Table 1. Characteristics of the DC Motor.

Voltage		Without load	
Operation	Nominal	Rotation	Current
12 - 30 V	24 V	35 rpm	95 mA

Maximum efficiency				Start	
Rotation	Current	Torque	Power	Current	Torque
29 rpm	290 mA	5.5 kgf.cm	7.18 W	3.2 A	33 kgf.cm

D. Batteries

Batteries are elements able to store energy. They are used as energy source to drive the DC motors when we have little solar incidence or in critical moments like transient starting or reversing the direction of rotation of the motors.

Moreover, those batteries have the functionality of providing auxiliary energy to the whole electronics system of the vehicle.

Each vehicle has two batteries model UP1213 from Unipower. A picture is shown in Figure 7.

In Table 2 we present the main characteristics of the batteries model UP1213. Datasheets allow analyzing other electrical characteristics as the table of discharge with constant current.

Fig 7. Battery model UP1213.

Table 2. Battery characteristics.

Nominal Voltage		12 V
Nominal Capacity (C20)		1.3 Ah
Dimensions	Total height	57 mm
	Height	52 mm
	Length	98 mm
	Width	43 mm
Approximate weight		0.58 kg

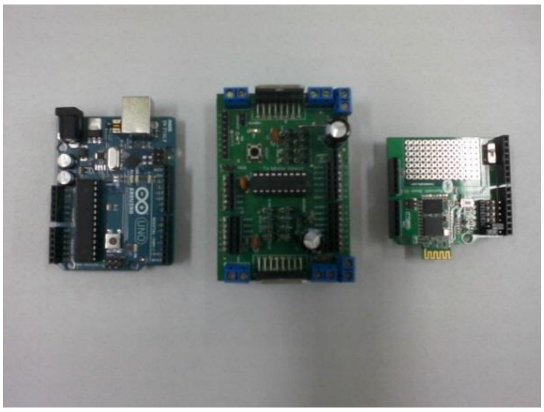

Fig 8. Arduino, Motor Shield, and Bluetooth Shield.

The structure of the vehicle was tested to ensure that it is capable to move with all components needed (batteries, solar panel, etc.).

Beside the items of the basic platform, we have also made available Arduino development kits, motor shield, and Bluetooth shield. Those kits are optional and they are presented in Figure 8.

III. Using Scenario

As this project is part of a one semester course of the Electronics program, some characteristics change each semester.

The projects are developed in laboratories of electronics, where the students have many appropriate equipment available. The development lab is shown in Figure 9.

We have already experienced this project by three times. In the first semester, students organized in doubles, were instigated to investigate on ways to integrate different components like batteries, solar panels, DC motors, etc., in order to get the vehicle ready to move around.

In addition, the development of a remote control for guidance of the vehicle was also part of the project. In Figure 10 the first version of the project is shown.

Fig 9. Development lab.

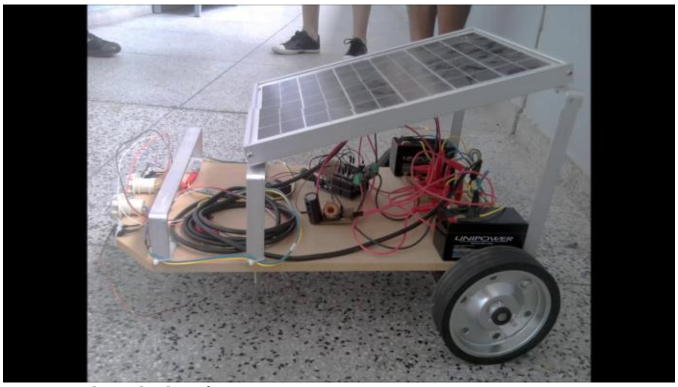

Fig 10. Solar vehicle – first semester.

For the second semester, students have faced an additional and different problem. They needed to provide sensors in the vehicle in order to avoid obstacles.

Thus, besides the energy specifications, the students also had to implement a wireless remote control. In Figure 11, the second version of the project is shown.

Finally, in the third semester, students have developed a global position system (GPS) to locate and guide the vehicle; as shown in Figure 12.

In this semester, students have incorporated to the original project (which is already composed of static DC-DC converters for battery charging, voltage boost system, and motors driving) a remote control with the technology to be defined by the team.

In addition, a GPS shield and SD card recorder shield were made available to students in order to obtain the vehicle's location and promote its displacement according to a predefined trajectory.

In the end of each semester, students are motivated to participate in a kind of competition. All groups take their vehicles to run in a rally, in which their work is evaluated based on the various aspects of the project.

We consider this experiment a very good way for students to put in practice a lot of the knowledge acquired during their undergrad program. As examples of areas worked in this project, we could point out: power electronics, energy management, control systems theory, microcontrollers, electronic drives, alternative energy sources, etc.

In the Federal Institute of Santa Catarina (IFSC), projects to integrate knowledge are developed in all levels, from the technician to undergrad programs.

In particular, in the Electronics undergrad program, two projects like that are done. One in the third semester and the other in the seventh. The photovoltaic electric vehicle is done in the second project, which is accomplished almost in the end of the program.

Thinking of that, the project is developed in the way that students have to define the power system structure having in mind that they have some mandatory elements: photovoltaic panel, batteries, and motors.

After, they need to calculate the system energy and determine the appropriate converter to integrate the mandatory elements.

Now they are ready to start the remote control project (usually using a smartphone) and put the vehicle to move around. The last part of the project is modified at each semester in order to motive the students to search different solutions to different problems.

In the following, we present the main information, focusing in the pedagogical point of view, of the project evolution over the three semesters.

A. Information for the second semester of 2012

Title: “Unmanned vehicle moved by DC motors powered by batteries, charged by photovoltaic panel, controlled remotely”.

Blocks of the system:

- Circuit for motor driving;
- circuit to wireless remote control;
- battery charging system;
- adjustment of the power extracted from the photovoltaic panel system, to the point of maximum operating power;
- circuit to provide key information about the whole functionalities of the vehicle, consisting of a liquid crystal display (LCD) 2x16 characters with backlight

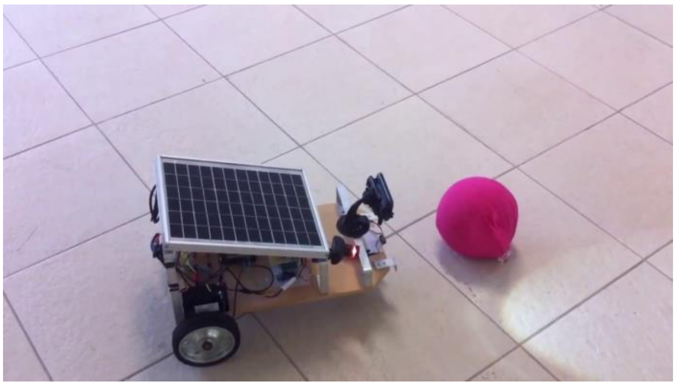

Fig 11. Solar vehicle – second semester.

Fig 12. Solar Vehicle – third semester.

Score for each goal:

- Goal 1 – Presentation of the motor driving circuit (10 points)
- Goal 2 – Presentation of the remote control circuit (10 points)
- Goal 3 – Presentation of the battery charging circuit (10 points)
- Goal 4 – Presentation of all parts operating together (integration of the system) (40 points)
- Goal 5 – Presentation of the video report (10 points)
- Goal 6 – Participation in the race (rally cars) (20 points)

B. *Information for the first semester of 2013*

Title: "Unmanned vehicle moved by DC motors powered by batteries, charged by photovoltaic panel, controlled remotely".

Blocks of the system:

- Circuit for motor driving;
- circuit to wireless remote control;
- battery charging system;
- sensing system.

Score for each goal:

- Goal 1 – Presentation of the motor driving circuit (10 points)
- Goal 2 – Presentation of the remote control circuit (10 points)
- Goal 3 – Presentation of the battery charging circuit (10 points)
- Goal 4 – Presentation of the sensing circuit (10 points)
- Goal 5 – Presentation of all parts operating together (integration of the system) (40 points)
- Goal 6 – Presentation of the video report (10 points)
- Goal 7 – Participation in the race (rally cars) (10 points)

C. *Information for the second semester of 2013*

Title: "Unmanned vehicle moved by DC motors powered by batteries, charged by photovoltaic panel, controlled remotely and guided by GPS".

Blocks of the system:

- Circuit for motor driving;
- circuit to wireless remote control;
- battery charging system;
- location and moving system by GPS

Score for each goal:

- Goal 1 – Presentation of the motor driving circuit (10 points)
- Goal 2 – Presentation of the remote control circuit (10 points)
- Goal 3 – Presentation of the battery charging circuit (10 points)
- Goal 4 – Presentation of the GPS circuit (10 points)
- Goal 5 – Presentation of all parts operating together (integration of the system) (40 points)
- Goal 6 – Presentation of the video report (10 points)
- Goal 7 – Participation in the race (rally cars) (20 points)

IV. RESULT DISCUSSIONS

The solar vehicle project was developed successfully for three semesters in our Undergraduate Electronics Program.

It was noticed along its development that the student involvement with the subjects taught in the course increased, because the focus of the project is well defined and the themes are not free choice of the students.

Despite the subject and the functional blocks are pre-specified, students' creativity is encouraged by the development of individual stages and propose solutions.

This is possible because some elements of the project are not described in detail, and we do not provide all of the materials and components needed to the students.

Another positive aspect is the interactivity of the students and teamwork, since most projects are developed in pairs, with few cases of individual works. We do not encourage the realization of projects with teams of three students or more.

We have clearly noted throughout the development of the projects that students have poor methodology in organizing their activities, which can often result in failure to complete the activities.

Thus, we tried to enhance the current course with guidance on the best sequence for the development of the activities. In addition, we start a timetable to ensure students are working in the right direction.

The work is guided from the simplest to more complex tasks in this timetable, leading students to develop the system with a view in the final integration.

With respect to the final integration of all the systems developed in the project, a higher score is assigned to the step of the presentation of all parts working together.

At this stage we note that students, even those who were successful in the presentations of the individual steps, present difficulties to compose the complete system, solving connectivity issues, interference between the parties, among other possible causes of erroneous operation of the complete system.

Finally, the platform development projects based on the solar vehicle has been shown effective for teaching electronics, allowing the incorporation of new and small, but substantial technology changes each semester, avoiding simple copying of projects but encouraging the generation and accumulation of knowledge for use in the students' career.

V. CONCLUSIONS AND FUTURE WORK

The platform described in this paper has been showing adequate to the development of projects to integrate knowledge in our undergrad programs.

Students are instigated to make use of all the contents worked during the undergrad program in order to accomplish the proposed tasks in each project.

The platform used has been shown to be robust and flexible. With minor changes in the specifications of the projects or tasks in the final race is possible to propose new challenges and insertion of different technologies such as digital signal processors, sensors and power controllers,

The continuity of the project is to improve vehicle performance in terms of speed, replacing the DC motors for greater speed models. In addition, it is intended to provide students with component to sound and image processing in order to involve more advance controls like voice and gestures recognition.

REFERENCES

[1] Marchezan, A. R.; Chella, M. T.; Ferreira, E. C. (2008) "Laboratório Remoto aplicado ao Ensino de Engenharia Eletrônica". Available in: <http://inf.unisul.br/~ines/workcomp/cd/pdfs/2211.pdf> Accessed on June 2011 (in Portuguese).

[2] Jiang W., Yu, F., Mo, Y. (2013) "A problem oriented model for teaching power electronic circuits". IEEE 10th International Conference on Power Electronics and Drive Systems (PEDS 2013), Kitakyushu, Japan, pp: 142 – 146.

[3] Juan, J., Ostua, E., Guerrero, D. (2012) "Methodology updating experience in basic digital electronics teaching". Technologies Applied to Electronics Teaching (TAEE 2012), Vigo, Spain, pp: 58 – 62.

[4] Xu, H. et al (2010) "Exploring research of "Project-driven" teaching methods of Electronic Technology courses". International Conference on E-Health Networking, Digital Ecosystems and Technologies (EDT 2010), Shenzhen, China, pp: 273 – 276.

[5] Tawfik. M. et al (2013) "Virtual Instrument Systems in Reality (VISIR) for Remote Wiring and Measurement of Electronic Circuits on Breadboard". IEEE Trans. Learning Technologies, Vol.6 nº 1, pp: 60 – 72.

[6] Alves, G.R. (2011) "Using VISIR in a large undergraduate course: Preliminary assessment results". Global Engineering Education Conference (EDUCON 2011), Amman, Jordan, pp: 1125 – 1132.

[7] Bauer, P. Kolar, J. W. (2013) "Teaching Power Electronics in the 21st Century". 15th European Conference on Power Electronics and Applications, EPE Journal, Vol.13 no 4, Lille, France, November 2003.

[8] Rompelman, O.; Vellekoop, M. (1999) A first year course in integrative learning: A practical example of 'back to the basics'. In: Anders Hagström (Ed.): Engineering education: Rediscovering the Centre; Proceedings of the SEFI Annual Conference, Winterthur/Zurich, Sept. 1-3, 1999, pp. 225-230.

[9] Sulkowski, W.; Hjertenaes, A. K.; Ljunggren, P. A. (2002) The one year project as a method for fusion of power electronics with other studies; EPE-PEMC 2002, Cavtat/Dubrovnik, ISBN 953-184-047-4.

[10] Friedli, T.; Round, S. D.; Kolar, J. W. (2007) Modelling the Space Elevator - A Project Oriented Approach for TEaching Experimental Power Electronics, Proceedings of the 12th European Conference on Power Electronics and Applications (EPE 2007), Denmark, Aalborg, CD-ROM, ISBN: 9-7890-7581-5108, September 2-5, 2007.

[11] Pacheco, J. O.; Petry, C. A.; Batista, F. A. B. (2012) Multi-platform education system of frequency inverters. In: Industry Applications (INDUSCON), 2012 10th IEEE/IAS International Conference on Industry Applications, 2012, Fortaleza. Power Eletronics, 2012.

[12] Auer, Michael E. (2001). Virtual Lab versus Remote Lab. 20th World Conf. on Open Learning and Distance Education. Dusseldorf (Germany) April 2001.

[13] Lloret, Jaime, et al. (2008). A remote network laboratory to improve university classes. WSEAS International Conference. Proceedings. Mathematics and Computers in Science and Engineering. Eds. J. L. Mauri, et al. No. 5. WSEAS, 2008.

[14] James E. Corter , Jeffrey V. Nickerson , Sven K. Esche, Constantin Chassapis. (2004) Remote Versus Hands-On Labs: A Comparative Study. 34th ASEE/IEEE Frontiers in Education Conference. October 20-23, 2004, Savannah, GA USA.

[15] Lima, C. B. de; Villaça, M. V. M. AVR e Arduino: técnicas de projeto. 2ª ed. Florianópolis: Ed. dos autores, 2012.