Automation and Renewable Energy: Outreach Efforts in Brazilian Public Schools

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Abstract

The interest in Control and Automation Engineers (CAE), in the southern region of Brazil, has been progressively decreasing over the last few years. Therefore, an outreach project has been idealized by the Renewable Energy Research Group (GPER, which belongs to the Federal University of Santa Catarina) seeking to disseminate recent scientific results achieved by the group. The progress of this outreach project, "Automation and Renewable Energies" (ARE), is discussed in this paper. This project entertained visits to local public schools in Florianópolis (capital of the Santa Catarina state), aiming to encourage high school students to be future CAE actors and, to urge their interest of this course, correlating this degree with the topic of Renewable Energy Sources (RES). Moreover, the development of scaled renewable energy testbeds is also discussed; these small mock-ups make an allusion to why control-oriented purposes are of most important to the RES context, given that adequate control strategies can be used to maximize global efficiency and allow the adequate integration of renewable sources to modern electric networks.

Keywords: Control Engineering; Renewable Sources; Outreach; Brazil; Public Schools.

1. Introduction

The use and generation of electrical energy in efficient ways are key subjects for a more sustainable and ecological-friendly future. The foundations of energy generation are changing in a profound manner (Lund, 2007), (Dincer, 2000): the prices of fossil fuels increase each year (due to scarcity), energetic demands increase in every country and the search for viable renewable sources becomes evermore important **(**Shafiee and Topal, 2009). With an imminent need for distributed power and heat generation to guarantee demands (Jiayi et al., 2008), clean and renewable energy generation is indisputably a matter of great importance, that will guide the public policies for the energy scenario of the coming years.

Energy generation from individual renewable units is associate to as many problems as it may intend to solve. It has been demonstrated (Lasseter, 2007) that a better way to solidify and expand the emerging potential of renewable energy generation is to model and understand these systems as local "blocks" from which generation and loads can be viewed as subsystems. Such paradigm is the basic idea behind the concept of Microgrids: smaller units that can operate in parallel to the main grid or in islanded mode, providing utility power station services. They are usually combined with the use of waste heat from the available sources to increase global energetic efficiency.

The greatest problem related to this kind of systems is the inconsistency and quality mistrust regarding the renewable sources, since these are intermittent and cause fluctuations upon the energy outlet. What literature indicates as a practical solution to treat this problem is the insertion of intermediate energy-storage facilities (such as batteries, fly-wheels, *etc*) to compensate the renewable inconsistency and intelligent, autonomous supervisory energy managers (controllers) that adequately coordinate all the internal units/subsystems of a renewable microgrid. Such controllers have been progressively called Energy Management Systems (EMS), in the broader sense (larger-scale) coordinators (Chen et al., 2011), and Microgrid Central Controllers (MGCCs), regarding the local coordinators (Olivares et al. 2014), (Kaur and Basak, 2016). Practical,

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experimental verification of such tools have been presented in (Gouveia et al., 2016), (Lidula and Rajapaske, 2011).

Since 2014, the Renewable Energy Research Group (GPER) has been studying these EMS and their application concerning the Brazilian energy context. Exciting results have been achieved: (Morato et al., 2017), where an MGCC is designed for a sugarcane-based microgrid; (Vergara-Dietrich et al., 2019), where stochastic control methods are applied for the same microgrid, but now considering the variability of renewable sources (solar irradiance and wind speed); (Mendes et al., 2019), where an energy management system is developed for an experimental microgrid coupled to a vehicle-to-grid system.

GPER lies inside the Automation and System Department (DAS) of the Federal University of Santa Catarina (UFSC) and has as its main focus in research and development of projects in several areas linked to Control and Automation of Renewable Energy Systems, with experience in advanced control applications in microgrids with renewable energy, energy generation plants in the sugarcane industry, heliothermic solar fields, large-scale wind power generation, solar desalination, hydrogen production from renewable sources, among others. The group has several contributions (in both national and international scale), taking part in congresses and publishing several scientific papers, as well as collaborations with national sugarcane and energy industries. Today, GPER is the lead control-oriented renewable energy researcher in Brazil, and one of the largest groups in Latin America devoted to this topic.

The main scientific method/control framework that GPER has studied and established is the use of Model Predictive Control (MPC) as formal EMS/MGCCs. MPC (Camacho and Bordons, 2007) is a (very well-established) optimization-based control loop, with a strong industrial practice. The use of MPC as these autonomous microgrid coordinators is a very natural development, once it can deal with the inherent model characteristics of renewable energy-generation systems (Geidl et al., 2007) and explicitly deal with operational constraints (on the actuation, generation, conversion *etc*). MPC can also inherently exhibit *feedforward* compensation capability (Vergara-Dietrich et al., 2016), (Vergara-Dietrich et al., 2017), which means it can use some estimation of the future availability of renewable sources (solar forecast, for instance) to enhance the energetic efficiency performances.

GPER has been investigating solar and renewable paradigms for the Brazilian scenario because the country has a very miscellaneous energy matrix (Walter et al., 2014)[1]. Solar energy can be considered as one of the possible energy sources to increase the renewable energy quota, given that the investment in this sector has been largely increasing for the past few years; moreover, the climatic conditions are appropriate to explore this kind of source, showing competitive prices face to other sources such as natural gas (Tiba et al., 2005). All of these issues reinforce the need for qualified Control and Automation engineers that know how to manage/plan controllers for renewable microgrids. The Brazilian market is already demanding such engineers, once the renewable energy technologies must be adapted to the national context. This demand will progressively increase, given that trends are given towards sustainable energy matrices, as discussed by (Lund, 2007).

Nowadays, GPER has two main research branches, one that is focused on *i*) (large scale) solar collectors and their efficient management and another focused on *ii*) Energy management and fault estimation in sugarcane-based microgrids. Some of the recent results achieved by the GPER group concerning MPC applied to renewable energy systems should be recalled; with respect to branch *i*: (Mendes et al., 2014) shows a method to regulate the outlet temperature of a solar collector used for desalination; (Elias et al., 2019b) exhibits nonlinear MPC results for large solar fields; (Elias et al., 2018) exploits a controller for the optimal defocusing of solar panels, based on maximum temperature maintenance; the temperature control of such solar panels, using a stochastic MPC method, is developed in (Vergara-Dietrich et al., 2017). It must be noticed that GPER has had six papers accepted in this conference concerning solar heliothermic plants.

[1] Today, the total (primary) Brazilian energy matrix is 44 % renewable; within this share solar energy represents around 2 % (which will rapidly and vastly increase), whereas ethanol and bagasse stand for 40 %. The sugarcane industry already plays a major role in the energy generation, but this should also increase if the local producers are treated as islanded microgrids, being a transition alternative for a completely *green* matrix, as thoroughly discussed in (Morato et al., 2018).

With respect to branch *ii*, it must be pointed out that Brazil has the world's largest sugarcane industry, with intense sugar and ethanol production. Such plants can also be understood as distributed microgrids, once they have large amounts of residues that can be used as *bio*-sources, such as the bagasse and straw (biomass) and the vinasse (that can be converted into biogas via anaerobic digestion). In these plants, solar energy also plays a vital role, being an auxiliary source for energy generation. When solar irradiance is low, energy is generated from biomass and biogas sources, whereas when it is intense, it powers by itself these plants. Notice that the biomass/biogas stocks are used to compensate the variability of the solar source. This, combined with the autonomous microgrid coordinators, guarantees energy generation throughout the whole year (whereas the harvest period is of around 200 days). Therefore, in (Morato et al., 2018), these sugarcane-based industries are modelled from scratch as renewable microgrids; an MPC EMS is designed in (Morato et al., 2017a) and enhanced with *feedforward* compensation in (Morato et al., 2017b); in (Morato et al., 2019), the issue of faults is incorporated in the control layer.

Besides that, GPER is an extremely productive research group that studies exactly this field. Today, a disclosure page is available on social media[2], a pilot plant for heliothermic solar field tests (experimental stand) is mounted in UFSC and partnerships the µgrid-Lab[3] are standing, counting with the contribution of many students from the first years (scientific and technological research initiates), master's and doctoral students; and post-doctoral researchers. GPER members have already participated on countless scientific nationals and internationals congress and have already given several disclosure lectures around the world: Argentina, Uruguay, Bolivia, Chile, Spain, among others. Besides that, GPER has technical and historical collaboration with several foreign universities: University of Sevilla, University of Almería, University of Valladolid, Universidad Nacional de La Plata and Université Grenoble-Alpes, as well as national collaboration with the Federal Universities of Bahia (UFBA) and Minas Gerais (UFMG). All these factors should reinforce the student appeal for the CAE degree at UFSC.

2. On Automatic Control

The Control and Automation Engineering (CAE) diploma started in March 1990 at UFSC, being pioneer in Brazil; currently it receives 72 students per year. During five years of study, the future engineer receives license to act in several areas related to process control, as well as renewable energy system control. Since the beginning of its creation, the CAE course has always had a high-level demand. CAE used to be one of the three most popular courses of UFSC, with an over 14.5 candidates / places ratio (in 2005); the students needed very high grades in the admittance exams for approval. Nowadays, the course is grade 5 out of 5 at the national evaluation system[4], being a 5-star diploma as ranked by Folha[5], with the second best-ranked teaching quality in Brazil.

The use of automation and control methods for renewable energy systems is essential: these tools can maximize efficiency, allow their adequate integration to modern networks and solve the issue of intermittency. Therefore, there is an increase in the demand of automation engineers with renewable energy focus being implanted by the industry, and from their increasing value to the progress of technology in Brazil. Of course, there is a crescent in the need for renewable energy production for more ambitious sustainability goals, which directly converts into the need for prone engineers to solve the issues that arise with such sources, as previously discussed.

Unfortunately, high-school students do not relate CAE with the application of automation to renewable energy systems! It is consensus among the CAE/UFSC teachers that there is a great need to further disseminate what it means to be a Control and Automation Engineer in the context of energy generation. For such, since 2017 there has been a great effort to spread material about the course through social media and local newspapers,

[2] See facebook.com/GPERUFSC.
[3] See *ugridlab.paginas.ufsc.br*.
[4] ENADE exame, see dpgi.seplan.ufsc.br/files/2018/10/Relatório-Enade-2018.pdf.
[5] Local news journal; it rates, every year, bachelor courses and degrees from all the universities in the country, ranking from 1 to 5 stars. See the latest ranking (in Portuguese): ruf.folha.uol.com.br/2018/ranking-de-cursos/engenharia-de-controle-e-automacao/.

but that did not seem to be enough to revert the panorama: the candidate/place ratio for the CAE/UFSC degree had continuous drops, going from 9.28 (2016), 8.16 (2017), to 6.24 (2018).

To strengthen this troublesome scenario, the interest in the CAE degree at UFSC has been slightly decreasing over the course of the last few years, which can be easily verified by the number of enrolled students in vestibular/ENEM exams[6] (in Brazil, vestibular and ENEM are contest exams that work as the sole ways to enter the country's public - and internationally renowned - universities). Moreover, a considerable circumvention is verified in students of the first two graduation years, which leaves many unoccupied places for candidates who chose CAE as a second course option. This fact seems to go against the increasing value of control and automation engineers.

One of the reasons for this decrease in demand may be related to the lack of awareness of the impact and importance of these engineers to several sectors of development in the country; very few people relate CAE with the sustainable development and *renewables*.

Therefore, the outreach project "Automation and Renewable Energies" (ARE) was launched by the GPER/UFSC research group in the beginning of 2019, with the main focus as to visit local public schools for the dissemination of CAE's performance in this strategic sector (in respect to the global goal of more ambitious sustainable development, as discussed in Section 1), with hopes to boost the search for the CAE degree at UFSC and motivate students with renewable sources themes (which are, incontestably, topics of increasing appeal).

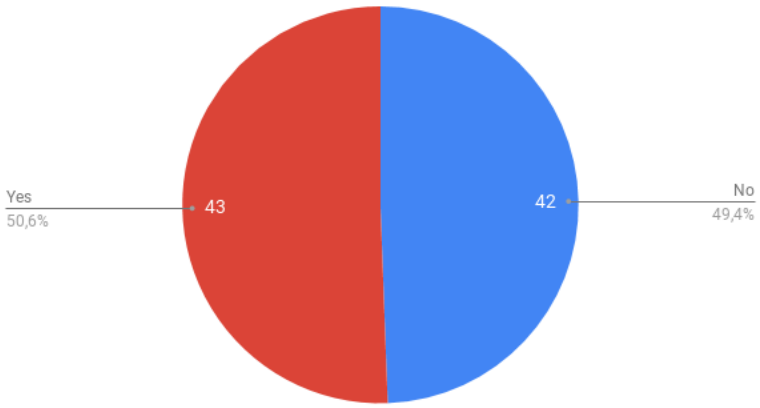
For all the reasons stated, it was noted that there is, evidently, a huge need to encourage high school students from public schools to get excited about the possibility of becoming future Control and Automation Engineers. Therefore, the outreach project consisted in several visits to schools (and with students to the CAE department) bringing to them information about the CAE course and about the Renewable Energy Research Group. The outreach methods and results are discussed in the sequel.

3. Outreach Methods

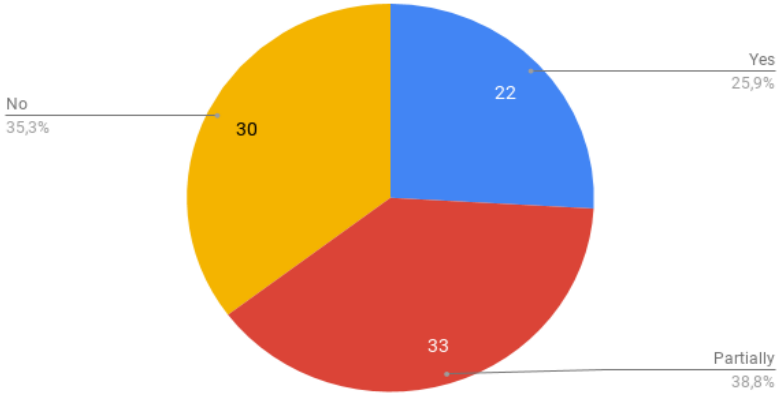
The ARE outreach project was carried out through lectures in schools, as well as internet dissemination, through social media and the GPER website, about what kind of research was underway. These dissemination actions were carried out throughout all regions near UFSC, essentially bringing simple technical and scientific knowledge to the outside community. Students and teachers of public schools in Florianópolis (capital of Santa Catarina) were the main beneficiaries of this project, as well as the **undergraduate** students that were involved, who had their CAE career directly enriched by activities in the context of this outreach project. The visits to the schools consisted in conversation circles and hands-on experiments by the high-school students in scaled testbeds and experimental mock-ups[7].

These visits intended to bring to these students knowledge and information about the Control and Automation Engineering (CAE) course in the local federal university (UFSC). Up to this present day, this project has reached over 85 students. These were: 61 from the last year of high school, 14 from the second year and 10 from the first year. Essentially, none of these students knew much about Automatic Control or how it is related to the renewable energy context. From interviews with the students, Graphs 1 and 2 (below) were elaborated. It becomes clear that a great part (50.6 %) of the interviewed students did not even know of the CAE degree, neither its relationship with *renewables* (Graph 2: 74.1% of the interviews students said to known nothing or very little of it). The dissemination of topics related to practical usage of renewable energy will certainly help with the future development of the country (which has the biggest renewable energy matrix on the planet and a great unexplored potential), encouraging the training of qualified professionals, oriented to science and technology, besides having the power to attract young people to the study of CAE.

[6] Respectively, local and nationwide exams for last year high-schoolers to be admitted to the Brazilian public universities.
[7] Some of these mock-ups are presented in Figure 4, in the sequel.



Graph. 1: Interview 1: Have you ever heard about the CAE degree?



Graph. 2: Interview 1: Did you know about the CAE – Renewable Energies relationship?

The ARE outreach schedule consisted in: i) inviting CAE teachers and students that produce high-impact research to prepare lectures to non-specialized audience; ii) contact with public schools in the region around Florianópolis, requesting visits to high-school classes; iii) elaboration and development of small energy-related testbeds by first year CAE students; iv) visits to the schools and exhibition of relevant topics in the area of renewable energies with participation of GPER members and CAE students; and v) disclosure of the developed activities by social media and institutional websites.

The visits were either in the schools, or in the CAE department, at UFSC, if there ever was the possibility of the students coming to the university. The latter proved to be more efficient, once it visibly brought up much more interest from the students, who were inside an academic environment (many for the first time). Figure 1 shows photos of two of these encounters: on the left (1a), a visit to the CAE department is shown, whilst on the right (1b), a visit to a school is demonstrated.

Fig. 1: ARE Encounters: Left: CAE Department (1a). Right: Visit to a High School (1b)

The dynamics of these encounters consisted in: 1) a formal presentation about the Control and Automation Engineering degree, explaining the main activities of a graduated professional and the connection of this course with the theme Renewable Energies (Fig. 2). Much attention was given to this last topic due to the expertise of the GPER research team; concepts of solar energy, microgrids and Energy Management Systems were discussed with the high school students using informal discourse and simplified analogies. 2) After this presentation, the students were taken to two main laboratories of the CAE department: the Projects Laboratory (LPR) and the Manufacturing Laboratory (Fig. 1a). In the first, an experimental Automated Guided (AGV) made with LEGO NXT Mindstorm kits were presented to the students in order to explain the essential concepts of CAE: actuation, instrumentation (sensors) and control. At the second lab., CAE undergrad students presented to the high school visitors their own projects and the material used to manufacture them. Finally, a longer guided visit was performed at the GPER Solar Plant Lab. (Fig. 3), a scaled solar collector plant built by the GPER group to test and verify different control methods; its main goal is to maintain the outlet water temperature despite the variability solar irradiance.

Fig. 2: ARE Encounters Dynamics

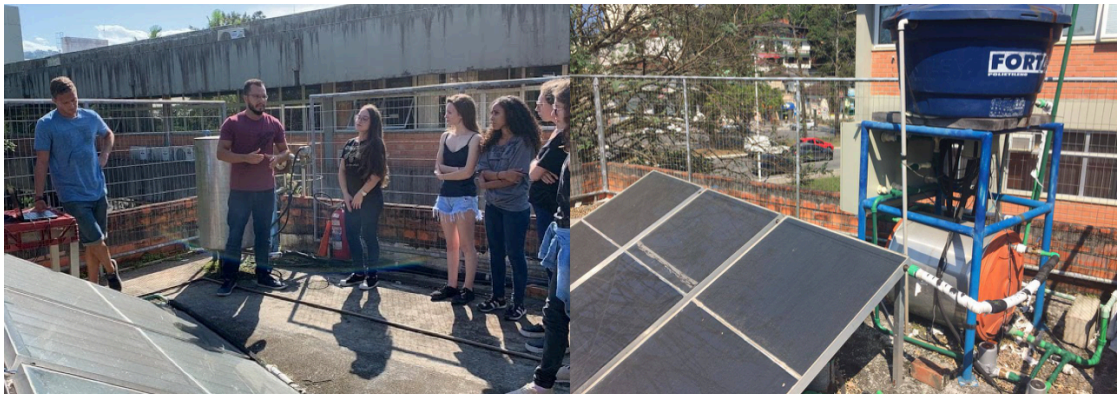


Fig. 3: GPER Solar Plant Lab.

The visits/encounters at the schools themselves (Fig. 1a), which happened when there was no availability for the students to come to the CAE department, had a different dynamic. Whilst the same presentation about Renewable Energies and CAE was performed, small mock-up testbeds were taken to the schools so that the students could play/interact with them (some of these are shown in Fig. 4). These were: the same LEGO AGVs, an intelligent "renewable" house, an automated sugarcane harvester and an intelligent photovoltaic panel. The intelligent house regulated the amount of internal lighting (some few LED bulbs) based on the amount of clarity that entered the environment, to save energy and provide a more peaceful eye environment; the sugarcane harvester is a simulator of crop harvester that can be put either in manual or automatic mode - it illustrates/emulates how hard it is to keep the harvester on track manually, while it is done very easily by the embedded automatic controller; the intelligent photovoltaic panel is a scaled panel that tracks the direction of source of light, aiming to guarantee maximal energy generation with respect to the irradiance angle.

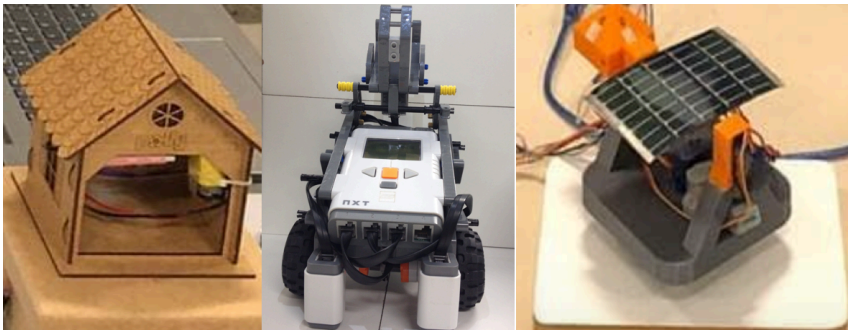
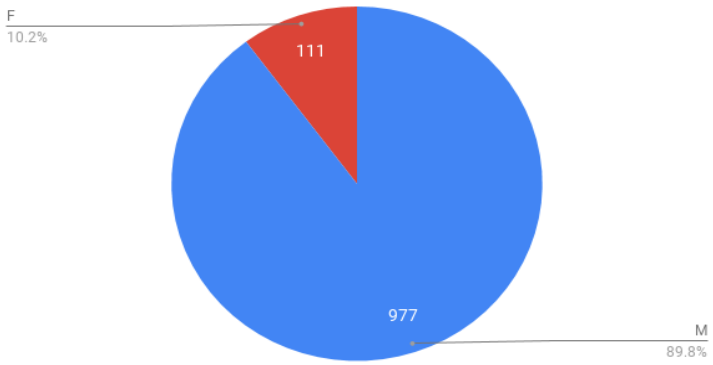


Fig. 4: Experimental Mock-ups: Intelligent House, AGV, Intelligent Photovoltaic Panel

Of most importance, in the presentation dynamic of all these encounters, a CAE gender equality panorama was discussed. Note that of the 434 students that are part of the UFSC CAE course (nowadays, 2019), only 57 are women (and they represent 51,35% of all female students that have ever been part of the CAE/UFSC alumni). Considering the total of 1088 graduated engineers (from 2003 to 2019), only 111 were women (around 10 %), as displays Graph 3. This discussion about gender in an extremely important topic to be touched concerning high school students, since they are going to be the future generation of CAE students; the project's goal was to pass a message of motivation and self-trust for these girls, hoping that this scenario can be reversed. In the graph below, the discrepancy of gender in the department became more visible.

It is also important to mention that, during the ARE encounters, the emerging role of artificial intelligence (in the sense of machine learning algorithms) and its relationship to the CAE course was also strongly highlighted. Being this topic of increasing importance in engineering and science, discussing it with the students also served as another motivational venue for possible interest in CAE. Closely related to artificial intelligence, the issue of engineering safety and the human replacement by machines was also a topic debated in the ARE visits.



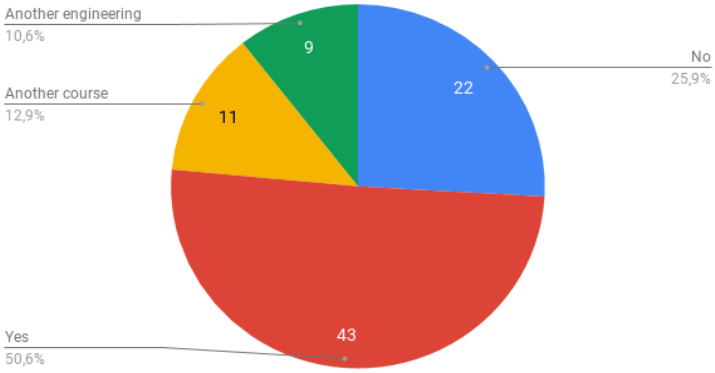
Graph. 3: CAE/UFSC course: Gender Distribution

Finally, it must be remarked that the impact of this kind of (outreach) activity is very interesting, since the engineering knowledge of high school students in Brazil is very reduced (see Graph 1). The results that concern the visits derived from the Automation and Renewable Energies outreach project are already being felt, as discussed in the sequel.

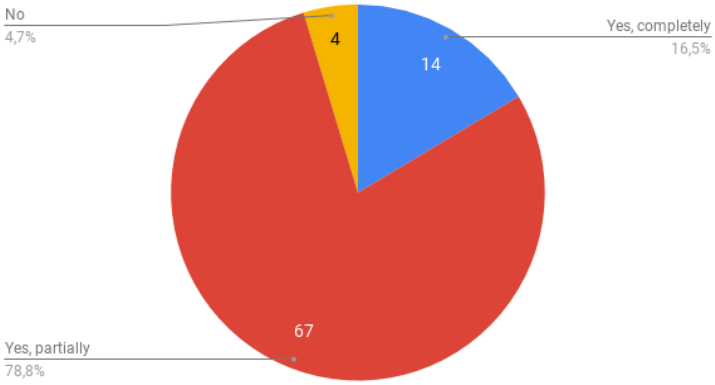
4. Outreach Results

Concrete practical results of this outreach project are still to be harvested, given that an increased demand for the CAE degree will only be noted in one or two years, via vestibular/ENEM inscription data, which is still not available.

Nonetheless, some expressive results are already being harvested. After each visit was over, a second interview was conducted with the students, to evaluate how their knowledge of CAE had changed with the ARE encounter. The achieved results / answers are summed in Graphs 4 and 5, below.



Graph. 4: Interview 2: Are you interested in Control and Automation?



Graph. 5: Interview 2: Can you define what a Control and Automation engineer does?

Notice that the majority of students could conclude partially or completely on what a CAE engineers does. They all agreed, after the ARE outreach encounter, to understand how CAE engineers act with respect to the renewable energy context. Moreover, many of them said to have interest being future CAE engineers, which is of great enthusiasm to the Authors.

It must be remarked that the expressions of joy and interest[8] of the students, in all visits, was very noticeable. The message of the value of CAE in renewable energy domain for the near future was passed on, which hopefully will contribute in strengthening the transition plan of the Brazilian energy matrix to a more sustainable one.

It is hoped that the encouragement of these students will lead them to possibility attend the CAE degree and to specialize themselves on this field of renewable energy research. That, on a long term, will result in qualified trained professionals capable to solve renewable energy implementation challenges (nowadays there is little offer of this professional profile in the Brazilian market).

It must be remarked that the articulation of this project with teaching, research and extension is natural, since it acts directly through lectures/activities that crave the sharing of dedicated actions to science and technology divulgation. It is also worth highlighting that there are several high-school teachers looking for knowledge in Renewable Energy field, which can be used as motivational examples in pedagogical activities related to many school subjects.

5. Conclusions

This paper discussed the "Automation and Renewable Energies" outreach project deployed by the GPER/UFSC research group. ARE has the goal of urging the interest for the Control and Automation course at UFSC in high school students of the local public system, creating a methodology to present, to these students, other ways to view the possibilities of an university engineering degree. This project is still underway, since its final goals will only be concretely achieved in some years, when the inscription rate for the CAE course should increase. Anyhow, some interesting results could already be collected, as discussed: interviewed students disclosed to be much more interested in this course and positively confessed to understand its connexion to renewable energy systems.

[8] In fact, students form one of the visited schools came, after the visit, to UFSC to get help from the GPER members on how to concretize a project of theirs to construct solar photovoltaic panels for their school, which seeks to become the first sustainable school in the state of Santa Catarina.

6. Acknowledgments

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