Implantation of a photovoltaic system installation and design course

Manoel Henrique de O. P. Filho and Alexandre Manoel de Farias[1]

[1] Federal Institute of Education, Science and technology of Pernambuco, Campus Pesqueira, Pesqueira (Brazil)

Abstract

It was observed with the exponential growth of Brazilian market related to distributed generation with photovoltaic promoted by RN (Resolução Normativa – Normative Resolution) 482/12 and 687/15 published by ANEEL, that fast courses for photovoltaic (PV) modules installers are attended by non-qualified persons. This motivated the emergence of work groups with the goal to developing courses that deal with themes to comply with requirements of quality and security of those systems. This work presents a description of a designer and installer of photovoltaic systems course implantation in a public teaching institution. It´s presented the developing of contents relevant to the work force formation to attend the needs of market, as PV solar energy basic concepts, techniques and materials for rooftop installations and proceeding to develop PV design. The major of realized practices are also described, as MC4 connector and string box components mounting and the PV modules rooftop installation procedures (security and materials). As a result of the course, two classes already formed are described as well as the results of it to the local market.

Keywords: Education in photovoltaics systems, Photovoltaic solar energy, Grid connected solar systems.

1. Introduction

The Brazilian photovoltaic solar energy has presented an exponential yearly growth since the publication of Resolução Normativa (Normative Resolution) 482/12 and its update, the Resolução Normativa (Normative Resolution) 687/15, as demonstrate by ANEEL (Agência Nacional de Energia Elétrica – National Agency of Electrical Energy) data.

It was observed, in 2015, an increase of 258 % in photovoltaic solar mini and micro generators power installed, with an increment of 397 % in the number of installations. The Brazilian market presents heated with these rates, and it tends to keep these numbers in the next years. In fact, for instance, the increment of power installed was 409 % (2016), 164 % (2017) and 159 % (2018), and the number of installations were 320 % (2016), 127 % (2017) and 98 % (2018).

There´s a lack of qualified work force due to this area be relatively new in Brazil and the area being presenting a fast growth that can´t be followed by the capability in training persons to act in it. According to Mocelin (2014), the consequence of execution of design by non-qualified persons is that those ones could be barely projected and executed, which cause a negative influence in the technology reputation, and it could be discredit by the population.

Some problems have already been verified in some installations in Brazil, such as bad system operation, fire in junction boxes (figure 1a), fire in photovoltaics modules (figure 1b) and metallic structure bad evaluated (figure 1c) that did not bear the load above it.

doi:10.18086/swc.2019.50.06 Available at http://proceedings.ises.org

Fig. 1: Problems encountered in Brazilian photovoltaics installations.

Commendable initiatives, however pointed and isolated, in some Brazilian institutions, can be observed in order to fulfill the lack in workforce formation of this area. Blasques (2016), Neto et al. (2016) and Diniz et al. (2016), for instance, presented their proposals for courses in this area. There are *lato senso* courses in diverse universities in Brazil, highlighting, for instance, the Centro de Pesquisa e Capacitação em Energia Solar (Solar Energy Training and Research Center) in UFSC (Universidade Federal de Santa Catarina – Federal University of Santa Catarina) and the Centro de Energias Renováveis (Renewable Energy Center) in UFPE (Universidade Federal de Pernambuco – Federal University of Pernambuco).

Some action in this senses were proposed by national industry like the constitution of Grupo Setorial de Sistemas Fotovoltaicos (Photovoltaic Systems Area Group) by ABINEE (Associação Brasileira da Indústria Elétrica e Eletrônica – Brazilian Association of Electrical and Electronic Industry) in 2010, that resulted in the creation of formative itineraries and courses in the photovoltaic area inside the partnership between SENAI (Serviço Nacional de Aprendizagem Industrial – National Service of Industrial Learning) and GIZ (Deutsche Gesellschaft für Internacionale Zusammenarbeit - German Society for International Cooperation).

The creation, in 2015, of work groups about professional formation in renewable energy and energetical efficiency by SETEC/MEC (Secretaria de Educação Tecnológica do Ministério da Educação – Technological Education Secretary of Education Ministry) was another important initiative, supported by GIZ. One of them is dedicated specifically to the workforce formation in designers and installers of photovoltaic solar systems.

Many actions were developed as result of this group, such as 1) development of formative itineraries for three different types of courses: installer (160 h), designer (240 h) and specialization for graduated (360 h) (Pedrosa Filho *et al.*, 2018); 2) training for teachers of Rede Federal de Educação Profissional, Científica e Tecnológica (Federal Network of Professional, Scientific and Technological Education), in these three levels; and 3) description of a minimum infrastructure that permits that courses be realized in the Federal Network.

This work presents, in this sense, a description of a photovoltaic solar system installer and designer course implantation in the IFPE (Instituto Federal de Educação, Ciência e Tecnologia de Pernambuco – Federal Institution of Education, Science and Technology of Pernambuco), Campus Pesqueira, that belongs to the Federal Network. It´s described the methodology and curricular matrix of the course, as well as the practices developed by the students. The practical results of the course for the photovoltaic systems local market are presented at the end.

2. Course of designer and installer of photovoltaic solar systems

The creation of the designer and installer of photovoltaic solar system course considered that the IFPE Campus Pesqueira has a course of electrical technician working since 1993 (26 years old), that is consolidated and a reference in the region. It was also taking on account to the course that: 1) there is in the market a great number of technicians formed and with a practical expertise in residential and industrial electrical installations; 2) the Agreste region of Pernambuco State in Brazil has a big potential for photovoltaic system installation due to the high level of solar irradiance of order of 5,5 kWh/m² (Pedrosa Filho and Mariano, 2018); 3) there is a tendency of projects development of any level in the region and 4) the formation of a person capable of install and design these kind of system permits a better professional development towards to undertake his own business in the area.

It was considered, for attending these premises, that only formed technicians that work with electrical installation (priority) and tend to be an entrepreneur would be students of the course. These characteristics were evaluated through a quiz applied to the applicants of the course.

The course structure was divided in 4 modules: fundamentals of the electricity, fundamentals of photovoltaic solar energy, designer of photovoltaic systems and photovoltaic systems installation.

The table 1 presents a resume of course contents. In the module I, the students are taken to remember main electricity concepts and the specific instrumentation to be used in practical activities along the course. This initial approach is fundamental to the course continuity because prepares the students for using needed tools for electrical installation of AC (Alternate Current) side of the system as conduit, circuit breakers, AC cables, grounding, etc. The module II presents main contents that insert the students in PV world like solar radiation, PV solar cells and modules, that permits to the students understand technological terms that are needed to install either to design the systems.

The 3rd module introduces the student to the practices directed to PV systems design; it approaches Brazilian standards needed to develop a PV grid connected project and the sizing of components of installation. The main softwares used to simulate systems are also presented in this module. The last module is directed to practices of PV grid connected systems installation, approaching topics related to preparing, installing and commissioning these systems, as well as all equipment and standards needed to accomplish this activity. A practical installation of photovoltaic modules is realized on two kinds of roofs (ceramic and asbestos cement), very commons in Brazil; a commissioning basic tests are executed at end of installer module of the course.

Tab. 1: Topics approached in the course.

Module	Main theme	Topics covered
1	Fundamentals of electricity	**Electrical Quantities:** voltage, current, resistance, power; **Main installation concepts**: simple electrical circuits, measuring instruments, mains installation components, grounding, electrical shock protection and voltage surge. **Single-fase and three-fase electrical systems.**
2	PV solar energy fundamentals	**Solar energy fundamentals:** solar radiation, irradiance and irradiation definitions, irradiation databases, solarimetric maps and instrumentation. **PV cell and module:** PV effect, cells and modules, electrical and mechanical characteristics, temperature coefficients.
3	PV systems designer	**Energy charging model** **PV grid connected components:** inverter, string box, surge protection devices, fuses, disconnect switch, connectors, DC cables, mechanical structures. **PV grid connected sizing** **Descriptive memorial development:** Brazilians normative resolutions 482/12 and 687/15, regulations of the energy concessionaires, unifilar and multi-strand diagrams, PV mechanical and electrical layout, descriptive memorial and ART (Anotação de Responsabilidade Técnica - Annotation of Technical Responsibility) **Rooftop structural components.** **Entrepreneurship.**
4	PV systems installer	**PV grid connected installation:** security in rooftop installations, single protection equipments, materials used in rooftop installations, practice on rooftop PV systems, commissioning.

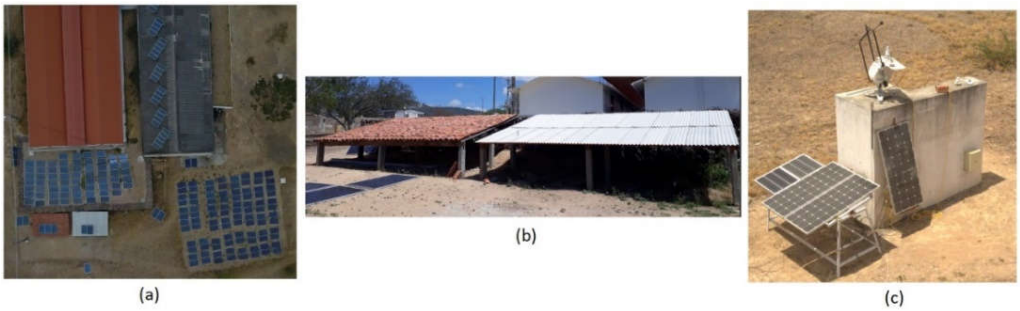


Fig. 2: (a) Modules of 42 kW photovoltaic plant, (b) Roofs for practices and (c) Solarimetric station.

There are practical activities in all modules of the course. The IFPE campus Pesqueira has a photovoltaic solar plant of 42 kW with modules installed under different conditions: on the rooftop of classrooms and on the ground (figure 2a). There are photovoltaic modules of different technologies: monocrystalline, polycrystalline, thin film and flexible, and two roofs for practices (figure 2b), one of them with ceramic roof tile and the other with asbestos cement roof tile; besides, there is also a solarimetric station with beam, global and diffuse irradiance measurement (figure 2c).

The practices realized in the first module of the course are related to measurements of electrical quantities in the electrical and photovoltaic systems of the institution and photovoltaics modules. Practices of module connections (serial, parallel) with measurement of electrical parameters, solar radiation measurements and solar radiation public databases search in the computer lab are accomplished in the second module. A project is developed and simulated with all documentation needed in the third module. The practices in the final module consist of an assembly of an array of modules considering its mechanical layout, assembly junction boxes with different configurations and MC4 connectors and mounting modules on the roof, using all protection equipment, commissioning basic test are realized at end, according to the Brazilian standard NBR-16274. The table 02 presents a resume of practical activities realized in the course.

Tab. 2: Details of practical activities developed during the course.

	Activity	Description	Workload	Previous knowledge
1	Measuring Instruments and electrical installation	Execution of practical procedures in an electrical installation laboratory to train the use of measuring instruments like multimeter and clamp meter, and installation of AC cables and circuit breakers.	4	Fundamentals of electricity
2	PV modules connections	Approaching the electrical characteristics studied at module II about serial and parallel connections of PV modules. Electrical measurements of voltage and current are done at major of configurations and number of modules connected.	4	Fundamentals of electricity and PV solar energy fundamentals
3	Solarimetric software demonstration	Demonstration of the dependency the daily and monthly solar radiation of location, azimuth and inclination of module, permitting to estimate its values for practical situations.	2	PV solar energy fundamentals
4	Development of a real PV grid connected system design	Development of a complete and real project of a residential client using all knowledge built about PV solar energy, mains and standards. Some project details	20	Fundamentals of electricity, PV solar energy fundamentals

		are presented such as materials and price lists, drawings of installation details and project documentation needed so it can be approved by electrical companies.		and PV systems designer
5	Installation of PV systems electrical protection components	Mounting of diverse input and output configurations of string boxes and MC4 connectors mounting	8	Concepts approached at all modules of course
6	Installation of rooftop PV systems	Mounting of two PV systems on different roof tiles (ceramic and asbestos cement) permitting to all students to overcome all implicit difficulties in each situation	8	
7	Commissioning	Execution of security procedures needed to start-up the PV grid connected and maintenance of these systems, like fix systems fails.	8	

3. Results after the course

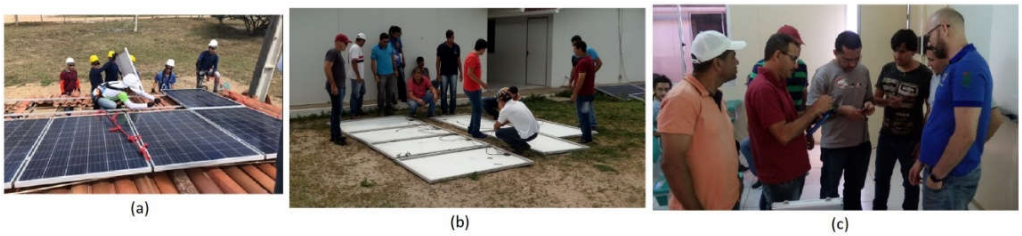
The course was implemented in the 1st semester of 2018. The table 3 presents the course numbers. There are three groups trained until this moment. The interest in the course increased; in the last group, we received applicants from many locations further than 200 km from Pesqueira city, and from other Brazilian States.

The course period has changed from morning to night due to the waiver of many student due to their working time. It can be observed that, the night course has got a higher number of candidates due to their profile, that normally work during the day and intend, after the course, act at a new area, but the practices time was a great problem, the morning Saturday was used, but not all students could come due to their working time. The 3rd group had a high number of candidates due to course disclosure and the PV area warming.

Tab. 3: Number of inscriptions and students of the course.

Group	Semester/year	Inscriptions	Timetable	Number of students at beginning	Number of students at end
1	1st / 2018	38	Morning	20	15
2	2nd / 2018	72	Night	25	18
3	1st / 2019	305	Afternoon	25	16

All practices were realized as expected. It was observed that the students applied many concepts and techniques during the practices moments, such as using at all time the security equipment (figure 3a), electrical connections and its expected values of voltage and current (figure 3b), the care of handle with the photovoltaic modules during its installation, and the verification of final quality of MC4 connectors assembly (figure 3c).



(a) (b) (c)

Fig. 3: (a) Modules installation on practice roof, (b) Electrical connection execution based in mechanical layout and (c) MC4 connectors assembly.

The results were positive in the 1st class; after the course, two installation and design companies of photovoltaic system were founded. The first one, called Agreste Energia, accomplished in 7 months 20 projects and 11 installations, with 0.3 MWp in total; 13 persons were employed in these activities. The second one was the company called Electric Station that accomplished 3 projects and installations, with 90.8 kWp in total; others 13 persons were employed. Some students that already execute electrical installations and design incorporated in those activities the photovoltaic solar system design. In the 2nd class, companies were no founded because the class was composed in majority by people who are self-employed, some students worked in the two 1st class´s companies to act in projects in development. In the 3rd class, some students started to elaborate designs after the end of classes and other began to organize new companies.

4. Acknowledgments

We acknowledge the IFPE Campus Pesqueira and the partner companies for supporting the course.

5. References

Mocelin, A.R., 2014. Qualificação profissional e capacitação laboratorial em sistemas fotovoltaicos. Instituto de Energia e Ambiente. Universidade de São Paulo.

Blasques, L., 2016. A educação profissional e tecnológica e os itinerários formativos como potenciais soluções para a escassez de mão de obra especializada em instalações FV no Brasil. Proceedings VI Congresso Brasileiro de Energia Solar, Belo Horizonte.

Neto, M.R.B., Costa, R.M., Coelho, F.J.S.d., Silva, P., Lopes, L.C.N., 2016. Ensino Técnico em Sistemas de Energias Renováveis no Semiárido Brasileiro. Proceedings VI Congresso Brasileiro de Energia Solar, Belo Horizonte.

Diniz, M.M.N., Scariot, E., Carvalho, P.C.M., Canafístula, F.J.F., 2016. Experiência do Instituto Juazeiro na Promoção de Cursos Técnicos na Área de Sistemas Fotovoltaicos. Proceedings VI Congresso Brasileiro de Energia Solar, Belo Horizonte.

Pedrosa Filho, M.H.O., Micha, D.N., Oliveira, R.C., Madukanya, U.E., 2018. Desenvolvimento de itinerários formativos para a educação profissional e tecnológica na área de energia solar fotovoltaica. Proceedings VII Congresso Brasileiro de Energia Solar, Gramado, Brazil.

Pedrosa Filho, M.H.O., Mariano, V., 2018. Análise da tendência da irradiação solar e temperatura ambiente no agreste nordestino empregando dados medidos de longo prazo. Proceedings VII Congresso Brasileiro de Energia Solar, Gramado, Brazil.