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Solar PV Installation and Troubleshooting Course Development

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Abstract

Renewable energy systems are environmentally friendly power generation solutions as compared to traditional fossil generators, and as a result have created a continuously expanding job market. The global investment in solar photovoltaic (PV) systems has gone through a mostly increasing trend in the past ten years, which implies that solar PV systems will own a major share of the power generation and distribution market in the near future. In this NSF-funded project, the state-of-the-art equipment are used to design and develop the new laboratory and course "Solar PV Installation and Troubleshooting". The new course is designed, developed, improved, and enhanced in close collaboration with industrial partners in order to prepare the students for the North American Board of Certified Energy Practitioners (NABCEP). In this paper, the equipment used in this new course as well as the course outline and laboratory experiments will be presented and explained.

Introduction

The renewable energy share in the U.S. energy production market is growing rapidly, while the fossil energy share is declining [1], [2]. The energy generation growth of the individual renewable energy technologies is depicted in Figure 1 for the time span of 1998-2017. As indicated in this figure, the share of "solar" and "wind" has been considerably growing in the past few years, and the trend is increasing over time. According to the Bureau of Labor Statistics (BLS), "solar photovoltaic installer" is the occupation with the highest percentage of employment with the growth rates of 105%, between 2016-2026 [3]. Based on the information from the department of energy (DOE) depicted in Figure 2, about 42% (2015), 43% (2016), and 40% (2017) of the job market in electric power generation technology was dedicated to solar technicians. These statistical data indicate the importance of curriculum development for solar energy technology to train hands-on students and technicians to meet the future job market.

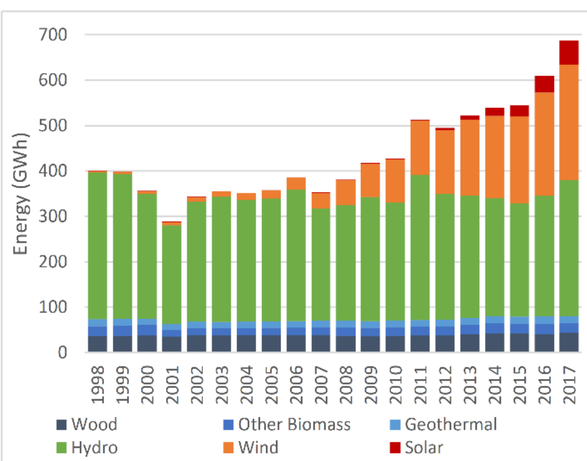

Fig 1. Renewable energy generation growth details, 1998-2017 [1], [2].

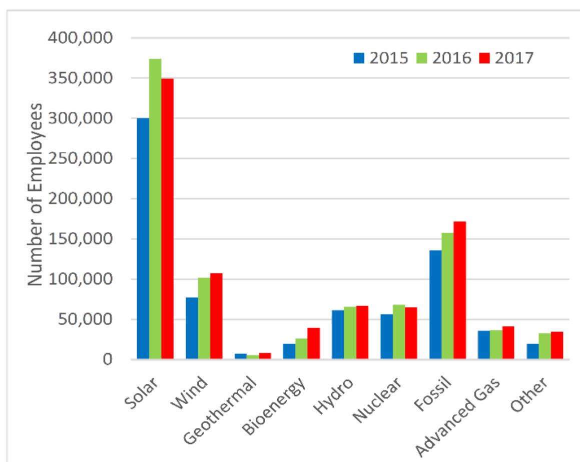

Fig 2. Electric power generation employment [4].

In this project, the focus was made on the solar photovoltaic technology, by developing the state-of-the-art laboratory and curriculum that match well with the relevant industry needs, to train the students in the Engineering Technology (ET) Departments at New Jersey Institute of Technology (NJIT) and County College of Morris (CCM).

New Courses and Laboratories Development

Two identical laboratories were developed, one per each partner institution, and were equipped with the following products from Amatrol Inc.: “Solar PV Installation Learning System”, “Solar PV Troubleshooting Learning System”, “Solar Thermal Troubleshooting - Closed Loop”, and “Solar Site Analysis Learning System” demonstrated in Figures 3, 4, 5, and 6, respectively [5]. These products include both equipment and multimedia software, which provides a series of laboratory instructions that were used to develop the laboratory manual. Moreover, the textbook “Understanding Photovoltaics: An Easy-to-follow Study Guide for Solar Electric Certification Programs” by Jay Warmke [6] was used to develop the lecture notes.

Fig 3. Solar PV Installation [5].

Fig 4. Solar PV Troubleshooting [5].

Fig 5. Solar Thermal Troubleshooting [5].

Fig 6. Solar Site Analysis [5].

The new course at NJIT, "Solar PV Planning and Installation", is a three credit hours course with two hours per week of recitation and two hours per week of laboratory experiments. This course is open to sophomores or higher, and the prerequisite course is "Circuits II". The new course at CCM, "Solar and Alternative Energy Systems", is also a three credit hours course with two hours per week of recitation and two hours per week of laboratory experiments. Since the focus of the two-year program at CCM is towards jobs as technicians, the course at CCM is more focused on troubleshooting, while the course at NJIT emphasizes the solar photovoltaic system design principles. In both of these courses, the assessment method is a combination of knowledge test, hands-on troubleshooting scenarios of embedded faults, and final research project. These courses will also prepare the students to conduct their capstone senior design (SD) projects in the field of solar energy systems. The outline of these courses is presented in Table 1.

Table 1. Outline of the new courses at NJIT and CCM.

NJIT and CCM	
Topic 1	Solar energy systems, DC/AC PV systems, solar thermal systems, active and passive water heating, space heating/cooling, and solar PV/thermal industries.
Topic 2	Solar irradiance characteristics/measurement/calculation, peak sun, sun path characteristics (global positioning, solar time, and sun path diagrams).
Topic 3	Solar panel orientation, site measurements, and insolation data.
Topic 4	Perform array site planning: assessment and permitting, analysis, component location identification, and layout drawing.
Topic 5	Perform maximum circuit voltage and current calculation, and wire selection and sizing; Select and install grounding and surge protection systems.
Topic 6	Draw 1- and 3-line PV circuit diagram, assemble a PV array and mounting system, install conductors, and label components based on safety rules; Perform pre-startup PV system checkout and initial startup, and tie an interactive PV system into the grid.
Topic 7	Connect and operate a PV module, and measure the open circuit voltage, short circuit current, and operating point; Calculate PV output given changes in solar irradiance and ambient temperature, determine PV module efficiency and interpret its specifications, and describe the types of PV module materials.
Topic 8	Calculate the theoretical power output of a PV array, and connect it given a wiring diagram; Measure the open-circuit voltage of a solar battery, calculate its discharge rate, interpret its specifications, and connect it given a schematic.
Topic 9	Interpret the battery charging characteristics, connect a charge controller and adjust its settings, and operate a charge-controlled DC PV system; Connect, operate, and troubleshoot a stand-alone AC PV system, and an interactive PV system to be tied to the grid with/without battery backup.
NJIT	
Topic 10	Manually operate a solar collector in a solar thermal system based on safety rules; Interpret the specifications of the solar thermal components, and connect and operate a circulator pump and a heat exchanger.
Topic 11	Connect and operate a digital differential controller; Program, operate, and troubleshoot a drainback solar thermal system.
Topic 12	Program, operate, and troubleshoot a pressurized solar thermal system.

Outreach to K-12 Students

As part of the NSF grant activities, summer workshops were offered to the K-12 students through the Center for Pre-College Programs (CPCP) at NJIT. For this purpose, the "Horizon Renewable Energy Science Kit" demonstrated in Figure 7 [7] was purchased. The experiments presented to the students included: Solar Panel, Wind Turbine, Electrolyzer, and Fuel cell. Moreover, real-size solar PV systems and basic circuit calculations were demonstrated to the students.

Fig 7. Horizon Renewable Energy Kit [7].

Conclusions

In this NSF-funded project, the new laboratories and the two new courses "Solar PV Planning and Installation" (at NJIT) and "Solar and Alternative Energy systems" (at CCM) were designed, developed, and are being offered to the engineering technology students at both institutions. These new courses and laboratories are being continuously improved and enhanced in close collaboration with industrial partners in order to target the real industrial demands in this field. The significance of this project is the contribution to the renewable energy workforce training. The new courses and laboratories provide the students with the functional knowledge and understanding of solar PV systems integration, installation, startup, commissioning, protection, and troubleshooting, to meet the knowledge requirements established by the NABCEP.

Acknowledgement

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