10 Megawatts to a Better Education

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Abstract

Rowan University Engineering students have been given a unique opportunity to work towards the creation of a 10 megawatt (MW) photovoltaic (PV) system as one component of the university's commitment to carbon neutrality. Students are learning a broad range of skills that apply to all levels of PV system design. For example, they are learning to assess site feasibility through the use of specialized equipment and software including shading assessment and expected power production. As they evaluate the quality of each site, the student team must understand the flow of energy through every stage of the system from an individual PV module, through the combiners to the inverters, and then to the transformer at the campus power substation. They are also learning about the documentation associated with a project of this size, which spans CAD drawings, impact assessments, and permitting. The team is responsible for the creation of request for proposal (RFP) that will be issued as a solicitation. A project of this magnitude also involves important engineering economic assessments since the project cost and potential is based on return on investment calculations, which must be attractive to prospective power purchase agreement (PPA) partners. Students are defining the system that the university and the winning bidder will create to deliver power for a fixed period of time, after which the system will be transferred to the University. The project is structured using the Engineering Clinic program, which places students in interdisciplinary, creative teams. Students are expected to individually own portions of the final product, while collaborating in a team environment. Progress through the milestones is monitored through weekly status meetings with a graduate student manager and with supervising faculty. Another important dimension of the project is the requirement for frequent interaction with external vendors in order to develop the most accurate cost model for the project design. One industry connection is to a manufacturer of a novel inverter technology, which we plan to incorporate into the design to bring significant reductions in total system costs. The paper will describe the project in more detail and provide an assessment for the effectiveness of this education approach as measured by the maturity of the final design product and by the range and depth of experiences students gain from this project. The 10 MW system represents a major element of the University's push to achieve carbon neutrality, diversify its energy portfolio, and provide enhanced learning experiences for students. The resulting system can serve as a reference model for other large-scale PV designs, student project structure, and represents a good example of sustainability engineering.

Introduction

Typically, an undergraduate program consists of four years of acquiring knowledge mostly in a classroom setting. It is not until finding employment that a student meets their first truly open-ended problem. Rowan University has created a unique learning environment for its students [1].

Over the course of eight semesters students complement their classroom learning with a structure that provides small teams with open-ended problem solving experiences. At Rowan the Clinic is the structure that offers the critical missing step in a student's progression into a successful engineer. The Clinic brings the challenges of open-ended problem solving back into an environment conducive to learning, where the student is responsible for solving a problem, yet has access to a support team consisting of other students, faculty, and technicians.

Throughout the Clinic process, students have opportunities to work in multidisciplinary (civil, chemical, electrical and computer and mechanical) teams. This exposes students to a variety of viewpoints. As freshman, students work on projects primarily involving engineering measurements and reverse engineering to perform systematic testing of existing products for the purpose of improvements. As sophomores, the students are confronted with engineering design problems that have a clear project statement and defined guidelines. The projects simulate realistic problems, and for the first time, ask students to work in multidisciplinary teams to accomplish their goals. Compared to the freshman year, this level focuses on communication [2]. Students are required to demonstrate a significantly higher level of communication skills through papers and presentations. Additional improvement in verbal skills is ensured by a course in Public Speaking taken in unison with the Sophomore Clinic.

By their junior and senior years students possess the foundation to be able to work more independently. In these Clinic years, students are presented with open ended projects under the guidance of a professor and often a graduate student. This semester (spring 2011), four Graduate Students oversee four different Clinic teams. The primary role of the Graduate Student is to help manage the day-to-day project management functions in coordination with the faculty project manager. Graduate Student involvement in upper level Clinics is not a requirement, but allows for a more smoothly functioning team and gives the Graduate Student opportunities to develop project management skills and experience directing a team to achieve well-defined goals within constraints. The organization and execution of a Clinic project is flexible, but most follow a basic sequence. Upon forming the 2-5 student team, projects start out with an information search and review, followed by development of a clear and concise problem statement. From that point students research and design solutions to the problem and develop methods for down selecting alternatives, prototyping, testing, documentation, etc. During the semester, students for the most part work independently. Meetings are minimized in order to preserve as much of the scheduled Clinic time (3 hour blocks, twice weekly) for substantive project work. At the end of the semester, students are required to present their work.

Project Background:

The need for the Clinic project described in this paper, derived from the President of Rowan University signing the Carbon Neutrality Plan. This document outlines thirty steps to achieving carbon neutrality over the next twenty years [3]. Rowan University ultimately hopes to go a step further by becoming a net–producer of energy. The plan charts a course of educational, community, and international channels in which to realize its sustainability goals.

Thirty measures have been identified to achieve carbon neutrality, one measure calls for a 10 megawatt photovoltaic system on the University's West Campus by the summer of 2012. To further increase the system's benefit to the university, it was decided that engineering students could provide the preliminary system design beginning in the fall of 2010. Because of the early start, the project will span across multiple semesters and will involve many different Clinic students. The project challenge requires students to research land usage, perform solar irradiation surveys, complete preliminary layouts, perform system comparisons, evaluate utility interconnection methods, and deal with the documentation associated with a project of this size. A fall 2010 Clinic team began the work focusing on a northern parcel of land, but midway through was asked to change sites since the original plan used land that had substantial utility developments intended for buildings. A continuation Clinic project in spring 2011 picked up where the fall team left off.

Economic Assessment

Before designing a photovoltaic system, a cost analysis is typically performed. For this project, the University's current power usage needed to be known in order to estimate the potential savings of the system. Since the University acquires energy from both on and off campus sources, it was important to take both into consideration. All of the data was acquired from the University Engineer in the form of a table displaying the monthly production of the University's Cogeneration system (on campus source) and the power received from its off campus supplier (Atlantic City Electric). In order to conduct an analysis it was necessary to make a series of cost assumptions over the projected 20-year project lifetime. The variables considered were, historical utility costs, cost of the electricity from the University's Cogeneration Plant, usage patterns, estimated installation and maintenance costs, projected energy costs, photovoltaic module degradation, etc.

A key assumption for the system analysis was the assumption that electricity sold to the University will cost 0.05-0.08 $/kWh. Solar renewable energy certificate (SREC) prices fluctuate with supply and demand. The price of SREC's also depends on the solar alternative compliance payment (SACP) value, which has been set by the New Jersey government through 2016 [4]. Using these values and initial projections, the sale of electricity and SREC's, should produce between 35 and 37 million dollars between 2012 and 2016.

Request for Proposal

One of the first tasks given to the team was to establish a price for the project. As a preliminary step, the students attempted to contact numerous suppliers and installers, in order to get a range of prices for a system of our size. After doing so, the students found that most suppliers were hesitant to provide pricing information without knowing the job was officially open for bidding.

They felt that any pricing information was proprietary and that providing a price would be giving away their competitive edge. This was a setback, but a manageable one, since the team was already in the process of drafting a Request for Proposal (RFP).

A Request for Proposal (RFP) is created to engage a company's interest and to establish a formal basis for competitive bidding. The RFP serves as the official document which is the legal basis for the approval of the project. It outlines the requirements, expectations, rules and restrictions which are placed on the project. Additionally, the RFP establishes the basis for the Power Purchase Agreement (PPA), which Rowan had selected since it would be more beneficial to allow a company to build and maintain the PV system on Rowan's land while selling electricity to the University at a discounted cost. As a public institution, Rowan would be disqualified from taking advantage of many of the tax rebates as well other financial incentives available for solar projects. For these reasons, the PPA was the most reasonable fit for the project.

There were a number of amendments made to the original draft of the RFP. First, a university buyout option was added, allowing purchase of the system after a duration of 10, 15, or 20 years of operation. This allows the university to purchase the system, if it is economically advantageous, at such a time. Next, a clause requiring any bid to include a proposal to implement Alencon inverter was included. Since the inverter technology has the possibility of greatly reducing inverter and wiring costs, the University wanted to explore such an option. Third, the university expects the successful bidder to incorporate a number of education possibilities for research and development into the system, which could be integrated with students working at the South Jersey Technology Park. There were a number of other adjustments made to the document, including a security requirement.

With the completion and eventual release of this document we will receive detailed bids of our project. We expect a large amount of interest for this project from industry and each bid received will act as a wealth of knowledge and further lessons in photovoltaic design.

Site Layout/ Feasibility Analysis

After the fall 2010 team had plotted their system, concerns about the existing infrastructure of the location resulted in a request to re-site the project to another location. When the spring team began working on the project, they unanimously agreed that a consolidated site plan was of high priority. Based on the previous reaction to site selection, the team decided to pick an area that posed the least likelihood of interference with future work on the West Campus. The site that was chosen is at the southern most point of the property. The area is also adjacent to a major highway, which provides high visibility to passing motorists to advertise the system and Rowan's efforts towards carbon neutrality. Site planning was supported using online mapping resources such as Google Maps and Bing Maps to rank possible new sites. This approach offered a significant advantage due to the fact students were able to familiarize themselves with various plots without having to be on every site. Once a final area was chosen (see Fig. 1), the team was ready to move on to the next phase of their assessment.

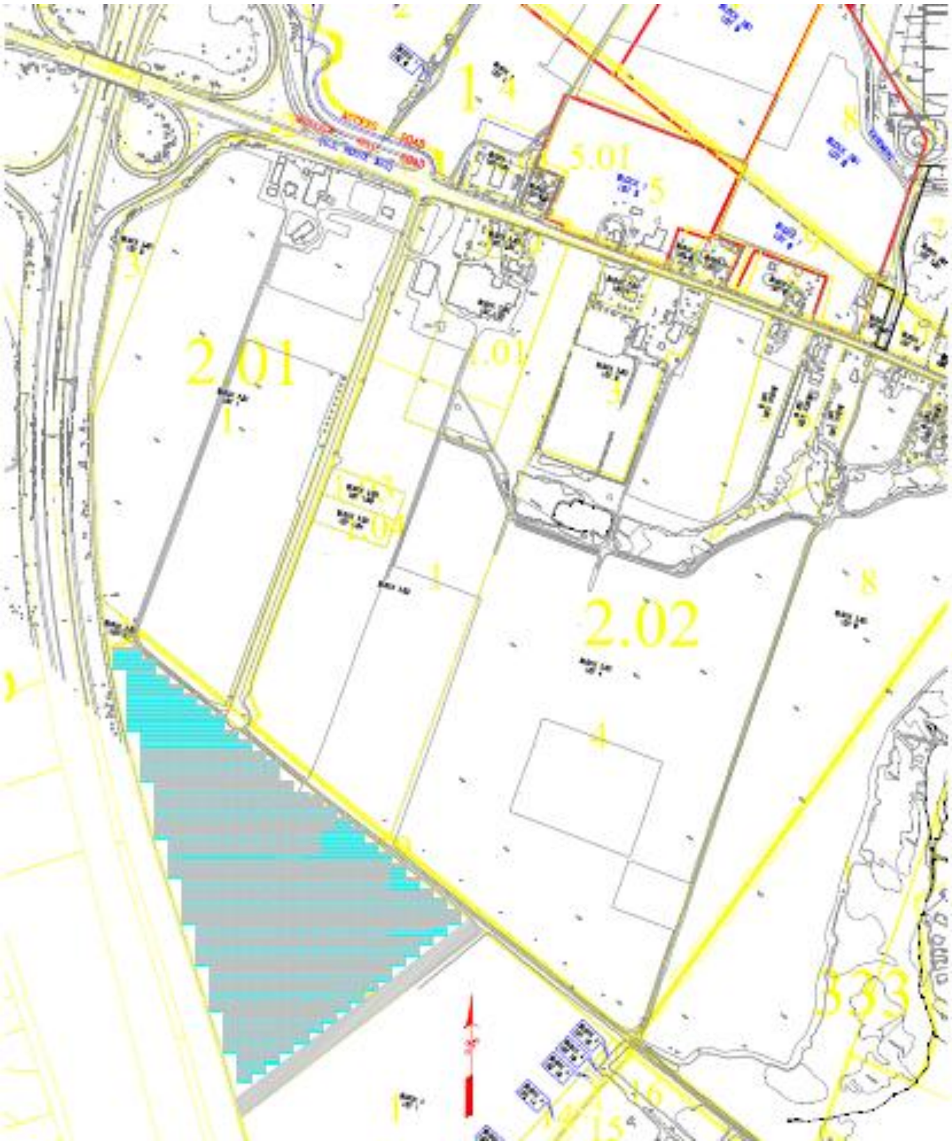

Figure 1. Site map of West Campus with preliminary design shown in the bottom left corner. Blue representing the PV modules, and Grey representing the expected inter-row shading.

When designing a PV system it is important to understand the technology, and as with each step in the process, this was another learning opportunity. Understanding PV system operation begins at the molecular level with the silicon used in the PV module, to the technologies required to achieve final grid interconnection. In order for each member to gain an understanding of photovoltaic design, they each started by designing single strings of modules. Next, they combined multiple strings to create an array, and finally tied their entire system together. An advantage of producing several unique layouts of the same system is that the team was able to find an optimal design. With each successive design comes additional experience. A multitude of designs created in an educational environment, some designs incorporate new technologies and practices that challenge existing paradigms.

Besides knowledge of system components students must also learn skills specific to conducting a site feasibility assessment. These include using solar pathfinder [5] equipment to conduct shading analysis, and entering this data into software like PV Watts [6], to estimate system output and annual performance. Along with skills specific to photovoltaic layout, broader skills are also acquired. For instance, CAD software was used to develop the site plans. Although students have not have a formal CAD course, they understood its importance and self-taught the use of available CAD software in order to be able to develop drawings. The combination of these lessons and achievements resulted in a rough site plan that met all the requirements set forth by the team.

Lessons Learned

After four months of working on this project, a number of lessons learned have been identified.

1. Project students have all had a chance to deal with each of the major design elements of a large-scale PV system.
2. Students have participated in weekly status meetings. This has exposed them to project management methods and given them further opportunities to improve their communication skills.
3. This project actively engaged students in economic assessment of large-scale engineering projects.
4. Students working on the PV project have learned a variety of new engineering tools.

It is noteworthy that the Clinic environment gives a student the chance to make the best of an opportunity—self starters are particularly successful on a Clinic team. The more a student displays leadership and ownership over the project, the better his or her grade will be [7].

A student who completes all of the work asked of them earns a C. By taking charge of the project as evidenced by generating their own tasks, goals, and objectives, a student can improve their grade. The student who uses his or her knowledge of theory, analytical techniques, and ability to demonstrate a mastery of engineering sciences and/or design principals to develop an original solution will receive an A. The A-worthy student shows personal investment in the success of the team and the project – qualities that are critical in the engineering field.

Project Future:

The scale of this project means that its size and complexity generates the risk that it will never become a reality. The commitment to energy neutrality was signed by a President who is completing the final months in that position. The next President will need to carefully review the project before it can move ahead. In fact, that is one final lesson of engineering—not every project will be completed. However, no decision can be made without a carefully designed and analyzed study—the Clinic students can be proud knowing that they directly contributed to such a high-visibility, large-scale project.

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