Solar 2013: Summary and Performance of Florida's SunSmart Emergency Shelters Program

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ABSTRACT

In 2003, the Florida Energy Office (FEO), in partnership with the Florida Solar Energy Center, initiated the Photovoltaics (PV) on Schools program in Florida to install solar electric (photovoltaic) systems with data monitors on schools as educational demonstration applications. Initially, the program was intended for the design and installation of photovoltaic systems as a way to raise awareness, build understanding and provide experience with photovoltaic technology for students, teachers and the general public. In 2010, the program was renamed the Sunsmart Schools Emergency Shelter Program and received funding through the Department of Energy American Recovery and Reinvestment Act. The contract called for the addition of 90 schools throughout Florida which would each receive a 10 kW array PV system with battery storage on schools designated as emergency shelters to provide backup-power during power outages. The purpose of this paper is to review the Sunsmart Schools Emergency Shelter (E-Shelter) program planning and execution so others contemplating a similar project can benefit from our experience.

1. BACKGROUND

Florida has had its fair share of dangerous weather including hurricanes, tornados and floods. Many people without a place to go during a disaster seek refuge in one of the many public schools that double as shelters during an emergency. In 2004, hurricanes Charley, Jeanne, Frances and Ivan struck Florida. As a result, the need for school designs to meet new standards for protection of those seeking shelter became more evident. The new requirement for Enhanced Hurricane Protected Area (EHPA) required a design that made the shelter part of the school fortified and sustainable with conventional resources.

The PV on Schools program began in 2003 with the Florida Energy Office (FEO) and the Florida Solar Energy Center (FSEC) partnering to install solar electric (photovoltaic) systems on schools in Florida. The program was initially designed as a way to raise awareness, provide experience and understanding of photovoltaic technology for students, teachers and the general public. Initially, 47 schools received grid-tied photovoltaic (PV) systems designed with a 1 to 6 kW array operating as an educational demonstration application. By 2005 the program was renamed Sunsmart School and the hurricane season of 2004 lead to the expansion of the program to include larger PV systems with storage to be installed on schools designated as emergency shelters. In 2008, Middleton High School in Tampa was the first school to receive a bi-modal 10 kW system with battery storage. The system was installed on the shelter part of the school as a viable application for use during power outages and disasters. This was an example of a real life application that generated power during normal times as well as during and following emergencies when utility power was unavailable.

The Sunsmart Schools Emergency Shelter program started in 2010, with funding from the U.S. Department of Energy and the Florida Energy Office through the American Recovery and Reinvestment Act. The Florida Solar Energy Center was tasked with managing the installation of ninety, minimum ten thousand watt (10kW) bi-modal PV systems at shelter-designated schools throughout Florida. The newly designed and expanded PV systems would include a grid-connected 10 kW array that generated power during normal daytime operation and with battery storage to provide backup power to the shelter area of the school during emergencies or power outages. These new systems were designed as uninterruptable power supplies (UPS) to power critical loads in the Enhanced Hurricane Protected Area (EHPA) shelter part of the school. Previous program phases allowed for multiple contractors with various designs, but this phase called for one ground-mounted PV design to be installed at each site, thus streamlining the process. Despite the challenges, 85 of 90 schools were completed in the two-year installation period.

Additionally, two electric utilities – Progress Energy (which has been absorbed by Duke Energy) and Tampa Electric (TECO) joined the DOE E-shelter program to fund additional ten schools which mirrored the E-Shelter program. . A new phase of the program continues to evolve with basically the same mission with all required funding coming from Progress Energy and TECO with another ten schools to be completed in 2013. The next few years will be funded by these utilities, as the Public Service Commission promotes major utility participation under the Utility Power (Plus-UP) program.

2. SCHOOL SELECTION

The selection of the schools involved several steps including application, external review, site inspection, identification of critical loads and signing of the School Agreement. At any step along the way, a school could be removed from eligibility by not passing that phase of the selection.

Schools that applied had to meet certain minimum criteria that included their status as a shelter, local demographics, the school's energy education plan and level of commitment to the project. A selection team, which included state level representatives including the Florida Department of Environmental Protection, Florida Emergency Management, Florida Department of Education as well as the Florida Solar Energy Research and Education Foundation evaluated all school applications and ranked them according to the criterion. A total of 125 potential candidate schools were identified within 46 school districts. Because the PV systems become the property of the schools once the installations were completed, each school was required to sign a "School Agreement" form that specified certain expectations. The school had to agree to install an IT port for the data monitoring system, was required to send two teachers to attend professional development workshops and would allow at least one facilities manager to participate in system maintenance training. It was also expected that each school would incorporate solar energy education into their school program and operations. The last requirement was for the school to host a ribbon-cutting ceremony to announce the operation of the system to all involved, the media and the general public

Reviewing school applications and identifying candidate schools for PV systems was the first step in the school selection process. The next step was to visit the school facility and determine its compatibility with the program. A kickoff meeting was conducted at each selected school where representatives of all parties involved met, reviewed requirements and concerns and evaluated physical site conditions. The final location of the PV system was determined based on many physical site issues. The first consideration is whether there is an area large enough for a ground-mounted array of this size. Earlier phases with demonstration applications used 1 to 6 kW arrays and allowed ground, pole or roof-mounted systems providing more choice of locations. Roof installation was not considered for two reasons; school policies which discouraged roof penetrations and the diminished educational value of a PV system that cannot be seen by students. Ground and pole mounted systems provide greater educational value. The PV design had a requirement for communication and power runs not longer than 250 feet to reduce power losses and trenching issues, making placement of the PV system near its use important.

The E-shelter program called for a ground mounted 10 kW array with battery back-up requiring an area to be at least 20 by 60 feet. Due to site specific challenges, Vergona Bowersox (VB) had three array configurations that were utilized. These consisted of one long array, a split array divided in two sections and a triple section array divided in thirds to accommodate unique array foot print placement at locations with limited or irregular space. The PV system was intended to power critical items during a power outage, requiring locations with at least 90 percent availability of solar radiation, thus making shading an important consideration when finding suitable locations.

Safety was a priority for all parties during both installation and for the long term use and operation of the PV system. All aspects of the PV installation and associated construction processes had to meet all of the national, state and local code requirements, as well as the E-Shelter program requirements. To assure operation during a storm, the E-shelter program required 150 mph wind loading. Liability concerns affected every participant, whether the utility or the school owned the PV system, resulting in agreements defining each participant's liability. The PV system owner's manual and code required equipment labels providing notice of safety issues and safe practices. In order to minimize risk of inappropriate human contact, E-shelter systems owned by schools have fences surrounding the equipment installation. Also, utility interconnect agreements posed liability issues between school districts and difference types of utilities, whether they are municipal, coop or investor owned.

Another safety issue with schools is being wary of unknown and un-authorized people on school campuses. FSEC and contractors were encouraged to wear some type of uniform or insignia while on campus for official business. Florida school districts require a security badge to be worn at all times, which is individually issued by each district. The Jessica Lunsford Act enacted in Florida in 2005 requires a background check to be passed before a school security badge is issued to an individual.

Fig. 1. PV array at Fairmount Park school.

For the E-shelter phase, the PV system had to meet local school district requirements of 42 different counties, which posed several challenges in keeping the PV system designed as a standard package kit. A typical PV system is shown in Fig. 1. The proposed design housed the balance of system components in a shed, but some districts viewed the shed as a building that needed to meet enhanced building code requirements. A solution was to replace the shed with an metal enclosure, causing two design configurations and adding to the cost of the systems. Sheds were proposed to allow for maintenance in a weather-protected area. Permitting, code interpretation and enforcement posed problems throughout the program, from one installation to another.

The E-shelter program had the challenge of completing installation of at least one school a week to meet DOE requirements. FSEC and the PV contractor worked an intense timeline of activity requesting permits, scheduling availability of system hardware, constructing systems, installing data acquisition systems and completing acceptance testing with each school representative. A few schools were dropped due to various issues, resulting in completion of 85 DOE schools and 10 utility co-funded schools.

Several major issues were encountered consistently, impeding program progress. Examples included physical site barriers, liability concerns, local code requirements, maintenance, ownership and school commitment. These concerns were typical across all phases of the program and were raised primarily by the county school boards, principals and facility personnel.

3. SYSTEM DESIGN AND ACCEPTANCE

The E-shelter program was designed to demonstrate that photovoltaics with batteries could provide a viable, real life application for backup power in an emergency or power outage. The critical power needs of the residents of a shelter during an emergency could be met with battery power if key electrical applications were identified and kept within the limits of the battery bank's capabilities. The parameters of the PV system and the interior electrical of the shelter to power selected critical items were defined by a committee consisting of the local American Red Cross, Emergency Management, school facility personnel and FSEC. The committee determined selected lights and receptacles that would function as the critical loads in each particular shelter design. In most cases, the designated areas within the shelter were gymnasiums, cafeterias and classrooms. Each school shelter was surveyed and critical loads were identified on engineering drawings that were then provided to a local electrical contractor who then modified the existing interior building electrical system to meet the new design. The critical load was set at approximately 1 kW to power enough lights so people would not be in the dark during a power outage and to limit power to a few items such as radios, computers, phones and life-support equipment.

Fig. 2, Metal enclosure with balance of system components.

Specifications were developed for a PV system to operate as an uninterruptable power supply (UPS) to power critical loads in the Enhanced Hurricane Protected Area (EHPA) shelter part of the school. The PV system's major components were specified to be a 10 kWp SolarWorld PV array, a 25 kWH Sun-xtender battery pack, and a 10 kW multi- phase 120 VAC bi-modal Outback inverter configuration as shown in Fig. 1. Because the design was to be turn-key, an invitation to bid was solicited. PV system contractors were required to have a proper license to install systems that were approved by FSEC's design review committee. One contractor, Vergona Bowersox Electric was selected to complete all 90 schools and 10 Plus-UP schools.

Local licensed electricians wired the critical loads in the shelter and VB installed the PV system and made the interconnection. Once the system was installed local inspections by the Authority Having Jurisdiction (AHJ) as well as an acceptance test was performed by Florida Solar Energy Center staff to ensure the system was safe and operational, as well as meeting contract specifications and code requirements.

The acceptance test is conducted as a snap shot of a moment in time of what the SunSmart PV system is doing. Earlier phases used simpler acceptance test and depended on the school inspector to verify code compliance. The test covered installation issues such as array shading, array tilt, azimuth angle, and program requirements. The performance of the system was verified by measuring irradiance, DC voltage and current from the array, and AC power output from the inverter. A solar pathfinder was used to verify that there was no shading between 9 am and 3 pm during any month of the year. The acceptance test for the E-shelter phase was much more elaborate as it was discovered some school inspectors did not know the National Electrical Code (NEC) section 690 on photovoltaic system and NEC 708 on emergency power. One discrepancy found over half of the time was the PV interconnect circuit breaker connecting the PV system to the shelter building electrical panel was not at the opposite end of the utility power feed which many installers and inspectors did not know or identify. Because the PV system supplies power to a shelter during critical times of power outage the PV system wiring needs to be separate from the general wiring to function as emergency power. After a few test, we conducted a workshop on code requirements for school inspectors to overcome their lack of knowledge of NEC 690. E-shelter used newer test equipment like the Solmetric suneye replaced the solar pathfinder for shade measurements and a Solmetric PV analyzer was add to shot voltage/current (IV) curves of each string of the array. A power analyzer was used to verify AC voltage and current wave forms and phase. A mega ohm meter was used to verify ground connections.

Early phases of this program had problems with equipment such as inverters being compatible with school building electrical systems. Most of the approved systems chosen by the PV system installer used inverters designed primarily for residential applications with AC voltage output for single phase 120/240 VAC. Presently, the selection of inverters available now provide many choices of inputs and outputs for the majority of electrical services that are used in buildings.

The PV contractor was required to provide a five-year service contract including parts and labor to keep the system operational to minimize maintenance and other expenses for the schools. After this period, equipment warranties take over, as an example, the PV module warranty is for 20 years and the school will need to contract the Solar World.

4. MONITORING

Data collection and analysis is a critical component of the E-Shelter program. Over the years, FSEC has installed hundreds of data acquisition systems in order to monitor PV system performance under real life conditions. For long term analyzes of reliability and performance data, each PV system was installed with a data acquisition system (DAS) to monitor and collect selected data values. Raw data collected by the DAS is transmitted via the internet to FSEC where it is formatted and displayed for review and analysis. To complement the educational part of this program the data is retransmitted for display over the internet on a website for the students, school personnel and the world. Data collected can be used to evaluate the reliability of the system and determine any maintenance issues. Each school's data information is available at www.energywhiz.com.

For previous phases of the program the monitoring equipment was supplied by FSEC, but for the E-shelter program the equipment was selected by the PV system contractor based on specifications supplied by FSEC. This change was due to the fact that many of the present inverter manufacturers incorporate monitoring into their inverter designs, therefore, making FSEC monitoring equipment redundant. This strategy posed difficulties because the data monitoring system chosen by VB was not fully developed nor supported. This required a second monitoring system to be purchased that was backed by a team of IT and computer specialists. FSEC specified that raw data is to be sampled every second and averaged in 10 minute intervals and be stored on the device, then, transmitted to FSEC each day. The data-logger monitoring system is constructed with appropriate transducers to record irradiance, wind, temperatures, DC current and voltage, AC voltage and current and AC power values.

Using IEA Performance Reliability and Analysis of Photovoltaic Systems format of the raw data was converted and used to calculate performance ratio, array efficiency, inverter efficiency and system efficiency. The table shows these values and the installed cost per contract plus change orders.

Parameter	Results
Performance ratio	0.78
Array efficiency	11.70 %
Inverter efficiency	91.4 %
System efficiency	10.69 %
Installed cost $/W	$7.99

5. EDUCATION

The goal of having teachers and students at schools become more knowledgeable about solar technology and gain an appreciation for its many benefits was achieved. There is a network of over 250 more teachers throughout Florida who have experienced the science of solar first-hand. They are sharing that experience with their students by integrating lessons about solar energy into their existing curriculum or by using the curriculum provided to them through the workshops. Another benefit throughout this process is that school administrators, facilities personnel, school board members, parents, and code officials became familiar with the technology and are now champions of solar and photovoltaic technology. Schools are anxious to learn more and do more.

FSEC facilitated 12 regional professional development workshops for teachers on solar energy. In order to minimize the financial impact to the schools that released their teachers to attend the workshops, the program offset the cost of substitute teachers by providing up to $150 per school. K-12 teachers participating in the program attending the workshop received a $75 stipend and received a age-appropriate curriculum and a laboratory kit to be used with the students. An important feature of the workshops was to provide materials to aid teachers focused on meeting Florida’s Sunshine Teaching Standards through solar energy technologies.

FSEC organized and held 4 internet webinars on the schools PV system for facility mangers. Attendees learn about the various components and their interaction, system operation, performance characteristics, maintenance procedures, and safety issues. The 2 hour webinar is available at any time as a refresher course or for anyone interested in learning about the E-shelter PV system used. Because of inspection difficulties during acceptance testing, a code webinar was made available to participating facility personnel.

It was also expected that each school would incorporate solar energy education into their school program and operations. lessons into its existing curriculum utilizing materials and lessons provided by FSEC. During professional development workshops, teachers participated in hands-on lessons that utilized photovoltaic, solar thermal, and hydrogen fuel cell technologies. Once a workshop had been completed a kit of materials was provided to the teachers to take back to their school to be used in the classroom and shared with other teachers. In this way, students learned, not only about photovoltaic and other renewable technologies, but related science, technology, engineering, mathematics, emergency management and social studies applications. The PV system can also be used as a teaching tool as students access online performance data of their school’s PV system through a website (Energywhiz.com) developed specifically for this program. Students also learn about disaster preparedness and are introduced to energy efficient building design and construction.

6. LESSONS LEARNED

Over the years much was learned from the Sunsmart Schools program that was incorporated into the Emergency Shelter program. The E-shelter program had numerous challenges from the outset due to the new PV system requirements. The number of systems to be installed within a short timeframe was perhaps the greatest challenge of all. Pressure from outside to complete as many installations as quickly as possible increased the possibility for errors. Although the program has installations in 42 school districts (counties) in Florida by the time of its completion, 46 counties were dealt with from the beginning of the program as schools were assessed and subsequently removed from the program. Dealing with the variety of people within the school districts and inconsistency of policies across the state increased the amount of time and effort required to get approvals at this installation rate. One school district board member became so afraid that the PV systems would catch on fire that they wanted their schools to be removed from the program. Eventually, that board member left and the problem went away. One of the most important lessons learned from the earlier program phases was to have buy in and the cooperation of the school districts, school administrators and teachers.

Selecting a single solar installation company had its benefits and drawbacks. A drawback was the inability of a single company to install more than one system in about a week’s timeframe. The benefit was the relationship that was established and the give and take that occurred. Many of the challenges met throughout the program could have been mediated by doing more upfront education with the school boards, school district facilities personnel and school administrations. This would have reduced the time needed to approve permits and to approve the system installations once construction was completed. Much time was spent in the field answering questions, providing on the spot instruction and explanations.

The teachers at the schools once they had participated in a professional development workshop about solar technology became the champions of the program. Teachers integrated the lessons provided by FSEC and also created their own to be integrated into their existing science curriculum units. Teachers voluntarily participated in monthly phone conferences to share ideas and resources. A monthly newsletter was developed to promote more communication between the schools and FSEC.

Utility support continues to be a positive aspect of the program. In particular TECO and Progress Energy (Duke Energy) are supporters within their service territories. As the program continues to grow, the process is fine tuned and new aspects considered.

7. CONCLUSION

The Sunsmart Emergency Shelter program accomplished many of the program goals to educate teachers, school personnel, project participants and the general public on the benefits of solar energy. The program is no longer an 'unknown' to the schools and the initial questions and uncertainty that arose during introduction are no longer a barrier to school board and facility managers acceptance. One of the most important things learned from this program was to get teachers, facility managers and school boards trained and to promote more participation to gain more acceptance prior to completing a PV system installation in order to overcome solar technology misconceptions.

At this time, ARRA funding allowed 85 schools to be completed, 18 schools have been completed with Progress Energy funding and two schools have been completed with TECO funding under the Sunsmart E-shelter program. In total, 105 schools are now equipped each with a 10 + kW bi-modal photovoltaic array with battery backup. EHPA shelters required emergency power from fossil fuel generator large enough to power the building. E-shelter PV systems powered a minimal critical load for life support and safety of the residents of the shelter during a power outage. This phase of the Sunsmart program installed PV systems that provide minimal backup power during a power outage as a viable real life application as well as serving as an educational demonstration project.

At the writing of this paper, none of the E-shelter schools were used in an emergency to measure their performance in this task. Whether the systems are used as shelters or not the schools are now better prepared to educate their students and communities about solar technology and disaster preparedness.

8. ACKNOWLEDGEMENT

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9. REFERENCES

(1) K. Lynn, J. Szaro, A Summary of PV System Performance and Cost in the Florida PV for Schools Program, Proceedings of Solar 2004 conference, Solar Harvest, American Solar Energy Society, Portland, OR, July 2004.

(2) K. Lynn, J. Szaro, "Identifying Key Issues in Implementing Quality Solar For Schools Program", Proceedings of Solar 2004 conference, Solar Harvest, American Solar Energy Society, Portland, OR, July 2004.

.

(3) W. Young, S. Schleith, "Florida 's Emergency Shelters Go Solar", Proceedings of Solar 2007 conference, Changing Times, American Solar Energy Society, Cleveland, OH, July 2007.

(4) Pascale Rosemain, Susan Luster, "Convincing School Boards to Build Sustainably", Proceedings of Solar 2004, Solar Harvest, American Solar Energy Society, Portland, OR, July 2004

(5) Young, William, Photovoltaics Applications for Disaster Relief, FSEC-CR-849-95-C, Florida Solar Energy Center, Cocoa, FL, 2006