TEXAS CENTER FOR APPLIED TECHNOLOGY
TEXAS A&M ENGINEERING EXPERIMENT STATION

2015

Renewable Microgrid STEM Education & Colonias Outreach Program

Final Scientific/Technical Report

Performed under DOE Award
DE-OE-0000514

Texas Center for Applied Technology

4/1/2015

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Acknowledgment:
This material is based upon work supported by the Department of Energy DE-OE0000514.

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FIGURES AND TABLES

OBJECTIVE OF THE PROJECT:

To provide Science, Technology, Engineering, and Math (STEM) outreach and education to secondary students to encourage them to select science and engineering as a career by providing an engineering-based problem-solving experience involving renewable energy systems such as photovoltaic (PV) panels or wind turbines. All public and private schools, community colleges, and vocational training programs would be eligible for participation.

The Power Microgrids High School Engineering Experience used renewable energy systems (PV and wind) to provide a design capstone experience to secondary students. The objective for each student team was to design a microgrid for the student's school using renewable energy sources under cost, schedule, performance, and risk constraints. The students then implemented their designs in a laboratory environment to evaluate the completeness of the proposed design, which is a unique experience even for undergraduate college students. This application-based program was marketed to secondary schools in the 28th Congressional District through the Texas Education Agency's (TEA) Regional Service Centers. Upon application, TEES identified regionally available engineers to act as mentors and supervisors for the projects. Existing curriculum was modified to include microgrid and additional renewable technologies and was made available to the schools.

TASK DESCRIPTIONS

Task 1: Microgrid Outreach Program Development.

This task included the development of a microgrid demonstration and training system with associated curriculum to be used for STEM and microgrid program outreach to communities. The system was to demonstrate the integration and operation of residential level renewable, storage, and backup energy systems to provide continuously available power to a residence. Additionally, it was to provide a training platform for students to operate and experiment with renewable energy systems.

Task 2: Capstone Experience Program Development

This task included the development of an experiential curriculum for use in secondary schools. The curriculum was piloted at a single high school then was expanded to additional campuses to provide students will a background of the engineering process, renewable energy technologies, and a sampling of societal needs that can be addressed through economically feasible, engineering solutions.

RESULTS

Task 1: Microgrid Outreach Program

The demonstration system is sized at 3.5KW which is in the range of a typical residential load without a substantive air conditioning load. Power can be provided on a 24 hour basis through an inverter and battery storage system. The control system manages the state of charge of the battery pack and when the renewable sources are unavailable, the genset is used to charge the battery pack when required. The system includes 1 KW of solar, a 700W wind turbine, 24KWh of storage, and a 7KW LP gas generator. The storage technology is a combination of absorbed glass matt lead-acid and lithium ion batteries. The system provides insight into the operation of the generation and storage systems, renewable generation system installation, operation, and integration for both the residential and commercial systems and will give students experience in the operation and maintenance of residential and small commercial scale renewable generation systems.

As a testbed, the system provides insight into charging regimes for two different battery technologies. The system is equipped with both standard lead-acid deep cycle batteries and lithium-ion batteries. Both systems provide 12 kWh of storage capacity and are switched into the system on an exclusive basis. The system is controlled by a customized LabVIEW® control system allowing users and trainees to completely control and examine all aspects of the system operation. The system is installed in a dual-axle trailer allowing it to be easily transported for demonstration and training purposes. The system was designed and assembled from all commercial off the shelf components.

The system (shown in Figures 1, 2 and 3 on the following pages) has been demonstrated and utilized in many different venues and conferences.

Table 1. Demonstration and Utilization of Training System

Date	Venue
16-17 June 2011	Texas Rural Challenge Conference, San Marcos, TX
12 July 2011	Military Sustainability Conference, Joint Base San Antonio
22 July 2011	USAA Corporate Exhibition and Demonstration, San Antonio, TX
29 July 2011	Energy Systems Laboratory, College Station, TX
15 Sep 2011	EDGE Innovation Center Exposition, College Station, TX
26 Oct 2011	Joint Base San Antonio Energy Fair, College Station, TX
10 Nov 2011	Environmentally Friendly Drilling Workshop, Kingsville, TX
22 Feb 2012	Mission Verde Center Microgrid Education Event, San Antonio, TX
25 Feb 2012	TEA Education K-12 Event, San Antonio, TX
10 May 2012	TEEX Open House, College Station, TX
28 Oct 2012	Pulau Corporation Medical simulation training for US Army, College Station, TX
29 Oct 2012	CAE Inc. – Simulation training provider to DoD, College Station, TX
25 Jan 2013	Texas A&M University Statewide STEM Teachers Conference, College Station, TX

Figure 1: Microgrid Demonstration System on Display

Figure 2. Microgrid Demonstration System Control Station

Figure 3. Microgrid Demonstration System Power Wall

Task 2: Capstone Experience Program

Year one consisted of the development of the microgrid curriculum. This was accomplished through a partnership with the Transformation 2013 STEM Center at the Texas Education Service Center Regions 13 and 20 and Madison High School in the Northeast Independent School District in San Antonio. The curriculum includes the basic science of renewable energy system, utilization of the systems, design and integration of the systems, as well as electrical and other operational safety topics. The curriculum Scope and Sequence can be found in Appendix 1 for both 6 and 9 week school schedules.

Year two consisted of a pilot of the curriculum at Madison High School. Utilizing a special study course within the Agriscience Magnet Program at Madison High School, the curriculum was delivered to a group of 12 selected students. These students successfully designed and built an operational microgrid for their school entrance sign.

Year 3 implemented the curriculum at 6 high schools across south-central Texas. These schools successfully implemented the curriculum and succeeded in developing operational microgrid systems for a variety of applications and utilizations. Each school received $5000 to support teacher involvement and to pay for transportation services for the school's project. The school also received up to $5000 in equipment and supplies as required for the student's design. A summary of each school's project, and accompanying photographs, is included on pages 9-18.

Ann Richards School for Young Women Leaders – Austin ISD

The Ann Richards School for Young Women Leaders (ARS) dedicates itself to prepare young women to attend and graduate from college, commit to a healthy and well-balanced lifestyle, lead with courage and compassion, and solve problems creatively and ethically in support of our global community. ARS is a public all-girls school of choice that serves grades 6 – 12 for the Austin Independent School District. The Ann Richards team was made up of 16 students that designed a working model of a residential scale microgrid and the objective community that it would power.

Figure 4. Ann Richards School for Young Women Leaders

Harmony Science Academy – North Austin

Harmony Science Academy – North Austin (HSANA) is a comprehensive four year college preparatory public charter high school located in Pflugerville, Texas. Its mission is to provide an academically rigorous college preparatory program, in partnership with students, families, and the community, and guide all students in gaining knowledge, skills, and the attitude necessary to direct their lives, improve a diverse society, and excel in a changing world by providing dynamic, resource-rich learning environments. The school was opened in the fall of 2002 and graduated its first senior class in the spring of 2007. Harmony Science Academy – North Austin is accredited by Texas Education Agency and enrolls its students through a lottery process.

The HSANA Team was made up of five students and they completed a significant design problem and built a 700W microgrid.

Figure 5. Harmony Science Academy North Austin Team

Figure 6. Harmony Science Academy North Austin Microgrid System

Harmony Science Academy – Waco

The Harmony Science Academy – Waco is a comprehensive four year college preparatory public charter high school located in Waco, Texas. Its mission is to provide an academically rigorous college preparatory program, in partnership with students, families, and the community, and guide all students in gaining knowledge, skills, and the attitude necessary to direct their lives, improve a diverse society, and excel in a changing world by providing dynamic, resource-rich learning environments. The school was opened in the fall of 2007.

The Harmony Waco team was made up of nine students and they also developed and built a 700W microgrid system.

Figure 7. Harmony Science Academy Waco Team and Microgrid System

Pleasanton High School – Pleasanton ISD

Pleasanton High School is located south of San Antonio in Pleasanton, Texas. Pleasanton High School is committed to guiding students in identifying pathways of learning to support individual graduation into successful post-graduate careers and/or college experiences. With a goal of creating an environment that assists students in becoming independent learners and self-confident young adults, PHS is committing to a promise for all students to meet with academic and social success. An emphasis is placed advancing core coursework study in an application environment, with fully articulated learning in career pathways, healthy lifestyles, and fine arts engagement.

Areas of endorsement are aligned to study in Business/Technology, Health and Human Services, and Energy Resources and Management. Additionally, solid STEM, social and research sciences, and fine arts paths of study are provided.

The Pleasanton Team was made up of 15 students and designed a mobile power system that can be attached to a photovoltaic (PV) array to provide power. The system was a 2.5kW system powered by a 500 W solar array.

Figure 8. Pleasanton High School Team

Figure 9. Pleasanton High School Microgrid System

South San High School – South San Antonio ISD

South San High School is located in the southern part of San Antonio and offers a challenging academic, career and technology, and extracurricular activity program. The administration, faculty and staff are committed to the development of positive attitudes toward learning and providing all students with opportunities to enhance their ability to succeed in life. South San Antonio High School strives to maintain a safe environment which facilitates the attainment of academic excellence.

The South San team was made up of 17 student and designed and built a 1 kW system using 500 W of PV to provide charging.

Figure 10. South San Antonio High School Team

Figure 11. South San High School Microgrid

Southwest High School – Southwest ISD

Southwest High School has been serving the southwestern corner of Bexar County for over 50 years. Established in 1951, it has grown from a small rural high school with a graduating class of 11 students to a major 5A high school with over 3000 students. Southwest High School offers a complete academic program including 18 dual credit classes, in association with Palo Alto College, as well as Advanced Placement classes in Science and English.

The Southwest team was made up of four students and had the most ambitious design. Their system included 1 kW of solar, 2- 300W wind turbines (total) and 12kWh of battery storage mounted on a 12 ft single axle trailer.

Figure 12. Southwest High School Team

Figure 13. Southwest High School Mobile Microgrid

APPENDIX 1: MICROGRID CURRICULUM

Table A1: Six Week Curriculum Scope and Sequence

Units of Study	Time frame
FIRST 6 WEEKS	
What do engineers do? The student recognizes the history, development, and practices of the engineering professions. 1) Recognize that engineers are guided by established codes emphasizing high ethical standards. 2) Explore the differences, similarities, and interactions among engineers, scientists, and mathematicians. 3) Discuss the history and importance of engineering innovation.	1 week
Mini-project (8 steps NCTL) Process control methodologies (Gantt, WBS, etc.), application of process, relationship of process to engineering fields. Systems engineering process: 1) Requirements process • Problem identification • Characteristics of solution • Define acceptable performance 2) Functional Analysis • Decomposition of requirement to function [toast/toaster example Ted.com] • Allocation of functions 3) Detail design • Identification of feasible solution for each function • Integration of solution into systems • Testing and integration	2 weeks
Initiate Project Problem Statement Ex: There are citizens who do not have access to the same resources as you or I] • Have outside speaker come to present problem • Possible field trip to experience Colonias living communities	3 weeks

Research the problem and the people • Geography • Socio-economic status • Education levels • Access to technology • Basic services • History to today • Ethical problems • Interviews • Why does the problem exist? Goal: To provide power to those who don't have it in the Colonias Student's must develop: • Requirements Document • Project Schedule • Functional Allocation • Detailed Design	

SECOND 6 WEEKS	
Renewable Energy Energy storage Alternative energy sources Develop deliverables with mentors • Draft project schedule • Project milestones • Due dates • Requirements definition document	6 weeks

THIRD 6 WEEKS	
Function Allocation • Work breakdown structure • Gantt Chart	3 weeks
Detailed Design • Find technical/acceptable solutions to functions • Engineering Trade-Offs • Cost Constraint • Size • Code constraints	3 weeks

FOURTH 6 WEEKS	
Design • Parts, source selection, materials • Design iteration • Re-evaluate cost estimate • Sketch-Up • Complete design of prototype	6 weeks

FIFTH 6 WEEKS	
Build Prototype 1) Building of prototype 2) Testing: gather data, analyze, iterate design as necessary • Gather data • Analyze • Iterate design as necessary 3) Reporting • Performance of prototype system • Documentation of achieved design • Match against actual requirements	6 weeks

SIXTH 6 WEEKS	
Presentation 1) Field trip to Microgrid station 2) Final documentation 3) Presentation of Design to Client 4) Possible contest submissions [ISWEEP]	6 weeks

Table A2. Nine Week Curriculum Scope and Sequence

Units of Study	Time frame
FIRST 9 WEEKS	
What do engineers do? The student recognizes the history, development, and practices of the engineering professions. 1) Recognize that engineers are guided by established codes emphasizing high ethical standards. 2) Explore the differences, similarities, and interactions among engineers, scientists, and mathematicians. 3) Discuss the history and importance of engineering innovation.	1 week
Mini-project (8 steps NCTL) Process control methodologies (Gantt, WBS, etc.), application of process, relationship of process to engineering fields. Systems engineering process: 1) Requirements process • Problem identification • Characteristics of solution • Define acceptable performance 2) Functional Analysis • Decomposition of requirement to function [toast/toaster example Ted.com] • Allocation of functions 3) Detail design • Identification of feasible solution for each function • Integration of solution into systems • Testing and integration	2 weeks
Initiate Project Problem Statement Ex: There are citizens who do not have access to the same resources as you or I] • Have outside speaker come to present problem • Possible field trip to experience Colonias living communities Research the problem and the people • Geography	3 weeks

• Socio-economic status • Education levels • Access to technology • Basic services • History to today • Ethical problems • Interviews • Why does the problem exist? Goal: To provide power to those who don't have it in the Colonias Student's must develop: • Requirements Document • Project Schedule • Functional Allocation • Detailed Design	
Renewable Energy Energy storage Alternative energy sources Develop deliverables with mentors • Draft project schedule • Project milestones • Due dates • Requirements definition document	3 weeks

SECOND 9 WEEKS	
Renewable Energy - continued Energy storage Alternative energy sources Develop deliverables with mentors • Draft project schedule • Project milestones • Due dates • Requirements definition document	3 weeks

Function Allocation • Work breakdown structure • Gantt Chart	3 weeks
Detailed Design • Find technical/acceptable solutions to functions • Engineering Trade-Offs • Cost Constraint • Size • Code constraints	3 weeks

THIRD 9 WEEKS	
Design • Parts, source selection, materials • Design iteration • Re-evaluate cost estimate • Sketch-Up • Complete design of prototype	6 weeks
Build Prototype 1) Building of prototype 2) Testing: gather data, analyze, iterate design as necessary • Gather data • Analyze • Iterate design as necessary 3) Reporting • Performance of prototype system • Documentation of achieved design • Match against actual requirements	3 weeks

FOURTH 9 WEEKS	
Build Prototype - continued 1) Building of prototype 2) Testing: gather data, analyze, iterate design as necessary • Gather data • Analyze • Iterate design as necessary 3) Reporting • Performance of prototype system • Documentation of achieved design • Match against actual requirements	3 weeks
Presentation 1) Field trip to Microgrid station 2) Final documentation 3) Presentation of Design to Client 4) Possible contest submissions [ISWEEP]	6 weeks