Session: FF2-1

BUILDING TOMORROW: A STUDY OF RENEWABLE ENERGY STUDENTS BUILT RENEWABLE ENERGY TRAINING UNIT

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Abstract

Energy is one of the major building blocks of modern society. Understanding energy means understanding energy resources and their limitations, as well as the environmental consequences of their use. When preparing students for their future careers, real world training is a plus during their education. Renewable energy training units are very important for the hands-on laboratory sections of energy education and help the students to understand the concepts and applications of this type of energy. Due to the high costs of the training units, it becomes a budget concern to purchase training units for laboratory sections. Some of the pre-built training units that are already on the market have a price range from ten thousand to fifty thousand per unit. If there are budget concerns for the program, the only option that remains is to teach theory without the benefit of hands-on training. Taking these issues into consideration, the Students in Industrial Technology program has designed, built, and tested a multi-purpose renewable energy training unit for the alternative energy related classes. This prototype trainer is designed to be used for hands-on activities, which provide opportunities for students to engage in experiments that will reinforce the material covered. The safety of the unit was confirmed after several tests in different conditions on campus.

1. Introduction

We live in an age of environmental awareness, and alternative energy education is present in most of our daily conversations in engineering, technology, and science education. Renewable energy today provides about 9% of the world's energy and 8 to 10% of the U.S. needs [1]. However, in many parts of the world these percentages are increasing significantly. Based on current data on global warming, as well as the current U.S. dependence on overseas oil, there is an interest and urgency in utilizing alternative energy sources. In order to prepare students for their future careers, real-world training is imperative for their education. University campuses in the United States have been taking important steps to establish alternative energy research and education. For example, undergraduate engineering and engineering technology programs are now including laboratory-based curriculum in alternative energy [2-8]. Hands-on laboratory experiments using educational training units provide for enhanced learning experiences. These units provide real time display of key system properties as well as surrounding conditions through a data acquisition system.

Most of alternative energy educational training units are built and sold by the specific companies who offer custom-made systems according to the customers' needs, which increase the cost of the training units [9-13]. Alternative energy teaching tools help students to fully comprehend complex concepts with interactive educational training equipment and are very important for the hands-on laboratory sections of energy education. Due to the high costs of educational training units, it becomes a budget concern when purchasing training equipment for the laboratory sections of the courses. The costs of such equipment range from ten thousand to fifty thousand dollars per unit [14-17]. If there is a budget concern for a department, the only option is to teach only the associated theory of the course. Taking these issues into consideration, building an energy training unit becomes a smart idea to expose students to alternative energy field. The training units need to be designed to be used for hands-on activities, which provide opportunities for students to engage in experiments that will reinforce the material covered. The cost of the training unit should be kept below a manufacturer's cost in order to make the project cost efficient. In this project, the outcomes enable the participant to understand and work with the developed systems. The aim was to design and implement interactive educational training units that include solar and wind technologies, human power, passive air/water heating, and hydrogen fuel cell energy harvesting systems for any level of Alternative Energy Systems courses. This alternative energy educational training unit operates as a portable mini-lab.

2. System Design

Usually alternative energy training equipment is manufactured to train people the use of one single energy source. As a consequence, the customer is forced to buy separate units to teach different alternative energy technologies such as wind technology, human power, biomass, and hydrogen fuel cell systems. It is very rare to see combined training units to teach multiple energy sources in one integrated system. These issues make the establishment of the alternative energy program and laboratory more expensive and difficult to implement. In our prototype integrated training system, six energy sources were combined in one training unit including wind, solar, human power, passive water heating, passive air heating, and hydrogen fuel cell technologies. The unit serves to compare the efficiency and reliability of each source using a green meter data acquisition system [18]. The block diagram of the energy harvesting sources connected to the training unit is shown in Figure 1. In this figure, only major connections are shown, the details are not included. Figure 2 shows some of the major components and their connections through the training unit.

2.1 Metal Stand (Frame)

To begin planning the units, the current commercial training units were investigated to get a general design idea of different training metal housings, the nature of parts used and stands (frames). After investigation of the existing training unit designs a 3D CAD (Computer Aided Design) of metal stand with plywood was designed with real dimension before ordering the metal parts of the training unit. The 3D design of the system was accomplished with PTC Pro Engineer Wildfire 4.0 [19]. In the 3D design, the locations of each component was determined to identify distance of parts to make patch-cords. The prototype design of the metal frame is shown in Figure 3.

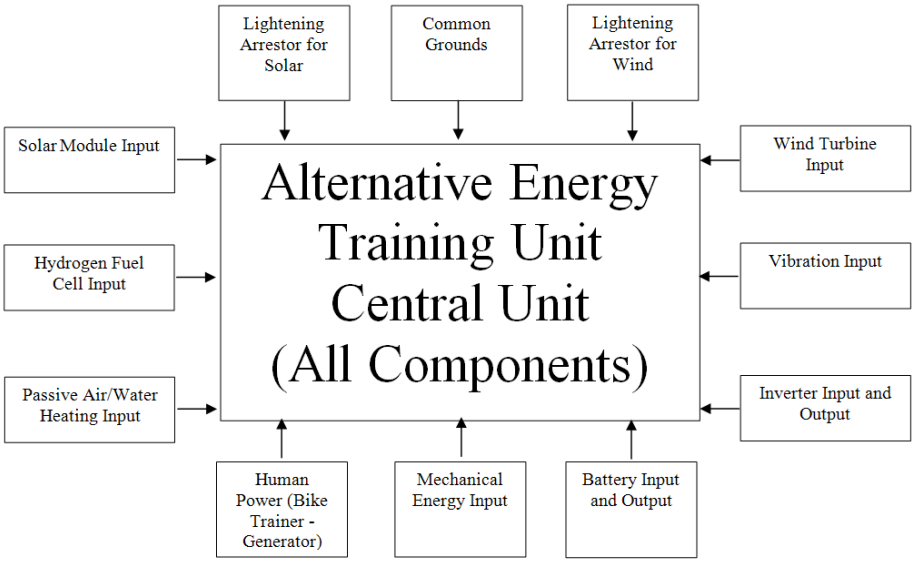

Figure 1. The general block diagram of the energy harvesting system

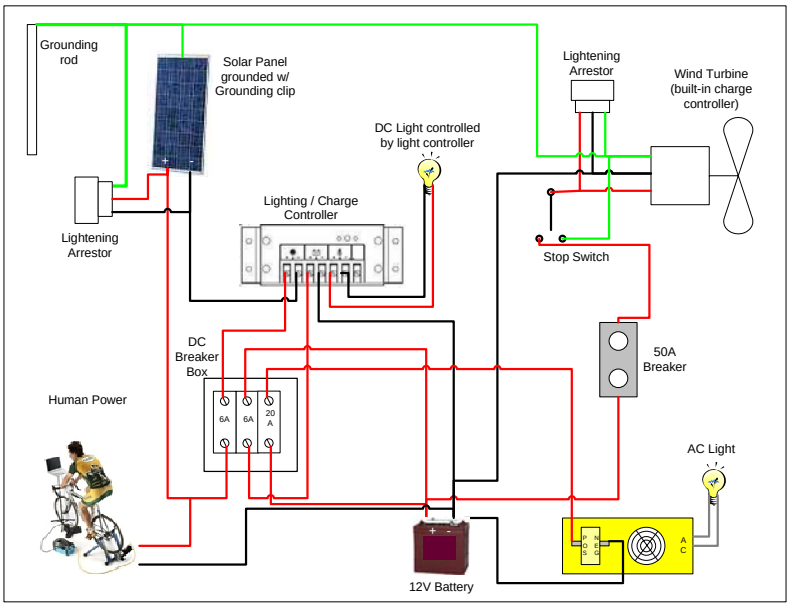

Figure 2. Major components and their connections of the training unit

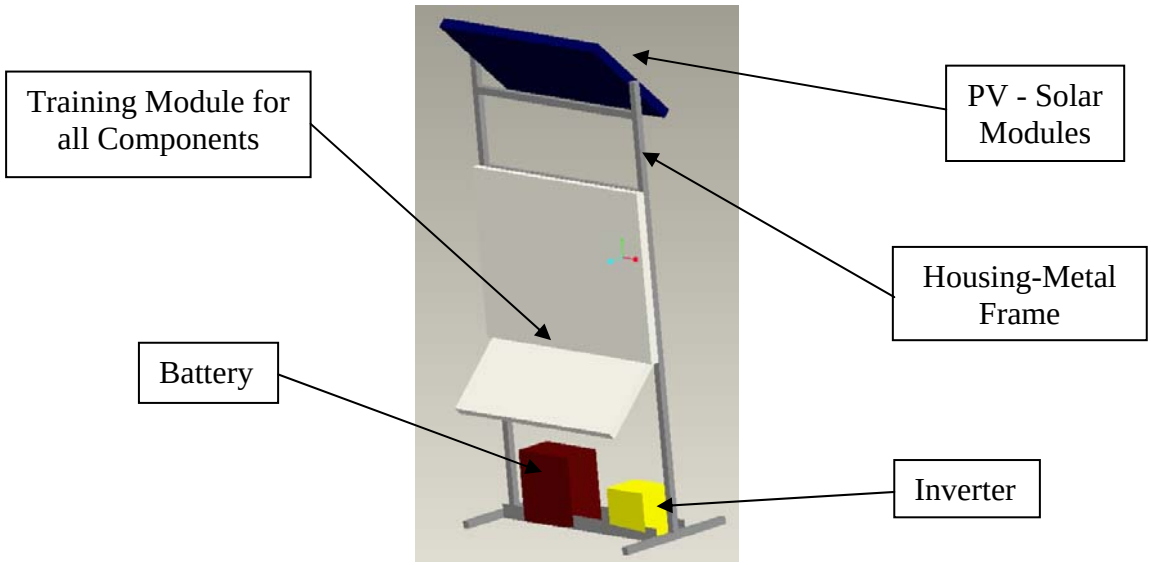

Figure 3. The Draft 3D Pro Engineer Wildfire Design of Training Unit

After 3D CAD design of the training unit stand, the necessary components were purchased to start building a metal frame in production lab. The specifications and the cost of the parts for the metal frame are summarized in the Table 1.

ITEM	1 1/4" Sq. Tube	1 1/2" Sq. Tube	1 1/2 x 1/8 <	1 x 3/16 Flat	4 x 3/16 Flat	
	51.5	54.5	48.25	4	3.5	
	17	54.5	48.25	4	3.5	
	17	32	7.5		3.5	
		32	7.5		3.5	
		48.25				
in./unit	85.5	221.25	111.5	8	14	
x 10 units	855	2212.5	1115	80	140	
# 20' pcs.	7.125	18.438	9.292	0.667	1.167	
20' joints	8	19	10	1	2	
LF	160	380	200	20	40	
						TOTAL
Total $	$120.00	$342.00	$112.00	$13.20	$67.20	$654.40
$ per Ft.	$0.75	$0.90	$0.56	$0.66	$1.68	

Table 1. The Specifications of the metal parts for training unit stand

The total price of materials to build ten stands is $654.40. This amount can change dramatically depending on building materials of the training unit stand. In our prototype, some metal tubing was donated by local steel companies.

2.2 Training Unit Module

The actual training unit components were identified after an extensive search in the market. The compatibility of the parts were confirmed and specification sheets were stored in a database to draw actual components using AutoDesk AutoCAD 2D drawing software. The size of the AutoCAD design is the same as training unit control module which is a board. The design layout

helps to drill holes and to make cuts to place and align the components on the board. The AutoCAD design layout with all the parts is shown in Figure 4.

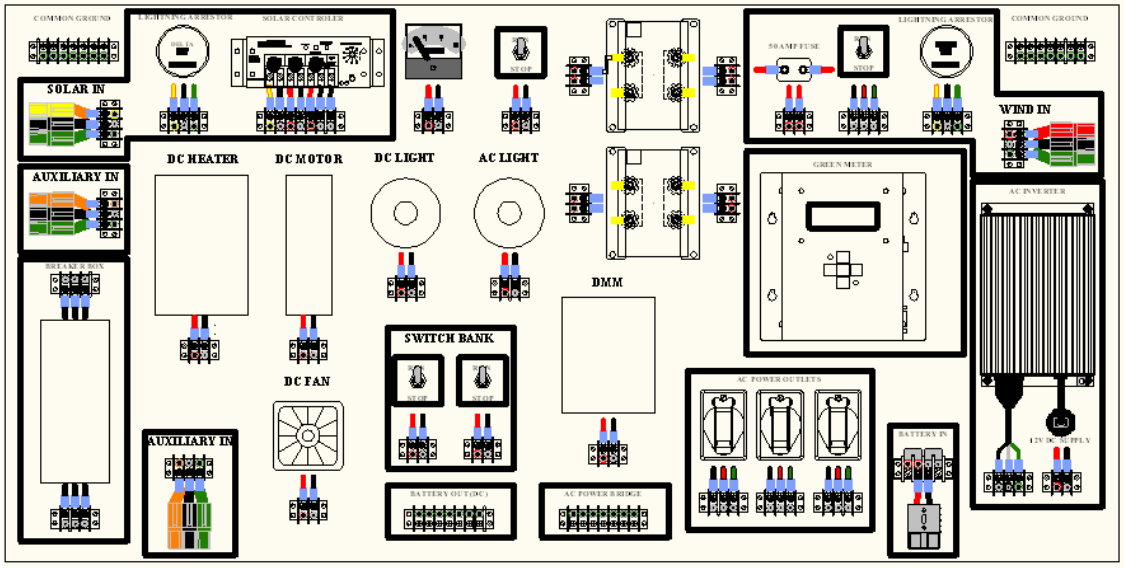

Figure 4. The AutoCAD design of training control unit layout

Each unit has the capability to train three students at a time. This mini-lab is capable of teaching wind and solar technology, active/passive human power, passive water heating systems, passive air heating systems, and hydrogen fuel cell technology. The unit includes: a solar module, a wind turbine, a charge controller, measuring tools, circuit breakers and fuses, lightening arrestors, a battery, an inverter, switches, a generator, hydrogen gas storage unit, fuel cell stacks, a green meter (a temperature sensor, irritation sensor, an anemometer, two power sensors, and data acquisition peripherals). The mini-lab training unit contains all equipment normally required for a residential installation. The system was wired with proper grounding, disconnects, breakers, and GFI load receptacles. The training unit also houses a data acquisition panel where solar irradiation, PV voltage, PV current, PV module temperature, and ambient temperature are displayed and available for computer data logging. The safety of the unit was confirmed after several tests in different conditions on campus. This unit is aimed to be used in general renewable energy classes offered in the technology program. It may also be offered for the workshops to high school/community college science/engineering instructors and students during weekends and summer breaks.

The system has the capability to accept several renewable energy sources at a time and convert to constant voltage to charge a battery. The charge controllers handle the charging process of the battery at different input voltages that vary by intensity of light energy, wind speed, human kinetic energy, and hydrogen fuel cell etc. The modules and sub modules of power generation from ambient energy sources using Alternative Energy training unit are detailed for each energy source.

- Solar Module Input
    - PV module
    - lightening and charge controller
    - lightening arrestor
    - circuit breaker
    - solar pathfinder

- Wind Turbine Input
    - wind turbine
    - charge controller
    - lightening arrestor
    - start/stop switches
    - circuit breaker/fuse

- Passive/Active Human Power Input
    - bicycle
    - bike power generator
    - portable power pack and power monitor
    - bridge rectifiers

- Green Meter®
    - temperature sensors
    - irritation sensors
    - anemometer
    - DC and AC power sensors

- General Components
    - DC loads (DC motor, LED light bulbs, heater)
    - AC loads (receptacles, LED light bulbs, heater, AC motor)
    - power inverter
    - battery (with protection fuse)
    - input/output jacks
    - different size terminal blocks
    - different color banana jacks and plugs with patch cords
    - passive air and water heating system (common source)
    - measuring tools and testing equipment

3. Overall System

The prototype training unit project had four phases and finished in six month. The first phase of the project was 3D design and simulation of the system using a 3D parametric modeling software tools. After the design of the system, all the necessary parts for one unit (prototype unit) were determined and ordered from various manufacturers or vendors. Then, the wheeled metal frame

which is the housing of the training unit was built in the production lab. The balance of the housing (frame) was important due to heavy components such as battery, solar module, and inverter. All the components were mounted on board (plywood) which is the actual training unit. The board was then assembled to the wheeled frame and all necessary wiring was done to test the system in different locations on campus and for use in Renewable Energy related classes.

The prototype unit was extensively tested to eliminate or reduce any safety concerns and improvements were applied before the production of the remaining ten units will be completed with a grant. It is important to build a reliable system to eliminate safety concerns because of the variable voltage outputs from different alternative energy sources. Special attention was given to the location of battery and circuit breakers/fuses to eliminate any hazard caused from short circuits in the system. The remaining units will be built quickly because of the completed prototype model when external funds become available. The photograph of the prototype training unit is shown in Figure 5. The wind turbine is not attached to the training unit; it was placed on the roof of a storage shed built to keep training unit components.

Figure 5. The photograph of the renewable energy training unit

4. Significance of Results

Students involved in this project conducted structured independent research, used creative thinking, and shared hands-on experiences that also were a plus in their gained knowledge. The training units were used to understand the way that the energy is collected and stored. Establishing alternative energy teaching and research interactive training units involve our undergraduate and graduate students, faculty, and community in future alternative energy projects and training.

A fully functional unit provides for applied energy education workshops for local community colleges, secondary/high school science/technology teachers and students and interested population who are not exposed to state-of-the-art renewable energy. Students can obtain valuable knowledge by doing this research related to their major/minor. The units will:

- Increase scholarly productivity of faculty
- Provide leverage to target larger state and federal external funding sources, i.e. NSF, Department of Energy Grants.
- Highlight unique expertise of new faculty
- Provide new opportunities for undergraduate/graduate research projects
- Offer educational workshops to especially High School students/teachers
- Provide enhanced teaching laboratory experiences for classes
    - IT 469 Energy Harvesting, Conversion, and Storage Technology
    - AGR 493 Alternative Energy
    - AGR 330 Electricity
    - IT 134, IT 232 Electronics Technology
    - X59X Alternative Energy
    - X500 Energy Harvesting

5. Conclusion

The outcome of this project was an efficient, easy to build and operate, cost-efficient alternative energy training unit which works as a stand-alone mini-lab. This study gathered students from a variety of disciplines together, merging their knowledge in this experimental project. The results of the reliability of these types of projects will lead other institutions to develop their own systems. The project engaged student participation from different disciplines (construction management, design and development, and electronics.). The team leader (faculty advisor) set up meetings to organize working schedules, progress reports, and the construction was conducted as part of the initial project. All necessary construction and production tools are located at the IT Building; therefore this location was used to construct the training unit. The Computer models of the system were designed using Computer Aided Design and Drafting software tools by the Design and Development Majors in the Design and Drafting Lab. The Electronics Majors used equipment in the electronics laboratory for the electrical part of the structure and for testing the system. The determination of the system reliability and safety was tested with detailed calculations and measurements by Industrial Safety Management Majors and Minors. Students involved in this project were able to participate in hands-on experiments that will benefit their future careers. Building a Renewable Energy teaching and research training unit as a mini-lab will help to establish a laboratory and involve our undergraduate/graduate students, faculty, and community learning about alternative energy. This lab and the hands-on renewable energy related classes will promote Alternative Energy Education at Sam Houston State University. A fully functional laboratory training unit will augment applied energy education workshops for local community colleges, secondary/high school science/technology teachers, students, and especially interested population who are not exposed to state-of-the-art renewable energy.

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