Session 3250

Design and Construction of a Solar Powered Outdoor Digital Display as a Capstone Design Project

by

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Abstract

The senior design project is a capstone course taken in the final year of the Electrical and Information Engineering Technology (EIET) and Manufacturing Technology programs in the Department of Industrial Technology at the University of Northern Iowa (UNI). Both the EIET and Manufacturing programs have 2+2 articulation agreements with Iowa community colleges.

This paper presents a detailed study on a capstone senior design project to design and construct a solar powered outdoor digital display for promoting environmentally friendly technologies in Iowa. This paper also illustrates how a student capstone design project can serve as an excellent marketing tool for engineering technology and industrial technology programs. The authors determined that an innovative use of environmentally friendly technology would be an outdoor marquee to advertise events and programs in the department. Students designed a panel mount frame using CAD software. Analysis of dynamic forces that could affect the outdoor display insured that the design could withstand strong summer windstorms. The system includes three 100 W solar panels, panel frame built by students and production lab technicians, electrical box, two deep cycle batteries, one charge controller, surge arrester for lightning strikes, switches, DC fuses, DC fluorescent lights directly connected to battery output, 120 ft underground data cable connected to a PC from the outdoor display, and a digital display with six inches letter size. Fabrication of the display framework, concrete footings, and electrical connection to the indoor control unit took nearly six months. The digital display has been an excellent marketing tool for the announcements of the undergraduate and graduate programs in the Industrial Technology Department at UNI.

I. Introduction

The senior design project is a capstone course taken in the final year of the Electrical and Information Engineering Technology (EIET) and Manufacturing Technology programs at the University of Northern Iowa (UNI). The purpose of a research course, as highly suggested by both ABET and NAIT accrediting bodies is to provide an opportunity for students to work on a cross-disciplinary team to perform research and develop a project with an industrial partner.

The EIET program was updated from an Electro-Mechanical Systems Program and it is also the first and only program in the state of Iowa that grants its students a Bachelors Degree in electrical engineering technology after the completion of a four-year course of studies. The EIET and Manufacturing Technology programs have 2+2 articulation agreements with Iowa community colleges.

Introduction of renewable energy applications to electrical engineering technology curriculum at the University of Northern Iowa (UNI) has positively impacted students, faculty, and the University community and promoted the feasibility study, and adoption of more eco-friendly energy technologies. This paper presents a detailed study of a capstone senior design project to design and construct an outdoor digital display for promoting environmentally friendly technologies in Iowa.

Engineering technology and industrial technology programs must offer a relevant and validated curriculum that prepares students for post-graduation success. Courses that cover traditional subject matter in mathematics, sciences, materials, engineering economics, and related topics, provide the foundation of knowledge upon which specific skill sets are added depending on emphasis. However, it is critical for engineering/technology to transition from theoretical work in the classroom and experiential learning with applications of technology and design. The main objective of senior design courses in engineering and engineering technology curricula is to bridge the gap between academic theory and real world practice. Accordingly, the proposed senior projects should include elements of both credible analysis and experimental proofing such as design and implementation as discussed in ABET criteria [1]. Additionally, the senior design seminar organized at the end of the academic year can serve as an excellent culminating experience in the program of study when it focuses on research and design projects that have practical value to consumers or to industrial partners.

For both technology majors at UNI, the senior design course is a year-long educational journey that takes an idea generated by a student or an industrial sponsor and culminates in a product or project. During the first semester, the students focus on the conception phase of the project consisting of problem identification, product development and testing, cost analysis, and process planning. The second semester includes the implementation phase focusing on research, testing, fabrication, documentation, and culminating with project completion and presentation. This course is an excellent capstone experience, which requires both teamwork and individual skills in solving a modern industrial problem [2-5]. Senior design projects seminar events in spring semesters bring the students, faculty, and industrial partners together to evaluate the student teams' results and to provide students additional experience of public presentation of their work.

II. Program Information

The EIET Program is a four-year undergraduate program leading to a Bachelor of Science Degree in Electrical and Information Engineering Technology area. The major prepares students for *application oriented engineering technology careers* in conventional and renewable electrical power, analog/digital electronics, microcomputer, telecommunications, and networking areas; there are also elements of mechanical, hydraulic, and pneumatic system controls as part of the curriculum.

The Manufacturing Technology program is a four-year undergraduate program leading to a Bachelor of Science Degree. The program has three emphasis areas: Automation & Production, Design, and Metal Casting. The major is designed to provide relevant and contemporary learning experiences to prepare students to manage technical, managerial or service careers in manufacturing or related industries. The program of study begins with introductory classes in math, physics, and computer programming and continues with practical engineering applications of EIET in industrial settings. In addition to the advanced level technical classes with computer simulations, the program incorporates extensive practical laboratory exercises and a variety of industrial-based project experiences.

The design team for this project was multi-disciplinary consisting of students from the EIET, Manufacturing, and Construction Management programs. Two students were selected to function as project coordinators for the EIET and Manufacturing components of the project. Individual group meetings were held by the program coordinators in addition to scheduling weekly meetings combining both groups and the authors. Interaction within the combined meetings was interesting to observe. Initially, the students were talkative within their respective groups, but were very quiet and reserved during the combined meetings. After several weeks, the students became more talkative, started asking questions about the project outside of their respective group, and demonstrated more interaction between the members, even outside of the scheduled meetings.

III. Project Methodology and Design

The senior design project was the design and construction of a solar-powered outdoor digital display. The student team determined that an innovative use of environmentally friendly technology would be an outdoor marquee to advertise events and programs in the department. Students designed a panel mount frame using CAD software as shown in Figure 1. Analysis of dynamic forces that could affect the outdoor display assured the design could withstand strong summer windstorms. The system includes three 100 W solar panels, panel frame built by production lab technicians, electrical box, two deep cycle batteries, one charge controller, surge arrester for lightning, switches, dc fuses, dc fluorescent lights directly connected to battery output, 120 ft underground data cable connected from a PC to the outdoor display, dc powered 6 inch letter size digital display. Fabrication of the display framework, concrete footings, and electrical connection to the indoor control unit took nearly six months. The digital display has been an excellent marketing tool for the program and for other announcements in the department.

One of the most challenging tasks for student members was securing permission from University Physical Plant and campus facilities planning offices. Student teams had to visit and present the project a number of times to the University facility planning group to make sure that all the safety rules and regulations were obeyed. Students, particularly ones who had never done such professional interactions including presenting their work professionally, mentioned their learning experience throughout the project phases [7]. After a three and one-half month-long fall semester work of senior design I, the student team developed their final technical report to be approved. The final report was approved at the end of fall 2001 semester and the construction work started in spring 2002. Figure 2 illustrates solar panel placement and securing wiring connections in the metallic frame.

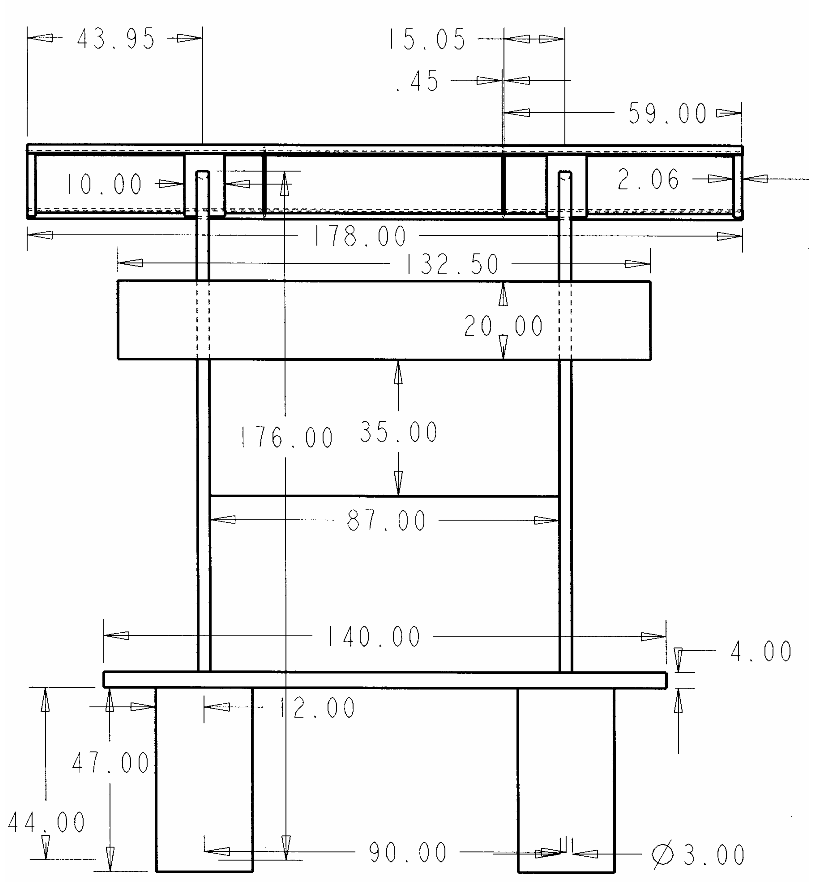


Figure 1. CAD Drawing of Metallic Frame

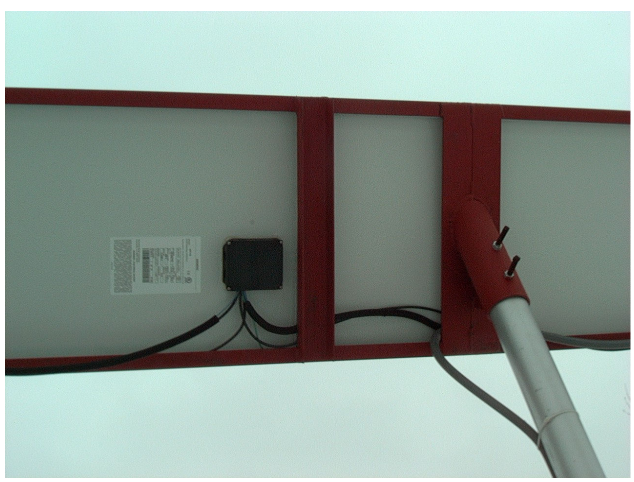
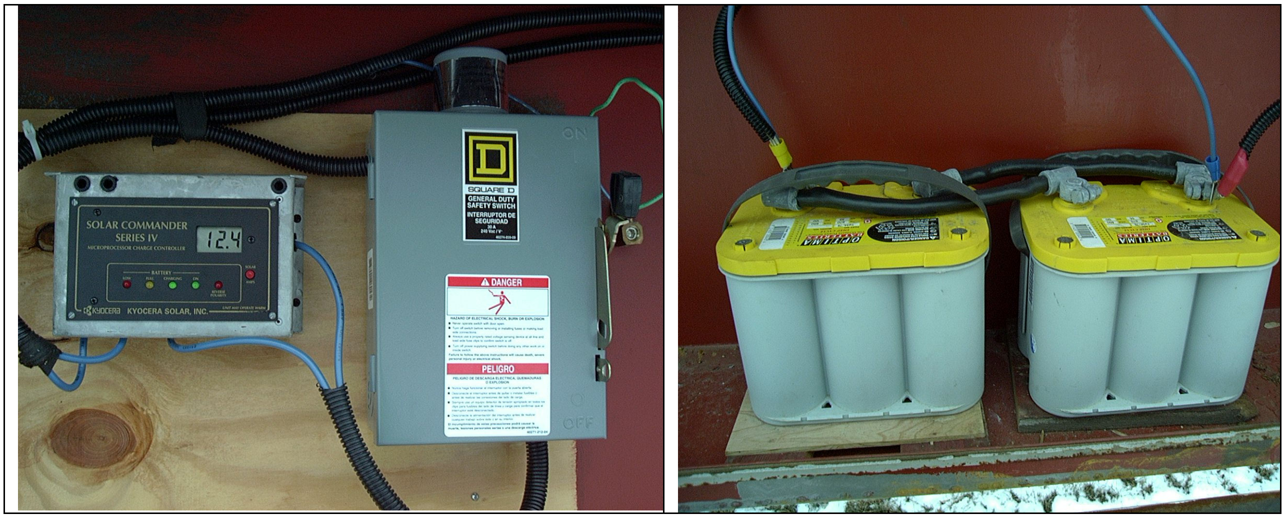


Figure 2. 100 W PV Panel placement and electrical wiring connection to the other PV module.

Figure 3 illustrates electrical connections inside the enclosed metallic box shown in Figure 1. A 12-15 V, 25 A maximum current capacity charge controller is used to avoid excessive voltage charge of deep cycle marine batteries shown in Figure 3 (b). A dc circuit breaker and a surge arrester to protect against lightning strikes are also wired in the power circuit. The battery bank includes two Optima® deep cycle marine batteries with yellow type 34/78, which are very suitable for continuous charging and discharging characteristics for solar power applications. Each battery has an ampacity factor of 55 Ampere hour (Ah) and a Cold Cranking Amp (CCA) of 650. The performance of the battery bank was excellent during the several days that Iowa could not see any sunshine. Figure 4 shows a concrete base of the display frame and final connections of the electrical system



(a) (b)

Figure 3. (a) Charge controller, DC circuit breaker, and surge arrester inside the electrical box in the metallic frame, (b) Two deep cycle type Yellow 34/78 batteries connected in parallel.

Figure 4. Installation of outdoor digital display into the metallic frame

Figure 5 illustrates the overall system running during the summer semester. The scrolled messages in the display can be seen clearly up to 200 m distance and it operates much brighter at night compared with day light operation due to the reflection.

Figure 5. The overall system runs 24 hours a day seven days a week using solar energy.

The main sponsors of the project were the department of Industrial Technology, and College of Natural Science Dean's SOAR grant for undergraduate research projects. The fiberglass cover seen in Figure 5 was donated by BC & T Bunn, Inc., a construction company in Iowa whose owner is an alumnus of the department. Table I illustrates a detailed cost analysis of the project.

Table I. Cost Analysis of the Digital Display Project

Item	Price
Sign-Board LCD Outdoor	$1,650
Solar Panels	$1,293
Deep Cycle Marine Batteries & Cables	$285
RS-232 to 485 Converter for Data Link	$95
2-Wire Data Cable	$40
Conduit	$120
Insulation, Water resist material, coding, Schedule 40 Pipe,	$440
Steel Plates for Box Design	$320
Miscellaneous small items	$150
Total	$4,393

IV. Solar Power Capacity on UNI campus

Iowa Energy Center (IEC) [8], a state institution promoting renewable energy use and development in Iowa, provided a web site on solar and wind power capacity of any location in Iowa. Using the IEC resources, it was determined that 1446 kWh electrical energy would be generated using an installed 1000W solar panels. This power exceeded the requirements for the digital display with two dc fluorescent lights. Therefore, using an installed 300 W power rating of three solar panels, 434 kWh annual clean energy would be generated through PV panels. This electrical power corresponds to savings of 629 pounds of CO_2 emissions on UNI campus. Using the facts of an azimuth of 0 degree corresponds to a south-facing array; 90 degrees to an east-facing array; 180 degrees to a north-facing array; and 270° to a west-facing array. Therefore, the azimuth of an array facing 20 degrees east of south will be 20°, while the azimuth of a PV array facing 20 degrees west of south will be 340 degrees. The selected latitude is 42.7 degrees, and the longitude is -92.9 degrees based on the location selected for Cedar Falls, Iowa.

Table II illustrates monthly average values of electrical power generated by 1 kW rated solar modules (PVs) which are located on a fixed surface of 40 degrees tilt and 60 degrees azimuth. The table presents the output of a PV system sized to deliver 1 kW-AC output under summer operating conditions, that is with an ambient temperature of 25^{o}C and a rate of solar radiation incident on the collector of 1000 W/sq.m. This table shows the mean AC power output of a PV array as a function of time of day and season in Watts per installed kW. The last column on the right summarizes total kWh production per month and per year.

V. Instrumentation of the Digital Display to a PC

The instrumentation part of the project includes the following software and devices: The Message Pro version 2.30, an Ethernet capable software developed by Electronics Displays Inc., a 2-4 wire RS 422/485 9-pin converter, a 12 V dc power supply, 9-pin gender reverser, and a 120-ft long 24 AWG two-pair low capacity wire. The RS-485 allows multiple devices (up to 32) to communicate at half-duplex on a single pair of wires, plus a ground wire, at distances up to 1200 meters (4000 feet). For future project expansion, both the length of the network and the number of nodes can easily be extended using a variety of repeater products on the market. Data is transmitted differentially on two wires twisted together. The properties of differential signals from PC to the digital display provide high noise immunity and long distance capabilities. The 485 network in this project configured as two-wire. In this configuration, devices are addressable, allowing independent communication at each node. The gender reverser as seen in Figure 6. changes a female port to a male port for data link to digital display through a 120 ft long low capacity wire.

Table II. The mean AC power output of a PV array as a function of time of day and season in Watts per installed kW [8].

	Time of Day (Local Time 0:00...24:00)												24hr Avg	Total kWh
Month	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24		
Jan	0	0	0	0	260	471	394	118	9	0	0	0	104	78
Feb	0	0	0	14	338	538	422	170	21	0	0	0	125	84
Mar	0	0	0	140	516	651	525	219	40	0	0	0	174	130
Apr	0	0	0	307	595	633	462	213	66	6	0	0	190	137
May	0	0	54	409	673	667	489	242	71	15	0	0	218	162
Jun	0	0	83	438	732	764	585	317	92	24	0	0	253	182
Jul	0	0	62	400	667	730	600	327	91	23	0	0	242	180
Aug	0	0	2	308	573	654	518	257	75	11	0	0	200	149
Sep	0	0	0	245	562	619	485	201	51	0	0	0	180	130
Oct	0	0	0	138	483	521	388	129	18	0	0	0	140	104
Nov	0	0	0	12	260	358	264	80	4	0	0	0	82	59
Dec	0	0	0	0	217	339	247	71	0	0	0	0	73	54
Yr. Avg.	**0**	**0**	**17**	**201**	**490**	**579**	**448**	**195**	**45**	**7**	**0**	**0**	165	1446

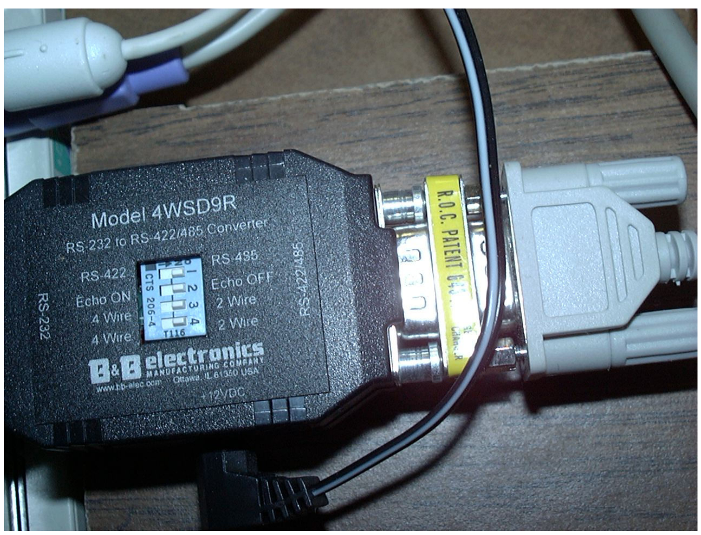


Figure 6. RS-232 to RS 422/485 Data Converter hooked up to the serial port of a PC.

Figure 7 illustrates the editor inputting and modifying scrolling text for the digital display. The software also allows user to review the entire text message before uploading to the display. In addition, the software also allows customizing futures such as flashing, scrolling, centering, or just a solid text. A final step to send the data to the digital display is completed by selecting sign address, message number, and indicating if the message is urgent as shown in Figure 8.

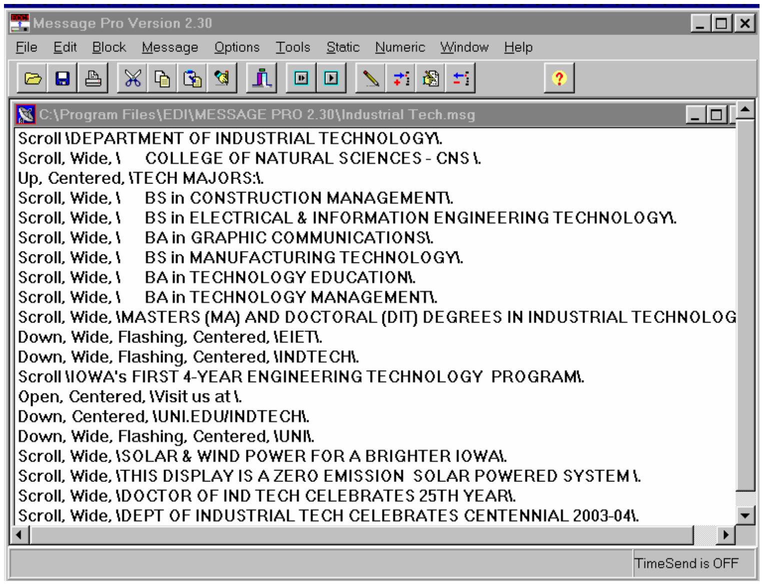


Figure 7. Entering display information through Message Pro-Version 2.30 [9].

Figure 8. Final step of selecting sign address and the message number.

VI. Conclusion

The design, implementation, and construction of a solar powered outdoor digital display project have been completed as part of Senior Design I and II courses at UNI. The project provided a unique opportunity to collaborate among the EIET, Manufacturing, and Construction students, faculty, and technicians. The project aspects included computer aided design of a metallic frame which encloses three solar panels, a digital display, electrical storage battery bank, and charge controller, circuit breaker, surge arrester, two dc fluorescent lights, and other wiring. Yearly average solar radiation amount for the location was also investigated and it was found out that 1446 kWh electrical power would be generated through clean energy technologies if a total power rating of 1000W solar panels would be installed. Student outcomes and project evaluations by other students in the department and industrial board members have shown that the project provided an excellent opportunity for student's development. Both student groups grew personally and professionally throughout this capstone experience. The students developed presentation and research skills utilizing a variety of research journals, flow charts, and other project management tools. Lastly, the students refined their technical skills and experienced the positive benefits of effective team work.

VII. Acknowledgments

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References

[1] ABET Criteria for Accrediting Engineering Technology Programs: Effective for Evaluations During the 2003-2004 Accreditation Cycle, Baltimore, MD, approved November 2, 2002.
[2] Wilcox, A.D., Engineering *Design for Electrical Engineers,* Prentice Hall, 1990.
[3] Dym, C.L., *Engineering Design: A Project-Based Introduction*, John Wiley & Sons, Inc., 2000.
[4] Goldberg, D.E., *Life Skills and Leadership for Engineers*, McGraw-Hill, Inc, 1995.
[5] Currin, T., "The Capstone Design Course and Its failure to serve as an effective outcome assessment tool", Proceedings of the 2002 ASEE Annual Conference and Exposition.
[6] http://www.uni.edu/indtech/recruit/itscholars.htm
[7] Davis K.C., "Enhancing Communication Skills in Senior Design Capstone Projects", Proceedings of the 2002 ASEE Annual Conference and Exposition.
[8] Retrieved from Iowa Solar Calculator Web Site at http:// www.energy.iastate.edu/renewable/ solar/ calculator/
[9] Message Pro-Version 2.30 developed by Electronics Displays Inc., 1999.

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