Design and Implementation of PV based EV DC Fast Charging Station for University & Community Engagement

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Abstract

This applied research paper reports efforts of engineering technology faculty and students to design and build a sustainable charging station that is fully sponsored by an energy services company. The objective of this project is to install a 33.6 kW solar array on Sam Houston State University's (SHSU) campus and connect it to a university owned substation by a 50 kW capacity grid-tie inverter. A Charge-Point Express 250 DC fast charger will also be installed on the SHSU campus near the PhotoVoltaics (PV) array to charge electric vehicles (EV). The project also includes an outdoor educational display describing how the system operates, and offsets carbon emissions providing environmental savings on campus. The project provides a multitude of benefits by placing an EV fast charger on campus with it being convenient for the citizens of Huntsville, TX and electric vehicle drivers that are traveling between Houston and Dallas, TX. It will also showcase to the SHSU community the increasing importance of renewable energy resources and display an example of how clean power is generated. We are promoting more sustainable operations of the university using renewable energy systems by designing a unique PV based EV fast-charging station due to lack of locations where EV owners can charge their vehicles. It will also introduce a cleaner form of energy that will help reduce the overall cost of the charger. The initial requirement of the project was to install 120 PV panels with a total capacity of 50 kW. Due to an increase in cost during the preparation phase of the project, this had to be reduced to 80 PV panels with a capacity of 33.6 kW.

Keywords
PhotoVoltaics (PVs), EV fast Charging, Campus Sustainability, Community Outreach

1.Introduction
According to the Energy Information Administration (EIA), the transportation sector is responsible for almost 23% of greenhouse gas emissions. Therefore, electric vehicles (EVs) may play a critical role in achieving the environmental objectives of the Paris agreement that strengthens the global response to the threat of climate change (DOE 2022 and Bauer et al. 2021). National Renewable Energy Labs (NREL) and International Council on Clean Transportation (ICCT) predict that there will be more than 3 million EVs roaming the U.S. highways by 2025 (Bauer et al. 2021). Design and construction of EV charging stations using zero-emission photovoltaic (PV) solar panels are expected to positively impact environmentally friendly efforts on reducing carbon footprints specifically in metropolitan areas.

1.2 Objectives
The main objective of this project is to design, construct, deploy and operate a fully sustainable fast EV charging system for university community as well as community outreach. The project has multiple phases and objectives.

The first objective of this project is to install a 33.6 kW solar array on Sam Houston State University's (SHSU) campus and connect it to a university owned substation by a 50kW capacity grid-tie inverter. Second objective is to install a commercially available Charge-Point Express 250 DC fast charger on the SHSU campus near the PhotoVoltaics (PV) array to charge electric vehicles (EV). The last phase of the project is educational and targets both the university and the nearby city community to promote solar power-based charging stations. The overall system on campus will be show case and demonstration laboratory for Electronics and Computer Engineering Technology senior students. The project also includes an outdoor educational display describing how the system operates, and offsets carbon emissions providing environmental savings on campus.

2. Literature Review

There are a number of campus and community projects completed by senior design students and faculty researchers utilizing renewable energy applications including solar PV panels, wind turbines, micro hydro, and Hydrogen fuel cell systems. The University of Massachusetts researchers installed 15,576 PV panels across campus to provide 5.5MW of clean electricity that was one of the largest capacity installed on U.S. campuses. This unique installation reduced the energy cost and provided savings of $6.2 million over 20 years and reduced greenhouse gas emissions (University of Massachusetts Amherst, 2022). The authors of this paper designed and installed multiple renewable energy projects both on campus and communities in multiple states (Pecen et al. 2021, 2024-11). A multidisciplinary engineering technology senior students designed and constructed two separate solar PV canopy-based charging stations for the City of Huntsville aquatic park that provided park residents shading and charging for phones and electronic devices (Pecen et al. 2021). An educational project promoting Math-Science-Engineering Technology in Iowa using renewable energy applications provides area middle school teachers with an applied mathematics and science curriculum package based on PV, wind power, and hydrogen fuel-cell fundamentals (Pecen and Humston, 2009). The main author designed and implemented a 10kW wind-solar distributed power and instrumentation system for educating and training of workforce of Iowa in renewable energy applications that exemplified positive work partnership for academia and industry (Pecen et al. 2012). Senior design students at the University of Northern Iowa established multiple grid-connected wind-solar hybrid power stations on campus. These systems have been used for teaching and research purposes besides the green power generation and a showcase for the recruitment to STEM fields (Pecen et al. 2001, 2004). A smart grid design and implementation using distributed power sources of wind, solar, and hydrogen fuel cell was completed by the authors at the Sam Houston State University (Pecen et al. 2018, 2019).

Researchers at Dublin Institute of Technology investigated performance of a campus PV based EV charging station in a high temperature climate. They measured solar resource and EV energy consumption with locational, mechanical, and electrical constraints and used that data to design an EV charging station comprised of 10.5 kW PV array with a 9.6 kWh Lithium-ion battery storage (Esfandyari et al. 2019, 2022). Rasin et al. (2022) developed a unique DC bus in a bidirectional storage management method to enhance the EV charging station's structure, size, and reduce the operational cost. After reviewing commercially available EV charging plugs developed by Blink Charging company and checking available infrastructure to charge plug-in EVs, students have become more informed on how to research detailed features of EV charging stations (Blink Charging, 2021 and U.S. DOE, 2015). Tulpule et al. (2013) worked on economic and environmental impacts of a PV powered workplace on a smaller scale. As senior students and faculty advisors, the mutual agreement is to choose a reliable commercial DC fast charging station to reduce the time in charging and expand the footprint of DC fast charging stations in the city.

3. Engineering Design

A functional block diagram of the overall project is shown in Figure 1. The project field work started with the digging of holes to mount the ground racks and the concrete pouring by SHSU faculty, staff, and students in January 2022. PV panels were wired and a 480V cable will be trenched underground with the help of Sam Houston State University faculty staff. An external contractor hired by SHSU facilities management will complete the wiring needed from the 50kW inverter to a 3-phase transformer in the nearest substation through the underground cable. Figure 1 also shows the placement of the American made 80x420W (Mission Solar, 2022) solar PV panels, Core1 50 kW inverter, and the unidirectional DC charger. The PV arrays output will be connected to the inverter and DC power will be converted to AC. In a separate circuit, the SHSU transformer will provide three-phase AC power to the DC fast charger. The Level 3 DC fast charger was chosen because it is the most effective and quickest commercially available charger.

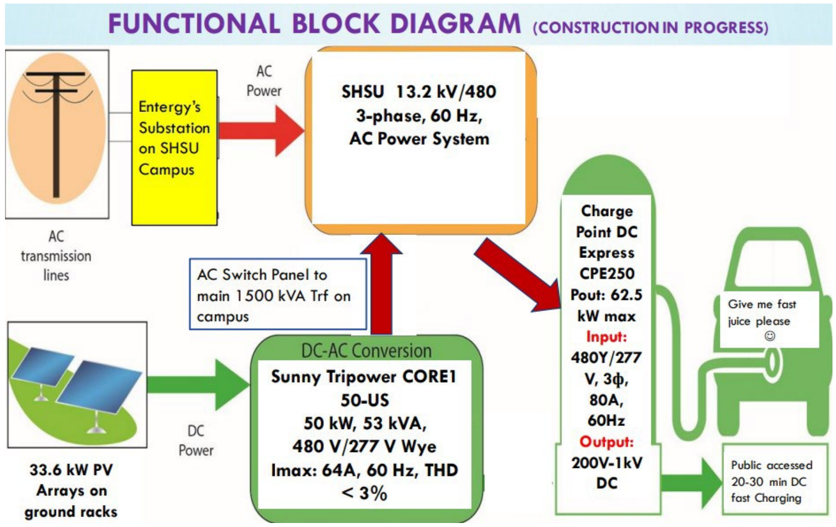

Figure 1. Functional Block Diagram

The foundation work of 8-foot holes that are filled with concrete for the solar array rack systems is shown in Figure 2a. The PV foundation holes had tubing placed in them to create a casing for the concrete to sit in and have it form a cylinder shape for the 12-foot beams to be placed in to support the structure of the arrays. The beams were also placed in by the facilities management team during the pouring of the concrete so the beams could cure inside of it creating a stable base for the array with about 4 feet of the beam sitting above ground to attach the rest of the metal purlins for the solar panels to attach on top of ensuring a stable structure.

Figure 2b shows the completed structure that each of the solar arrays will attach to. The structure of the array is set up with 3 long steel bars that are slanted at a 23-degree angle for the most optimal amount of sunlight to hit it on the slanted hill of the retention pond. These steel bars are connected at 4 points across each of them by a total of 8 purlins, 2 being bolted to each structure connecting all three steel bars. The purlins are in the shape of a “Z” to allow the solar panels to rest on top of each bar with 4 “L” shaped bars connecting the purlins to each other for extra support. The purlins had an extra 2 1⁄2 feet on one side so we used a bandsaw to cut off the extra steel to make them flushed with the slanted steel bars as shown in Figure 2c. Figure 3 shows the completed PV array installation.

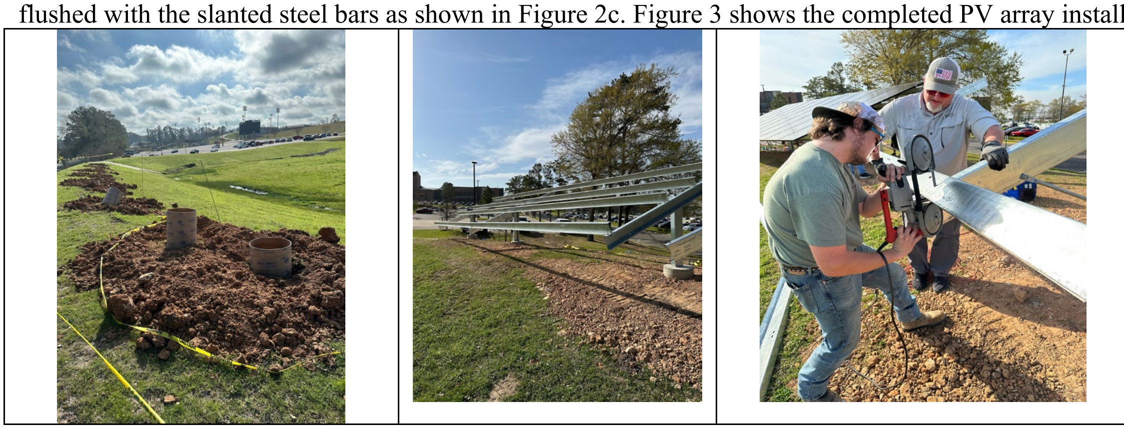

Figure 2 a-b-c. Foundation work and installation of PV racks by students and faculty

Figure 3. Fully constructed solar array of 80 x 420W PV panels on campus

Figure 4 shows 6 PV strings connected to the 50 kW Sunny TriPower CORE1 50-US Inverter. Trenching and wiring work from Inverter to the building transformer and AC connection to fast DC charger will be completed during Fall semester.

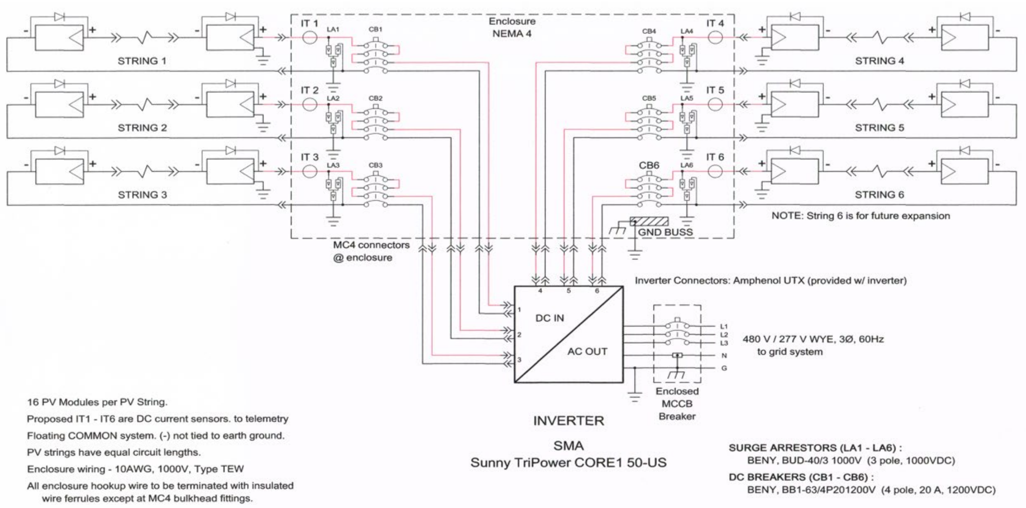

Figure 4. PV strings connection to 50 kW Inverter

Figure 5 exhibits the last phase of the project that includes AC grid connections will be completed by an external electrical contractor during Fall 2023 semester and it is expected to be completed by January 2024.

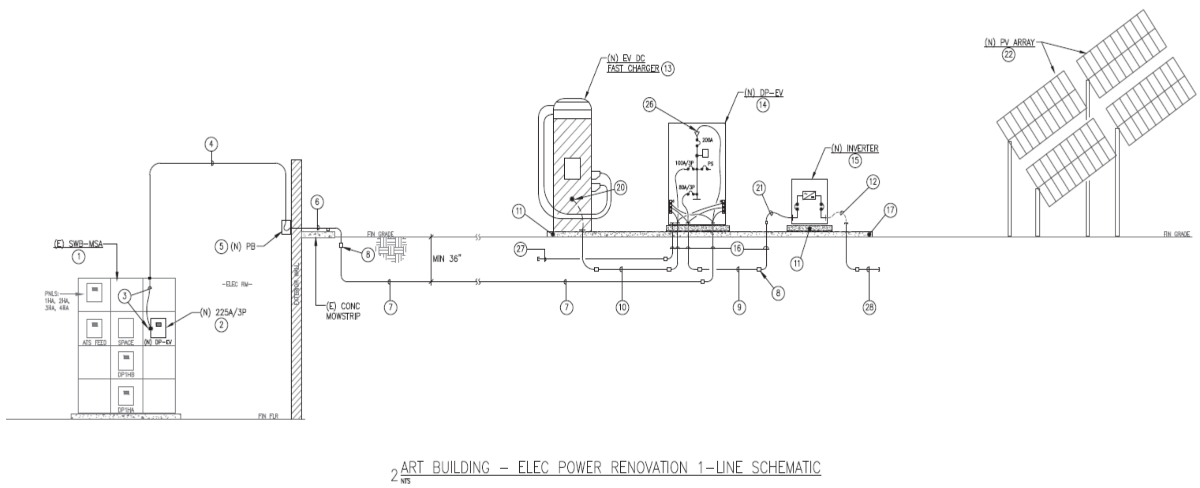

Figure 5. Conceptual design and electrical power connection of PV arrays, inverter, DC fast charger to the AC grid

An educational display made by wood working class of Construction Management students were completed in May 2023. A small group of construction students designed and built a wooden educational display board to be installed on the project location when the EV charger is serviced in 2024. This board will include information about the beneficial environmental outcomes of the panels and various data that will be collected from it once it is successfully collecting power.

4. Conclusion

This paper presented a work in progress to design and construct 33.6 kW PV- based DC fast charging station for promoting environmentally friendly technologies and serving the local communities. Eleven students from multidisciplinary majors including engineering design, safety management, construction management, mechanical engineering technology, and electronics and computer engineering technology are involved in this project. Three faculty members with expertise in electrical power, engineering design, computer networking and technology management are involved in this project. The eco-friendly charging stations project will help both students and the employee to expand their knowledge of energy, environment, sustainability, clean energy, and energy efficiency as they use the charging stations in their daily lives. The project will provide noise-free and zero-emission charging power to the city and the local community members enhancing both Entergy and Huntsville's sustainability and clean energy initiatives. 33.6 kW installed capacity solar PV panels are expected to generate 52,800 kWh of zero-emission electrical energy annually which will be equivalent to 59,664 lbs. of CO_2 emissions saved if the same amount would be generated by coal-fired power plants.

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Biographies

Reg Pecen is serving as a Quanta Endowed professor of Engineering Technology in the College of Science and Engineering Technology at SHSU in Huntsville, Texas since 2017. Dr. Pecen served as a President at North American University at Houston, TX from July 1, 2012 to December 12, 2016. Dr. Pecen was formerly a professor and program chairs of EET and Graduate Programs in the Department of Technology at the University of Northern Iowa between 1998 and 2012 where he established EET program and secured ABET-ETAC accreditation. He served as a Past-Chair (2013-14), Chair (2012-13), Chair-Elect (2011-12) and Program Chair (2010-11) of Energy Conversion Conservation and Nuclear Engineering Division (ECCNED), ASEE. His research interests are on electrical power systems, grid-integration of solar and wind hybrid systems, and PV-based EV charging applications. He served as a reviewer for DOE OCED FOA in Energy Improvements in Rural Areas program, and DOE EERE's Grid Engineering for Accelerated Renewable Energy Deployment. Dr. Pecen is a senior member of IEEE PES, member of ASEE, and Tau Beta Pi-National Engineering Honor Society, WY Chapter.

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