Off-Grid Solar-Powered Electric Vehicle (EV) Charging Station – A Design-Build Project

Project Description

Our University is undergoing an intentional process of transformation in several areas in pursuit of more sustainable practices and systems on our campus. As the United States slowly moves forward in evolving our automobile inventory from fossil-fuel, combustion-powered vehicles to electric-powered vehicles (EVs), our research faculty partnership began looking for opportunities to utilize faculty experience and our available student talent to help advance the infrastructure on our campus by creating a new charging station for powering EVs driven to campus by our students, faculty and visitors.

Technology and systems currently exist for grid-powered EV charging stations. Technology and systems also exist for a select few off-grid stations. Our group sought to design our own proprietary off-grid system intended to serve as a model for a universally adaptable solution that could be deployed on virtually any new or existing property at any parking lot configuration for either public or private owners.

Our faculty research partnership exists in an academic department that benefits from having access to undergraduate students who are pursuing the architectural engineering disciplines of either structural engineering or electrical engineering and students earning their degree in construction science and management. This building systems design and construction knowledge pool of student talent was leveraged to support a multidisciplinary effort consisting of industry-experienced faculty guiding emerging-professional students representing all these practices.

While our overarching objective was to design a universally deployable solution for off-grid, solar-powered EV charging, our secondary objective was to develop a concept that was also more economical than other existing systems that are currently commercially available. To accomplish this, the team value-engineered each iteration of the design to recognize opportunities to utilize off-the-shelf system components wherever possible to minimize the cost increases associated with fabricating custom elements for the station.

The resultant design originated through collaborative undergraduate research efforts of architectural engineering faculty and students working closely with construction management faculty and students in a “best-for-project" thinking environment. To help the participating students relate their experiences to a real-world collaborative scenario, the team approached the project with the mindset of a Design-Build (DB) construction project where DB professionals provide both design services and construction services to a client under a single contract. This approach benefits from both sides—design and construction—listening to the challenges and issues of the other disciplines to mutually establish project solutions that equally satisfy the needs of design while supporting straightforward constructability.

A roughly 75%-complete design was ultimately presented to the College under which our department serves and approval was granted to present the design to the University Facilities group as well as the leadership of the Campus Parking Authority. In support of the University’s sustainability initiatives, the project was green-lighted for site selection by both Facilities and Parking.

We are now finalizing the design, securing our funding, and making plans for our prototype to be fabricated and installed on our campus. Our team remains optimistic about the viability of our design and the possibilities for additional deployment at other locations on our campus pending the success of the first station.

<u>Collaboration of Faculty, Students, and Licensed Professional Engineers</u>

The Design-Build approach utilized by our research group involved numerous weekly team meetings where the evolving design and the estimated costs were iteratively analyzed, discussed and updated to push the station from a concept idea to being ready for actual, physical construction.

Licensed professional engineers were consulted during the initial schematic design and iterative design development phases of the project.

A licensed structural engineer, who has worked extensively in building-related structural design and who is also on faculty, provided guidance to our structural engineering students as they analyzed the wind and seismic loads on the photovoltaic panels to design the primary above-ground framework for the station as well as the necessary foundations that will allow the station to survive the seasonal and severe weather events that affect this campus in some years.

An electrical engineer, who has worked extensively in building-related electrical design and who is also on faculty, as well as an electrical engineering alumnus who leads their own electrical engineering design firm, provided expertise to the electrical engineering students who developed the design of the station's solar collection array, DC to AC power management apparatus and battery storage systems.

A construction management faculty member, who previously estimated and managed construction projects in the commercial and heavy civil industries, provided knowledge and oversight to the construction management students who worked alongside the architectural engineering students to develop and continuously update the project's cost estimate for the fabrication and construction of the design.

Weekly meetings were conducted to keep the team apprised of the group's progress and to assign tasks as needed based on their area of specialization. The interactions of the team were predominantly in person, supplemented by phone calls and Zoom sessions where necessary, specifically when involving out-of-state engineers for the electrical system design. Students were given weekly tasks to complete, however, they were required to be self-starters, researching and working on their own to learn and come up with innovative solutions. Often the students would meet or have discussions via Microsoft Teams to coordinate between disciplines prior to the weekly meetings. Having students from multiple disciplines allowed for a more real-world experience and one that brought about new and better solutions to the designs.

While the concept of collaboration is discussed in numerous classroom settings, the students may typically only experience this through group assignments with other students of their particular discipline. This Design-Build effort to develop this solar-powered EV charging station allowed true multi-disciplinary collaboration as a college experience where the contemporaries of these students likely won't reap the benefits of getting this experience until they begin their professional careers after their degrees are earned.

Protection of health, safety and/or welfare of the public

The project team evaluated several aspects regarding the safety of the system. One major concern was the structural integrity and designing to ensure the canopy does not topple over in high winds that are occasionally experienced on campus. A structural engineering and faculty member worked with several structural graduate students on this process, looking at foundation design, wind loads and the baseplate connection from the canopy to the foundation.

Electrically, the design needed to be safe for users, vehicles and college students passing by or interacting with the canopy in ways they shouldn't. Students evaluating the requirements of Electric Vehicle Charging stations, PV and battery systems outlined in the National Electrical Code. The team designed the system to comply with code and also also worked with an electrical engineering in industry to determine best design practices. This process required engineering students to engage with engineers as well as contractors to fully understand all of the details of the project from a construction standpoint.

Having the construction science students involved throughout the entire project proved invaluable to maintaining a focus on a safe and well-thought-out design. Early iterations of the project utilized a 7' deep foundation system. The depth presented safety concerns for the construction of the project since shoring would be required due to the hole depth being greater than 4'. The foundation was able to be redesigned to have a larger footprint, but a depth under 4'. This protects the workers installing the system by minimizing the potential for catastrophic collapse of the hole while a worker is in it.

Another re-design that came about due to construction concerns was the use of a pulley system for the PV panels. The system utilized allows the panels to be installed and fully wired with the PV array sitting a few feet off of the ground. The pulley system then allows the array to be hoisted into place, minimizing the need for workers to be on ladders during the install process.

Campus parking services also played a role in the safety of the project. The team worked with parking services to identify locations that would minimize the potential for vehicles to accidentally run into the solar canopy. The ideal location of the PV system from a solar generation standpoint would be away from any shading, in the middle of a parking lot. However, parking services expressed trepidation with this location from the perspective of the potential for vehicles to run into the canopy. Locating the canopy in the corner of the parking lot presented concerns with respect to snow removal as the snow plows currently pile snow into the parking lot corners. Eventually, it was determined the best location would be within an island with no nearby trees. This minimized the potential for vehicular damage while maximizing the output of the system.

The use of fossil fuels to power the electric grid and to power our vehicles has come at a tremendous cost to the environment. The pollution from coal and gasoline has led to cities struggling with filthy and unhealthy air. The transition to electric vehicles will alleviate the issues to some degree, but without clean power, electric vehicles still add to the pollution problem. Our proposed off-grid solution provides an opportunity to power vehicles anywhere in the world, with no need for dependence on the utility grid, minimizing the construction efforts involved in getting power to remote locations while at the same time helping to reduce our dependence on fossil fuels.

Multidiscipline and/or allied profession participation

For the solar canopy project, multiple engineering disciplines were involved. Structural engineering students designed the structure of the solar canopy for wind and seismic loads. They also created design documents with foundation and canopy structure plans. These students were guided by a licensed engineer who is also a faculty member in the same department as the students.

The electrical engineering students designed and developed drawings to provide the electrical components of the photovoltaic array and battery storage system for off-grid electric vehicle charging stations. The electrical students were mentored by two different professionally licensed engineers, including a professor from the department and an owner of an electrical design firm who is well respected in the industry.

This project also included construction science and management students who oversaw updating and keeping track of the project estimate as the design was developed. Additionally, these students provided insight and guidance on best practices in construction and offered aid in helping design solutions to keep costs manageable. These students were guided by a faculty member who has many years of experience in the construction industry with estimating and managing construction projects.

Knowledge and Skills Gained by the Students

The following narratives are direct quotes from the current students involved in the design process explaining what they have learned during the design process of the project:

"As a Construction Science major, my focus was on updating the budget for our first product. The solar canopy will first be built for the College of Engineering and then will be altered for other clients in the future, which means there will be changes to the overall cost for each unique build. Critical thinking was a skill that I improved upon while working on the budget due to the thought process that goes into estimating the cost of the final product. There are many different materials, labor, and equipment that are needed to successfully complete the solar canopy, and I want to get a price for it all so the owner knows what they are paying for. Another skill improved upon was collaboration with other disciplines such as electrical and structural engineers. Information that was needed to complete my budget was often found through discussions with them in our weekly meetings. Overall, the knowledge and skills I gained through this project were very similar to the professional setting but on a smaller scale. I will be able to apply the processes I learned from this experience to my career after school. As we get closer to the construction phase of the project, more management concepts will be used. This would include looking into lead times, managing subcontractors or other means of labor, and managing the purchase of materials to ensure we stay on budget."

"As an Architectural Engineering major, my focus on the project was to update and establish the design and drawings for our first product. The project has been through multiple designs as it has been developed. It was my responsibility to check the previous design calculations and to update them as necessary. By walking through the previous design, it allowed me to understand the components and connections that appear in a photovoltaic design and how to create a design for the components that were missing. I was also able to better understand all of the small components that we aren't taught in classes, that need to be ordered when constructing a project. By working directly with the faculty with the knowledge of components, I was able to expand my understanding of what is included when ordering materials. This also improved my ability to communicate with other disciplines to coordinate changes in the design and materials as the solar canopy was improved. By coordinating, we were able to reduce the length of materials, reduce the cost for materials and create a better design. These skills were some that I have not had the opportunity to have in the classroom and I can take with me into my career."