Design and Implementation of a Solar Charging Station

Kaitlyn Babiarz and Stephen Karpinsky
Gannon University: Electrical Engineering Department

Abstract

Due to climate change, there is a dire need to shift energy production away from fossil fuels and towards renewable resources. This project is aimed at exploiting the power of the sun by creating a solar charging station at Gannon University. The free-to-use solar charging station will allow students, staff, and faculty to charge cell phones, laptops, and other electronic devices, as it will provide 12 VDC and 110 VAC power. It will also include a locking mechanism which will allow users to store their devices while they charge. The solar charging station will be built and tested by the end of March 2018. Participating in this design project allows students to be fully immersed in the process of creating a new product.

Keywords

Solar Charging, Engineering, STEM

Introduction

The threats posed by anthropogenic climate change include higher temperatures, rising sea levels, and changes in precipitation patterns. Consequently, droughts will become more frequent and longer in duration, and hurricanes will increase in severity. Consequently, it is important to utilize renewable resources, while phasing out fossil fuels. Two students have chosen to create a solar charging station to implement on their campus for their senior design project. The station will charge both cells phones and laptops. The charging station will utilize a locking mechanism, which will allow users to safely store their device while it is charging. The students have a budget of $450 and two semesters to design and implement their idea. The first semester is used to focus on the design and the second semester is used for implementation.

Design Process

For the initial design the solar charging station was broken down into four subsystems: solar panel module, charge converter, battery module, and locking mechanism. All subsystems were designed to build by students. The solar panel module consists of 36 solar cells and a diode to prevent the back flow of current. It is made out of a wood frame that will house the cells and a piece of glass is placed on top of it to protect the solar cells from the elements. The solar panel module outputs 18V at 4 amps. The charge converter uses a microcontroller, a DC-DC converter, and voltage sensors to convert the output of the solar panel to be able to charge two 12V batteries. The charge converter uses the voltage sensors to read the output voltage of the solar panel. This information is used by the microcontroller to set the DC-DC converter. Solar panels due not always output the same voltage, so to maximize the efficiency of the solar panel it is implement this type of converter, also known as a maximum power point tracking converter. The battery module is composed of two relays, voltage sensors, two 12V batteries, a DC-DC converter, and a filter. The function of the battery module is store the energy created by the solar panel and convert it so it can power the internal devices in the charging station and charge cell phones. The relays are controlled using a signal generated by the microcontroller in the charge converter. These relays control which of the two batteries is being charged. The voltage sensors measure the charge level of the battery and send that information back to the microcontroller. The DC-DC converter is used to convert the 12V from the battery to 5V to power all the microcontrollers in the system. The filter is used to smooth out the 12V signal for charging cell phones. Lastly, the locking mechanism uses a keypad, microcontroller, ultra-sonic sensors, and a stepper motor to open and close the boxes that store cell phones. The keypad is used to enter a code. The microcontroller is used to store the code, to accept or reject codes that are entered, and to actuate the motor. The ultra-sonic sensor is used to determine whether lock box is open or closed and the stepper motor is used to open and close the lock box.

Level zero through level two functional decompositions were completed for this initial design. After further research and thought a revised design was created. For the revised design the solar charging station was broken down into six subsystems: solar panel module, charge converter, battery module, locking mechanism, and LED driver. All the modules remained the same expect the battery module was now broken down into two different modules (battery module and charge converter) for clarity and ease of building. Additionally, an AC-DC inverter was added to the converter module to allow the solar charging station to provide both 12 VDC and 110 VAC. The LED driver module was added due to increased complexities in the locking mechanism that were discovered during the initial design stage. The LED driver module includes the LEDs to display the real-time charge level of the batteries and a seven-segment display to display codes generated by the locking mechanism. The functional decompositions were revised to include all changes.

Once the functional decompositions were completed, a Gantt chart was created to ensure that the project will be completed on time. The Gantt chart is broken into six sections, corresponding to each of the subsystems, and includes the relevant tasks and milestones for that subsystem. Additionally, there is an extra section of Gantt chart that is for building the exterior housing and placing all of the subsystems inside of it. After the Gantt chart was completed a paper design was created for the solar panel module. This design included the frame dimensions and also the solar cell arrangement. Additionally, basic circuit designs were created for the five other modules. Once a there was a basic layout for each subsystem, a test plan was created. The test plan contains the test name, the necessary test conditions, the expected outcomes, and a description of the test. For the test plan each module has to have measurable inputs and outputs. This proved relatively easy for most modules, except the solar panel module, as the panel itself does not measure solar energy it receives. To be able to measure the sunlight coming into the solar panel, a light sensor was purchased and a small circuit was built using this sensor and a microcontroller. After completing the test plan, the functional decomposition was revised again to account for unseen complexities that arose during the creation of the test plan.

Implementation

For implementation, the six subsystems were divided among the two students. Kaitlyn is responsible for building the solar panel module, battery module and the converter module, while Stephen is responsible for building the charge converter module and the locking mechanism.

Both students are responsible for creating the LED driver module and building the final housing for the entire system.

So far for Kaitlyn's part, the solar panel frame has been completed. This frame was built out of plywood and then painted with outdoor deck paint to protect it from both UV rays and precipitation. Next, a waterproof silicone sealant was applied to all junctions between the wood to ensure that no water will penetrate the interior of the frame. Additionally, all of the solar cells have been soldered together. The solar cells were soldered in an arrangement of three columns, each consisting of twelve rows. All that is left is to purchase a piece of glass and seal it on the frame. Once this is completed, the battery module and converter module will be worked on at the same time and completed by the end of February. Both the battery module and converter module require voltage sensors, which will be built using operational amplifiers and these reading will be sent to a microcontroller. The battery module requires a simple relay circuit to control which will control which of the two batteries is being charged.

Stephen has completed the charge converter design and is currently testing the individual components before combining the entire subsystem. After the converter module is completed he will program and test the locking mechanism. These subsystems will be completed by the end of February. In the beginning of March, the LED driver will be built by both students. After this is complete, the remainder of the month of March will be used to testing the subsystems according to the test plan and integrating. This leaves the students with one extra month, in case any major issues occur.

Student Learning

While designing the project, the students were tasked with creating functional decompositions, a Gantt chart, a test plan, and doing FMEA (failure mode and effects analysis). These are all part of the process of creating a real product in industry, so it is excellent experience to be able to understand and have. The students started with an initial design that was updated at least three times. Each time the students were able to foresee potential problems within their design and revamp it to make their system more robust.

Another important learning experience that was gained from this project is the importance of documentation. Each step of the way the design was updated. With updating the design all other documentation had to be updated to match it. Furthermore, the students had to create a final report, which contain a summary of all the documentation that was done along the way as well as explanation for why components were chosen or why the subsystems were designed a certain way. Along with formal writing experience the students were able to gain a significant amount of presentation experience. Furthermore, both students were able to further their knowledge of building circuits and programming microcontrollers.

Conclusion

To allow community member and students access to renewable energy, two students at Gannon University have designed a solar charging station as their senior design project. Before implementing the project, the students did extensive design work. They decided to break the solar charging station into six subsystems for clarity in their design. A level 0 through level 2 functional decomposition was created and revised multiple times for the project. A Gantt chart was created for project management purposes. A test plan was created for comprehensive testing and successful integration. After the design process was completed, implementation began. It is still early in the implementation phase, but already the solar panel module is nearly complete and the circuits for the remaining modules have been designed and are being tested. This project provided a great look into the complexities of creating a real, working, safe product. The students were able to gain experience documenting their design, writing formal reports, giving presentations, programming microcontrollers, building circuits, and constructing frames.

Kaitlyn Babiarz

Kaitlyn is an electrical engineering student at Gannon University in Erie, Pennsylvania from Alpharetta, GA.

Stephen Karpinsky

Stephen is an electrical engineering student at Gannon University in Erie, Pennsylvania from North Versailles, Pennsylvania