ASEE 2014 Zone I Conference, April 3-5, 2014, University of Bridgeport, Bridgpeort, CT, USA.

Solar Powered Charging Station

Kondracki, Ryan; Collins, Courtney; Habbab, Khalid

Faculty Advisor: Bijan Karimi, Ph.D.
Department of Electrical and Computer Engineering and Computer Sciences
University of New Haven
West Haven, CT

***Abstract* — A solar powered charging station is designed so that devices can be charged outdoors and in an environmentally friendly way. This system converts solar energy to electricity and stores it in a battery bank. A microcontroller prevents the batteries from being overcharged and prevents the system from being used when the batteries need charging.**

Keywords— solar energy, charging station, mobile devices

I. INTRODUCTION

In the past couple of years, advancements in technology put devices in our pockets that we could not have even dreamed of years ago. However, these devices often have drawbacks. One of the most pressing issues with phones, tablets, and laptop PCs is power. We have not yet been able to develop efficient energy sources to match the efficiency of our devices. In fact, many laptops can drain a standard battery from a full charge in a matter of a couple hours. This team is proposing a solution that will provide power to charge devices using power generated from solar energy.

II. PURPOSE

Solar energy is a technology that has been increasing in popularity as it is further developed. Improvements in the panels and coatings as well as solar tracking have made solar energy more efficient. In this project, we will be utilizing solar energy to provide the supply for an outdoor charging station for devices.

This project will further efforts to reduce our dependence on fossil fuels as a means to generate electricity. If our system can charge several devices without having external power from the national grid, it will be able to reduce some of the demand for energy resulting in less fuel used to generate the electricity over time. Solar energy continues to be researched and improved as an alternative source of energy. This project will aid global research efforts in helping protect our environment. Many are becoming aware of the effects of using oil and natural gas as a form of energy. These methods do create plenty of energy, however they are non-renewable and can cause harm to the Earth's atmosphere and ecosystems.

The objective of this project is to investigate the problem of providing an outdoor power source for charging devices in an environmentally friendly way to help reduce the demand of power from other methods. Our objective for this project will not only be to generate power from solar energy, but to also conduct research to improve the efficiency of solar panels. We will have to not only create this device but to optimize the project for sale as to create a cost-effective, economically friendly outdoor charging station for most electrical devices.

Research on other existing solar stations and patents was conducted by the team. From research of the existing designs, we found several points that can be improved. Three key areas that we saw were cost, efficiency, and complexity. Many will say the goal of electrical engineering is to design a cost-effective, efficient, and easy to use device or product.

Patent #8,497,656 configures stationary solar panels in an "umbrella" formation atop a stand attached to a table [1]. We saw this idea as an ingenious use of a product that will not only generate solar energy, but shade users from the harmful effects of sunlight. The only downfall is the panels are stationary and smaller, which may result in less energy produced. Several examples of other solar charging station project, such as the University of Texas [2] and University of Fairfax (Virginia) [3], incorporated student design input, but ultimately were manufactured by solar companies and cost tens of thousands of dollars. This was another point we saw needed to be improved, so that the average homeowner would be able to own one of these devices. New York City implemented solar cell phone charging station prototypes in area parks [4]. These charging stations were very ingenious as they claim to be able to charge multiple handheld devices at a time. Many Americans, especially those in New York City, use their cell phones or tablets a lot. However, cost of production of these charging stations was also costly as well as aimed solely for use with hand-held devices.

III. DESIGN CONTRAINTS

This project will be required to take energy from the sun generated by solar panels and convert the energy to AC voltage, which will be able to power most electronic devices. The project must have a system to keep track of voltage levels and be able to protect the system from being overused or overcharged. It must also be able to keep track of its solar efficiency and be able to maintain the maximum amount of solar energy possible with the given environmental and weather conditions.

The biggest constraint to this project will be to maximize the solar efficiency to provide the most power to the system that can be generated by the solar panels. Weather and solar patterns must be accounted for when making all of the calculations for the efficiency and output of the solar panels. Climate factors, such as clouds, moisture, haze, dust, and smog will have a degrading effect on the output power of the station's panel array.

Obtaining the greatest amount of sunlight throughout the day needs to be for optimum output. Different enhancements to the solar panels such as adding solar concentrators or a solar tracking device may be necessary adding to the cost. Research on these devices is currently being done so that we may incorporate them into the final product while we test the smaller components of the charging station.

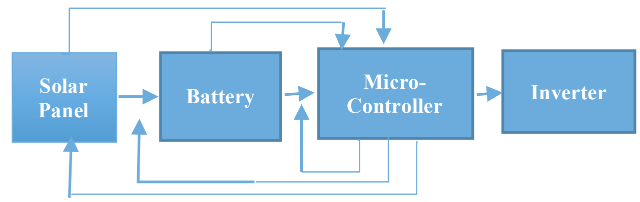
Another constraint is to ensure the efficiency of the battery system which will be used to store the energy from the solar panels. Measures must be taken to prevent damaging the batteries by over charging them. Deep cycle batteries will be used since they are able to handle charging and discharging very well.

Ensuring proper safety regulations are met is another constraint dependent upon the electrical design, but more importantly is the overall structure of the station. Building and safety codes must be researched and implemented. A stand - alone structure poses significantly less risk regarding fire safety when proper precautions are taken during site preparation. We have not yet conducted research into the structure of the system, but upon the successful testing of the electronics, this will be a major focus of the final product. Not only do we want a successful product, but we want to make sure it is ethical and is safe for all.

IV. SYSTEM DESIGN

From research on similar models and our knowledge from previous courses, we determined that this project would need to follow the example of any electrical system. It must have a source, a function, and an output. For our source, we will be using solar panels optimized with solar tracking. The system will contain the microcontroller to act as a charge controller and an inverter to convert from 12 Volt DC stored in the batteries to 110 Volt AC as the output. Figure 1 below shows a block diagram of the system. The solar tracker would be affixed to the solar panel and would relay information to the microcontroller. The microcontroller would then send a signal to the stepper motor to adjust the angle of the solar panels. The microcontroller would also read the battery level and determine if the battery needs to be stopped from charging or stopped from being utilized, if it has been fully used.

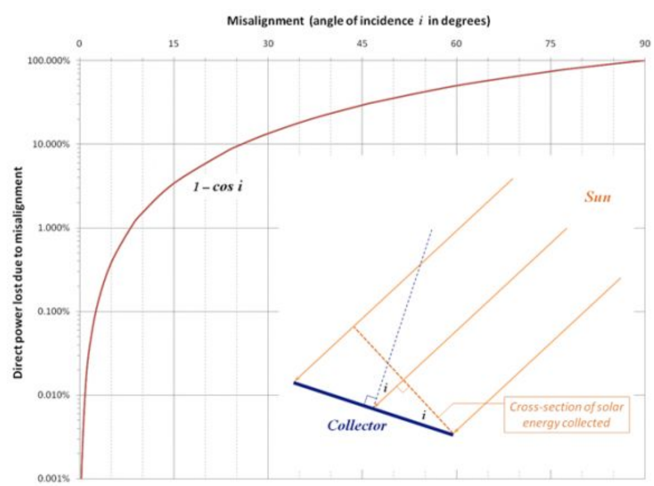
Fig. 1. Block Diagram of Circuit



A. Solar Panel Technology

A solar panel is a group of electrically connected photovoltaic cells made of semiconductor materials, such as silicon, which is currently most common. When sunlight hits the cells, its energy is absorbed into the semiconductor material. This energy pushes other electrons loose that are then forced to flow in a certain direction by an electric field created in within the cells. This is the current for which is then drawn off of the panels by metal contacts on the top and bottom of the panels. The amount of current a PV panel produces has a direct correlation with the intensity of light the panel is absorbing [5]. Figure 2 below shows a chart demonstrating the percentage lost based on the angle of incidence with the sun. Optimal conditions for a solar panel are at 0º, or directly perpendicular to the sun's rays. Whereas the least optimal at 90º, which is parallel with the sun's rays.

Fig. 2



Multiple panels are electrically connected in either series to achieve a desired output voltage and/or in parallel to provide a desired current capability. A single solar cell produces only about 1/2 (.5) of a volt. A typical 12 volt panel about 25 inches by 54 inches will contain 36 cells wired in series to produce about 17 volts peak output. If the solar panel can be configured for 24 volt output, there will be 72 cells, so the two 12 volt groups of 36 each can be wired in series, usually with a jumper, allowing the solar panel to output 24 volts. When under load, charging batteries for example, this voltage drops to 12 to 14 volts for a 12 volt configuration, resulting in 75 to 100 watts for a panel of this size.

The advantage of using a higher voltage output at the solar panel is that smaller wire sizes can be used to transfer the electric power from the solar panel array to the charge controller & batteries. This project was initially calculated utilizing two 12 volt, 100 Watts solar panels. Our decision to utilize two solar panels is being used based on the size of the panels and on the overall cost of the project. The size of each panel is 47 x 1.4 x 21.3 inches. The panels will be connected in parallel to acquire a maximum current. Equations 1, 2, & 3 provide our input current.

Solar panel 1: $I_1 = \frac{100W}{12V} = 8.33A$ (1)

Solar panel 2: $I_2 = \frac{100W}{12V} = 8.33A$ (2)

Total current for solar panels in parallel:

$I = I_1 + I_2 = 8.33 + 8.33 = 16.66A$ (3)

B. Solar Tracker

One solution to the aforementioned constraints is to integrate a solar tracker circuit into the design, which will allow constant alignment towards the Sun and can potentially increase the production of electricity by the solar panels by up to 30% [6]. An increase in output allows for a reduction in panel array size, which helps with overall cost and size of the team's design.

Solar trackers provide a precise tracking of the sun by tilting the solar panels towards the sunlight as it moves throughout the day and as well, the year. When sunlight strikes a solar panel, it comes in at an angle, called the angle of incidence. The normal angle to the cell is perpendicular to a PV cell's face and this normal is necessary to achieve the panel's proper alignment towards the sun. A tracking system can keep the angle of incidence within a certain margin and would be able to maximize the power generated.

A tracker produces more power over a longer time than a stationary array with the same number of modules. This additional output or "gain" can be quantified as a percentage of the output of the stationary array. These percentages will be tabulated after output measurements are taken once the tracker system is built and tested.

Trackers are categorized as either a single axis or dual axis system. Single axis accounts for horizontal east to west daily movement while dual axis integrates a vertical north and south seasonal tilt into the system. Single axis can provide a 15% to 30% increase of efficiency and solar power generated over a stationary panel while dual axis provides an additional 6% [7]. The cost comparison for implementing a dual axis tilt tracker vs. single axis shows that dual axis will not be cost effective for this project because of the complexity and maintenance of the mechanics. Less components, in this case, will mean greater reliability and less down-time for maintenance issues.

The tracking system will consist of 2 front panel LDRs (light dependent resistors), separated by a fixed plate, for tracking throughout the day and one fixed to the back of the solar panel for daily adjustment to its initial position, which is done through a control circuit and bi – directional DC stepper motor attached to a rotating shaft which will orient the panel towards the sun.

The comparison of the intensity of light upon each LDR and the difference between their output voltages will be what determines the orientation of the panel. The LDR's are made of a high resistance semiconductor material. This material absorbs photons from the light and some of their energy is transferred to the electrons. As the electrons break free, they gain sufficient energy to break free from the semiconductor lattice of the LDR and the overall resistance is lowered. This sensing from higher to lower density of sunlight is the driving force in the circuit design. The LDR's will be connected to a voltage divider circuit since any change in light density is proportional to the change in voltage across the LDR's.

One voltage will be higher depending on the higher intensity of light, while the other voltage will be weaker creating a weaker signal. The panel will rotate towards the stronger signal. Power for this design will be taken from the batteries charged by the solar panels, making this a closed loop system [8].

A microcontroller will convert the analog photocell voltage into digital values and provide output channels for motor rotation. A relay controls the rotation of the motor either to rotate clockwise or counterclockwise.

C. Motor

A bi – directional stepper motor has been chosen for this application because of their speed and torque yet low power and current consumption [9]. In order to determine the amount of torque needed, we need to take two details into consideration. First, we must calculate the center of gravity point of the panel, then measure the distance from the pivot point, using the mass of the panels at the center of gravity, to give the torque required for normal operation. The second detail is wind loading. There is also a frictional load situation, because many panel manufacturers prefer to design their equipment so the center of gravity is over the axis, such that the only torque needed is frictional and counters wind loading. So we will need to figure out how much force is needed to break frictional forces as well as wind forces when selecting our motor. The microcontroller will be programmed to run the motor to align the panels when there is a specified degree of misalignment towards the normal, which will save in power consumption

D. Charge Controller

The Charge Controller is a switching device that can connect and disconnect the charger to the battery and it will take control over charging and to stop charging at the correct voltage. This will protect the batteries from damage from over-charging and regulate the power going from the solar panels to the batteries. A microcontroller in the circuit will read the level of the batteries and then cut off the source of the solar panels to the batteries, once it sees the battery is at the fully charged state. If this was not in place, the solar panels would keep feeding the batteries energy and the batteries would become overheated and damage the internal components.

The advantage to have a microcontroller in the system is that it will open a variety of features to add to the system. For example the microcontroller will be programmed to control and display the battery level of the system. It will ensure that there is enough power to charge devices by displaying the gauge on a 7 segment LCD. If there is insufficient power, it will prevent the system from being used until sufficient power has been reached. The microcontroller will also be used in aiding solar efficiency by controlling the solar tracker, as mentioned previously.

E. Battery

The team has selected two deep cycle batteries to power the system. Each battery is a 12V and has a 35 Amp-hour capacity.

Batteries for PV system batteries generally have to discharge a smaller current for a longer period of time, such as at night or during a power outage, while being charged during the day. Deep cycle batteries are designed for the purpose of discharging to a lower capacity, between 50% and 80%, than a conventional battery. The most commonly used deep-cycle batteries are lead-acid batteries and nickel-cadmium batteries, both of which have pros and cons. The deep-cycle batteries are able to be easily charged and discharged many times and can last for several years due to the thicker plate materials utilized.

Batteries in PV systems can also be very dangerous because of the energy they store and the acidic electrolytes they contain, so you'll need a well-ventilated, nonmetallic enclosure for them.

The total power for the batteries can be calculated as follows:

Battery 1: $P_1 = 12V \times 35A = 420Wh$ (4)

Battery 2: $P_2 = 12V \times 35A = 420Wh$ (5)

Total Power for Batteries:

$$P = P_1 + P_2 = 420 + 420 = 840Wh \quad (6)$$

Total Amp-hour for Batteries:

$$35 + 35 = 70Ah \quad (7)$$

Charge time in full sun, zero load:

$$\frac{Total\ Batteries\ Ah}{Total\ Solar\ Panels\ A} = \frac{70}{25} = 2.8hours \quad (8)$$

Discharge time in full sun, full load

$$\frac{Total\ Batteries\ Wh}{Inverter\ W - Solar\ Panels\ W} = \frac{840}{600-300} = 4.2hours \quad (9)$$

Discharge time in no sun, full load:

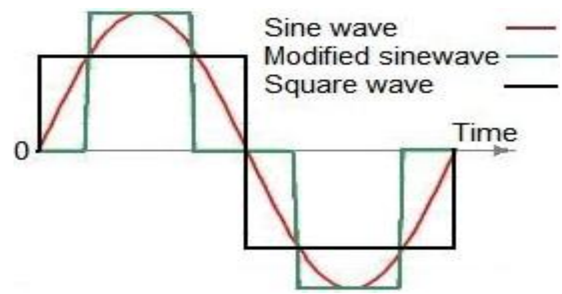
$$\frac{Total\ Batteries\ Wh}{Inverter\ W} = \frac{840}{600} = 1.4hours \quad (10)$$

F. Inverter

An inverter is an integral component in the solar station' design. It will convert the DC voltage generated from the solar panels to an AC voltage. The team will be testing two designs by using special ICs or several pairs of transistors and diodes.

An inverter can produce square wave, modified sine wave, pulsed sine wave, or sine wave depending on circuit design, demonstrated in Figure 2. The two dominant commercialized waveform types of inverters as of 2007 are modified sine wave and sine wave. There are two basic designs for producing household plug-in voltage from a lower-voltage DC source, the first of which uses a switching boost converter to produce a higher-voltage DC and then converts to AC. The second method converts DC to AC at battery level and uses a line-frequency transformer to create the output voltage.

Fig. 3 Sample inverter outputs



Inverter circuits can have a power loss of 10 % or even up to 20%. The team anticipates for a larger power inverted based on our maximum expected output and that the largest output will be required when two laptops are plugged into the system. Generally, laptops can draw anywhere between 65-90 Watts. For two laptops rated at 90 Watts, the inverter will be required to generate 180 Watts. From our calculation, we determined a 200 Watt inverter will suffice. At a 90% efficiency (10% power loss), the inverter will generate the 180 Watts we need.

V. CONCLUSION

This project has budgetary restrictions as an initially presented. Most Senior Design projects use industry sponsored projects as a way to introduce the student to working under real industry guidelines and also for companies to be introduced to the next generation of potential employees. This solar station concept came from students; no industry sponsor was involved in the thought process of the design. Our team has contacted several industry sponsors and is in the works of negotiating a sponsor. Having an industry sponsor gives the students a technical supervisor and collaborator to assist with any research and design issues that may arise in addition to financial support. Eliminating dependence on fossil fuels and limited resources while designing an environmentally friendly, self-sustainable, outdoor energy source is the goal for the solar powered charging station.. The team's research indicated a benefit to the campus for such a structure and also room for improvement on other existing charging stations. The other stations the team found to exist were quite costly to build. As well, rapidly advancing solar innovations and designs could lend themselves to creating a more efficient charging station.

ACKNOWLEDGMENT

Thanks to University of New Haven Professor Bijan Karimi for showing great support, encouragement, and guidance in this project.

REFERENCES

[1] PORTIS JR., M. (2013). UNITED STATES OF AMERICA PATENT NO. 8,497,656.

[2] PULIAS, B. (2013, JULY 2). *NEWS*. RETRIEVED FROM GEORGE MASON UNIVERSITY: HTTP://NEWSDESK.GMU.EDU/2013/07/SOLAR-POWERED-STATION-LETS-YOU-RECHARGE-OUTDOORS/

[3] CALAHAN, R. (2012). UT STUDENTS PUMP UP AT CAMPUS SOLAR STATION. *ALCADE*.

[4] GOAL ZERO. (2013). RETRIEVED FROM STREET CHARGE: HTTP://STREET-CHARGE.COM/

[5] TOOTHMAN, J., & ALDOUS, S. (2000, APRIL). *HOW SOLAR CELLS WORK*. RETRIEVED FROM HOW STUFF WORKS: HTTP://SCIENCE.HOWSTUFFWORKS.COM/ENVIRONMENTAL/ENERGY/SOLAR-CELL.HTM

[6] KIETH, J. (2008). *MAXIMIZING SOLAR PANEL EFFICIENCY AND OUTPUT POWER*. RETRIEVED FROM ELECTRO SCHEMATICS: HTTP://WWW.ELECTROSCHEMATICS.COM/8280/MAXIMIZING-SOLAR-PANEL-EFFICIENCY-AND-OUTPUT-POWER/

[7] WIKIMEDIA FOUNDATION, INC. (2014, FEBRUARY 7). *SOLAR TRACKER*. RETRIEVED FROM HTTP://EN.WIKIPEDIA.ORG/WIKI/SOLAR_TRACKER#DUAL_AXIS_TRACKERS

[8] ZUBAIR, S. (2011, AUGUST 10). *DESIGN AND CONSTRUCTION OF A MICROCONTROLLER-BASED SOLAR TRACKER*. RETRIEVED FROM ACADEMIA: HTTP://WWW.ACADEMIA.EDU/970786/DESIGN_AND_CONSTRUCTION_OF_A_MICROCONTROLLER_BASED_SINGLE_AXIS_SOLAR_TRACKER.._INNOVATIONS_IN_SCIENCE_AND_ENGINEERING_.1_4_41-47

[9] MOTION DRIVETRONICS . (N.D.). *GEARED MOTORS FOR SOLAR TRACKING*. RETRIEVED FROM MECH - TEX: HTTP://WWW.MECHTEX.COM/PDF/NEW%20PRODUCTS/GEAREDMOTORSFORSOLARTRACKING.PDF