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Design of a Solar Tracking System for Renewable Energy

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Abstract—**In this paper, a solar tracking system for renewable energy is designed and built to collect free energy from the sun, store it in the battery, and convert this energy to alternating current (AC). This makes the energy usable in standard-sized homes as a supplemental source of power or as an independent power source. The system is designed to respond to its environment in the shortest amount of time. Any source of error at both the software and the hardware level is eliminated, or at least controlled. The system is tested for real-time responsiveness, reliability, stability, and safety.**

The system is designed to be stable while it is operating. It is also designed to be resistant to weather, temperature and minor mechanical stresses. Furthermore, the system is fail-safe; it can recover from failures or at least indicate that it is in that condition.

Index Terms—**Solar tracking system, renewable energy, power inverter, integrated liquid-crystal display (LCD) unit.**

I. INTRODUCTION

In the United States, the top three energy sources of electricity are coal at 37%, natural gas at 30%, and nuclear at 19% [1]. These forms of energy are nonrenewable meaning they will eventually be depleted. For this reason it is important to seek renewable sources of energy for they are cleaner, easier to use, require less maintenance, and will always be available. This project focuses on solar energy, which is a renewable form of energy. On average the earth surface receives about 600 W/m^2 of solar energy [2]. This value depends on several factors such as the time of the day and the atmospheric conditions. In 2012, only 0.11% of solar energy was used to generate electricity [1]. It is estimated that solar energy will become the largest source of electricity by the year 2050 [2]. For this reason there should be a larger investment in harnessing solar energy.

People who live in secluded areas have limited access to efficient power because it is unavailable or too expensive. Also, with the rising cost of fossil fuel most people who live in standard-sized homes are interested in finding alternative energy sources to reduce domestic electricity cost. Solar energy is an abundant source of renewable energy which makes it a good solution for people living under these circumstances. In a single day, the amount of sunlight hitting the United States is more than 2,500 times the entire country's daily energy usage [3]. The most efficient solar panels of today's technology harness less than 20% of available solar energy [4]. Although this is a small percentage, it is a helpful amount of energy that may one day allow for independence from nonrenewable forms of energy.

This paper provides the description of a senior design student project including the goal of the project and the design specifications. Feasibility and merit criteria detailing the critical and desired attributes of the design are included. All designs are revealed via engineering sketches, drawings, discussion and engineering analysis to predict the performance of the designs in relation to the specifications. Conclusions consisting of the best design, the recommendations, and the costs of the prototypes are also presented and discussed.

II. PROJECT DESCRIPTION

The system's main purpose is to efficiently harness solar energy and convert the energy in a useful form for common domestic appliances and devices. The system responds to its environment in the shortest possible amount of time since it is designed as a real-time system. It is able to make decisions to increase its efficiency and to ensure its safety; it always be aimed at a position to maximize the irradiance and limit the battery charge/voltage to the indicated values. The system is fully autonomous; however, the user could monitor critical real-time information about the system on an integrated LCD unit.

The mechanical structure of the system is able to resist winds, storms or severe temperature. The electronic components are grounded and shielded to resist lightning and reduce electromagnetic interference. This project also provides a green solution of non-polluting energy sources. Some basic market analysis was performed to ensure that the product is relevant to real world needs. Observing the significant negative impact on the atmosphere caused by traditional energy sources, it has been recognized that there is an urgent need for cleaner energy. Moreover, the National Renewable Energy Lab (NREL) predicts that with the rising cost of traditional electricity sources and the falling price of photovoltaic panel, it will be cost effective to invest into solar panels in the years to come [5]. There are already numerous intelligent solar energy systems now available on the market, but the design team of this project is striving to offer the

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market an affordable and efficient solution. Hence, an autonomous semi-portable solar power system is constructed to supply power to a standard-sized home or remote areas. It is intended to serve as a supplemental power supply for home usage or a stand-alone power supply in remote areas. The key aspects of this product are that it is affordable, efficient, stand-alone, relatively easy to transport, and ready to use.

III. DESIGN SPECIFICATIONS

The solar energy system designed and developed includes a solar panel, a battery, and an inverter. The solar panel is designed with a tracking mechanism that directs the panel towards the area of high sunlight intensity. It also has a method of concentrating the sunlight onto the photoreceptors on the solar panel. All of these maximize the amount of solar energy collected from the sun within a specific timeframe; thus, increasing the efficiency of the solar panel in absorbing solar energy by at least 15%. Furthermore, a battery is connected to the solar panel to fully charge it in 8 hours. The system has an inverter to convert the 12 VDC from the battery to 120 VAC, 60 Hz. The inverter outputs at least 300 Watts which is enough to power electrical gadgets such as a laptop or a standard television. Lastly, the design has a method of collecting, processing, and displaying data such as voltage and charging status on an LCD monitor. The entire system weighs less than 100 lbs and is semi-portable.

IV. DESIGN CRITERIA

A. *Feasibility Criteria*

The purpose of the criteria is to narrow down possible solutions to one that fulfills the main goal of the project; which is, to design a semi-portable real-time solar energy system which can absorb solar energy from the sun, store it in a battery, and convert this energy to a useful form that can be used to power electronic gadgets. To be feasible, the design for the solar energy system should:

- Be possible to assemble: The design for the solar energy system must not be complex to construct. It must be realistic and something that can be assembled.
- Weigh less than 100 lbs: The system must be semi-portable so that it can be easily moved from one place to another since it is also meant to serve as a stand-alone source of power in remote areas. The weight is therefore a factor that must be considered. The entire system must therefore collectively weigh less than 100 lbs.
- Harness energy from the sun and use it to charge a battery in less than eight hours: The system must be able to absorb the sun's energy and use this energy to charge a battery. The battery must charge in no more than eight hours.
- Have a concentration method that yields at least 15% increase in efficiency than normal solar energy systems: The system must be able to concentrate the sun's energy it collects on the solar panel. The concentrating method used should increase the solar panel efficiency and allow it to maximize the total energy it collects.
- Have an efficient tracking system: The system must be able to track the sun in order to absorb the highest amount of solar energy possible. It must allow movement in at least two directions.
- Convert the energy stored in the battery to 120 VAC, 60Hz: The system must be able to convert the energy that is collected and stored in the battery to 120 VAC, 60 Hz. This is the form of energy used in homes in the United States and the output voltage needed to power American appliances.
- Collect, process and display real-time data of the system on an LCD screen: The system must also be able to collect real-time data from the system, process it, and display this data on an LCD screen.

B. *Merit Criteria*

A merit criterion was developed to compare the various feasible design alternatives for this system. This criterion is necessary because it exhibits the strengths and weaknesses of each design in terms of properties critical to the success of the project. The following information explains the merit criteria used to analyze and select the best design.

- Concentration: Standard conventional solar panels have a conversion rate of only 15% to 16% of power output efficiency [6]. The chosen panel, Kyocera KD135GX-LPU, loses between 10% and 30%, depending on the selected site location [7]. To compensate for the range of efficiency loss, this panel can be equipped with mirrors and/or a lens. Providing any form of concentration will increase the power output efficiency; however, the chosen method should achieve at least between 15% to 20% increase in power output efficiency, as well as maintain the budget, aesthetics, and portability. A merit matrix analysis (scale 0-10) was developed for the different concentrating methods. The different methods evaluated are Reflectors, Parabolic mirrors, and Fresnel lens (Fig. 1).
- Angular Movement: In order to achieve the project goal of efficiently harnessing solar energy, the panels must track the sun's movement throughout the day, along the azimuth, and throughout the season change, along the zenith (altitude). The motors and/or linear actuators used must be able to rotate and move the panel at the proper angle for the azimuth and zenith to be that of the sun, on a daily basis and as the season changes. After gathering a range of degrees of the sunrise and sunset at different latitudes, it was averaged that the azimuth and zenith to range from 0 to 45 degrees [8]. The angular movement of the system was weighed at 40% because it is the most important factor surrounding the goals of this project.
- Performance – Low Power Consumption: The performance of this system is strictly based on power consumption. It is weighted at the second highest, 30%. Not only does the system collect energy from the sun, but it is also powered by the same energy stored in the battery. Thus, the amount of power each design consumes is an important factor when selecting the best design.

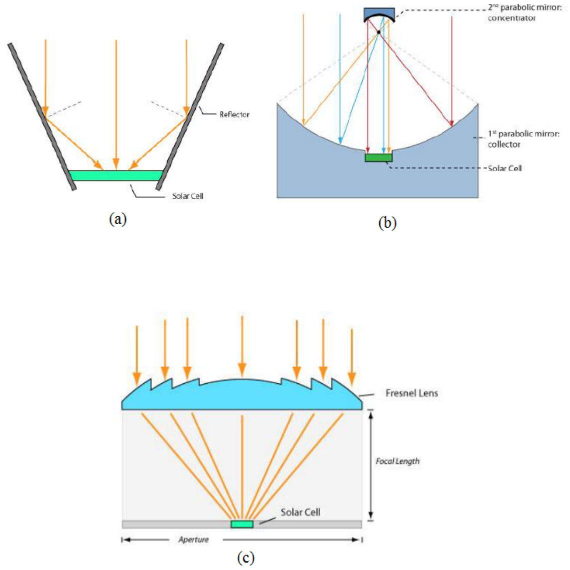

Fig. 1. Concentration Methods: (a) Reflectors; (b) Parabolic mirrors; and (c) Fresnel lens (Courtesy of: www.greenrhinoengery.com).

- Low Assembly/Installation Cost: A substantial amount of resources were provided. The assembly cost was strictly based on how much it would cost to purchase the motors required for each design and it is weighted at 15%.
- Aesthetics: It is based simply on the appeal of the system and is also geared towards the marketing aspects of this project. The system appealed to future consumers and met the cost and portability specifications. It is weighted at 15%.

V. ENGINEERING DESIGN AND ANALYSIS

Feasibility Analysis

The student team initially came up with six designs. Using the feasibility criteria listed earlier, a feasibility analysis was conducted to determine whether each of the suggested design alternatives were feasible. Only three designs were found to be feasible and those are presented in this paper. Each of the three design alternatives requires a fair amount of work to assemble. They each have tracking mechanisms to track the sun as well as the ability to harness energy from the sun and use it to charge a battery in less than eight hours. The three design alternative can also convert the voltage from the battery to 120 VAC to power electronic devices. Lastly, each design is semi-portable and able to collect, process, and display data on an LCD monitor.

Merit Analysis and Final Design Selection

A. Concentration Merit Matrix

Concentration methods have been designed to increase the efficiency lost in solar panels. Table I shows the different concentration methods and their merit values based upon each criterion in question. The analysis is based on a scale 0-10, with a score assigned for each category. The concentration method should cost less than $150. The method that costs less would have the highest rating in the cost category: Reflectors – cost $126 (merit factor 8); Parabolic mirrors – cost $130 (merit factor 8); and Fresnel lens – cost $139 (merit factor 6). The method that was lightweight would have the highest rating in the lightweight category: Reflectors – weight 21 lbs for 5 pieces (merit factor 7); Parabolic mirrors – 20 lbs/piece (merit factor 6); and Fresnel lens – 8 lbs for 12 pieces (merit factor 10). The method that was the easiest to assemble would have the highest rating in the assemble difficulty category. The student team decided that the Fresnel lens is easier to assemble and it is also more convenient for aesthetics of the designs. Voting on a scale from 1 to 10, the average score received are: Reflectors 5, Parabolic mirrors 3, and Fresnel lens 7.

TABLE I
CONCENTRATION MERIT MATRIX

	Cost	Weight	Assembly	Total
Reflectors	8	7	5	20
Parabolic Mirrors	8	6	3	17
Fresnel Lens	6	10	7	23

It is seen from Table I that the best concentration method is the Fresnel lens, which scored 23 out of 30. The Reflectors is the next best method with a score of 20 out of 30 and the worst method with a score of 17 out of 30 is the Parabolic mirrors.

B. System Design Merit Analysis

The following merit analysis was performed on the final three designs (Table II). The merit criteria discussed in section IV were used to select the best design: *Angular Movement* **-** In order to track the sun and obtain the maximum efficiency from the solar panel, the length at which the linear actuators extend and retract must achieve the proper angle of the panel. The panel must track the sun as it move across the sky, which is approximately 180 degrees east to west. Each linear actuator and/or DC motor required for each design should achieve the required lengths. Thus, they all received a merit factor of 10. *Performance* **-** Design II requires more power because the PDX16 Gear motor it uses rotates the entire base that the panel and linear actuator rest upon, which includes the weight of the panel with attached lens, the linear actuator, and the mechanical structure. The total weight resting upon the motor would cause it to have to work more, thus drawing more current and power from the 12 VDC battery (merit factor 1). Design III uses two actuators wastes power because one actuator cannot move without the other moving, which is not necessary and should be avoided if possible (merit factor 5). However, Design I power consumption is negligible because in this design majority of the solar panel weight rest up the zenith actuator, which only moves based on the season change. Therefore, the load on the azimuth actuator is much less, thus requiring less current drawn from 12 VDC battery to operate on a 12 hour tracking basis (merit factor 10). *Low Assembly Cost* **-** Maximum amount to spend for the motors is restricted to $300. Hence, Designs I and III received merit factor of 10 and the Design II received the merit factor of 0 (cost of motors > $300) on motors. The cost factor depends solely on that amount required to assemble this system. *Aesthetics* **-** On a scale from 1 to 10, each member of the student team voted on aesthetics of each design. Designs I and II received an average score of 8 and Design III received 6.

TABLE II
SYSTEM DESIGN MERIT ANALYSIS

Design I:				
	Weight	Characteristics	Merit Factor	Total Merit
Performance (Power Consumption)	30	Negligible	10	300
Assembly Cost	15	$277.98	10	150
Aesthetics	15	Appealing	8	120
Angular Movement	40	Achievable (two 24” actuators)	10	400
Total	**100**			**970**
Design II:				
Performance (Power Consumption)	30	Waste of Power	1	30
Assembly Cost	15	$339.98	0	0
Aesthetics	15	Appealing	8	120
Angular Movement	40	Achievable (40” actuators)	10	400
Total	**100**			**550**
Design III:				
Performance (Power Consumption)	30	Negligible	5	150
Assembly Cost	15	$223.98	10	150
Aesthetics	15	Appealing	6	90
Angular Movement	40	Achievable (24” actuator and DC motor)	10	400
Total	**100**			**790**

According to the merit analysis (Table II), design I is the best option for the system. Design I scored a 970 overall in merit analysis. The second best design is design III, which scored 790, and the third best design, design II scored 550.

VI. MECHANICAL STRUCTURE DESIGN

The CAD drawings in Fig. 2 provide a 3D view of the final design.

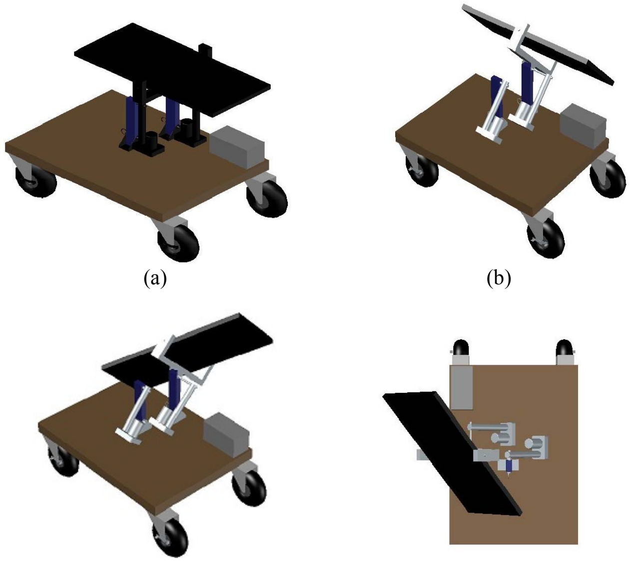
(a) (b)
(c) (d)

Fig. 2. (a) The system view; (b) Azimuth angle at 45 degrees; (c) Azimuth angle at 45 degrees and Zenith angle at 45 degrees; and (d) Top view - Azimuth angle at 45 degrees and Zenith angle at 45 degrees.

VII. ELECTRONICS AND HARDWARE DESIGN

This section describes the entire electronics and hardware components that are part of the system and how they are interfaced.

A. *Inverter*

The power inverter, commonly called inverter, is an electronic device or circuit that converts direct current (DC) to alternating current (AC). Inverters have many applications in the electronics industry due to this ability. In this project, it is needed to convert the power coming from the solar battery into an AC form which is needed to power electrical devices. The inverter does not produce any power. The power it outputs is provided by current supplied by the battery which serves as a DC power source. An inverter can produce a square wave, a modified sine wave, a pulsed sine wave or a sine wave as an output depending on the circuit. In this case, a true sine wave is desirable since most electronic devices are programmed to function on. Inverters can be self-designed or bought as ready-to-use manufactured device.

The PSPICE schematics in Fig. 3 were developed for the inverter which would be converting the 12 VDC from the battery to 120 VAC to power electric appliances.

The Wattage produced by the inverter depends on which transistors are used for Q1 and Q2 as well as the current produced by the transformer, T1. With Q1, Q2 = 2N3055 and T1 = 15A, an output power of 300 W is obtained. More power requires larger transformers and more powerful transistors. The 2N3055 transistor can only handle 15 A. 68 µF, 25 V Tantalum capacitors were used in this inverter circuit because regular electrolytic will overheat and explode. HEP Silicon diodes were used as the diodes in this circuit while the transformer was a 24V center-tapped transformer. Finally, since this inverter produces 120 VAC, it was built in a case with a fuse included. An outlet was then provided to serve as a connection for the electronic appliances. This circuit can be modified to produce an output of 220/240 VAC instead of 120 VAC by replacing the transformer with one that has a 220/240 V primary. The rest of the circuit stays the same but it takes twice the current at 12 V to produce 240 V as it does 120 V.

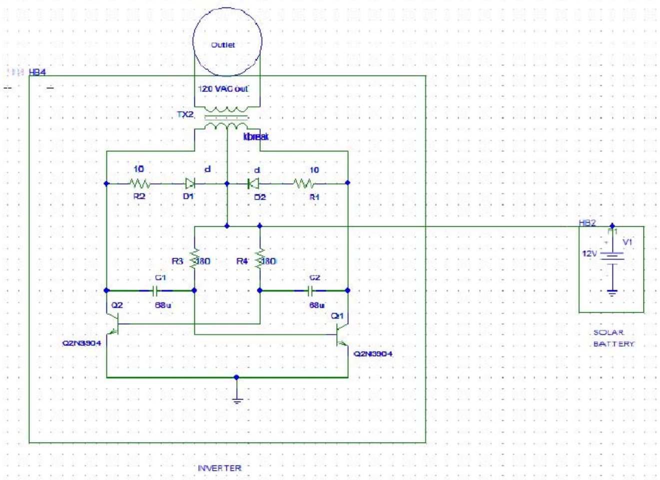

Fig. 3. The inverter PSPICE schematics.

The following equations and calculations were utilized to assist in coming up with the inverter design.

$$\text{Turns ratio of transformer} = (N2/N1)$$

$$V2 = V1*(N2/N1)$$

$$\Rightarrow (N2/N1) = V2/V1 \quad (1)$$

$$\Rightarrow (N2/N1) = 120V/12V = 10$$

Also, for current,

$$I1 = I2*(N2/N1) \quad (2)$$

B. *Arduino Uno*

The Arduino Uno (Fig. 4) is one of the most popular microcontrollers. It is open source, and is widely used among hobbyist and professionals for diverse applications. It was used in this design because it is cheap and performs well, and the team members are very proficient with it. While the Arduino Uno has 6 analog pins and only 12 usable digital pins, the design requires at least 20 digital pins. Nevertheless, it still needs to be used because it is very well suited for real-time applications. The Arduino Uno supports a large variety of sensors, actuators, and motors; moreover, there are many of those devices that are custom made for the Arduino Uno. Two of these microcontrollers were used to satisfy all of this project's requirements.

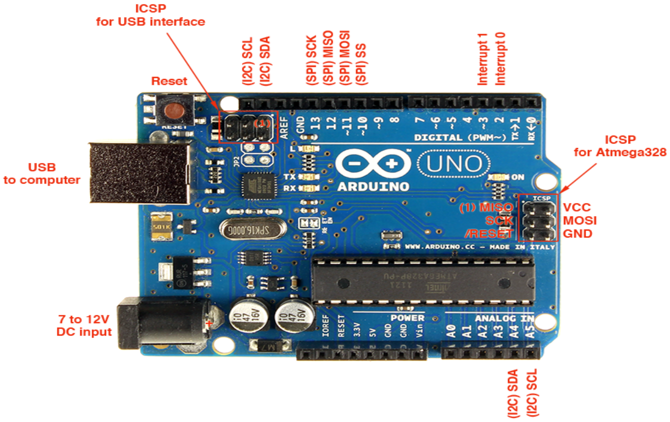

Fig. 4. Arduino Uno [Courtesy of Nick Gammon: www.gammon.com.au].

C. *Solar Panel*

The high efficiency multi-crystal, Kyocera KD135GX-LPU photovoltaic module (Fig. 5a) was used. It is 59.06" by 26.30" by 1.8". It has cell irradiance of 1000/m^2 at 25^{o} C, an open circuit voltage of 22.1 V, and a short circuit current of 8.67 A. Figs. 5b and 5c show the current voltage characteristics of the panel at various cell temperatures and at various irradiance levels respectively.

D. *Battery*

The DEKA 8G34 photovoltaic battery (Fig. 6) used in this design has a nominal voltage of 12 V and capacity of 70 Ah. It can operate between -60^{o} C and 60^{o} C.

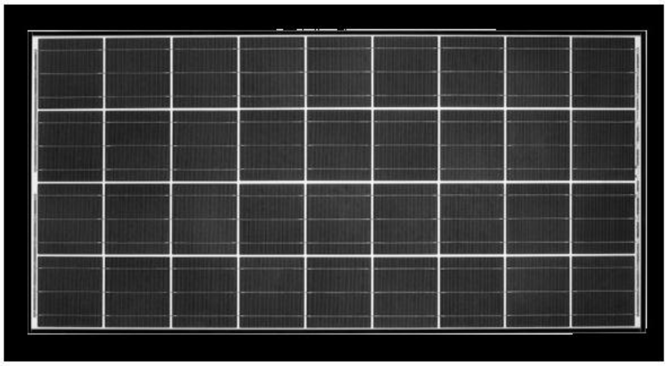

Fig. 5a. The Kyocera KD135GX-LPU PV module [Courtesy of manufacturer].

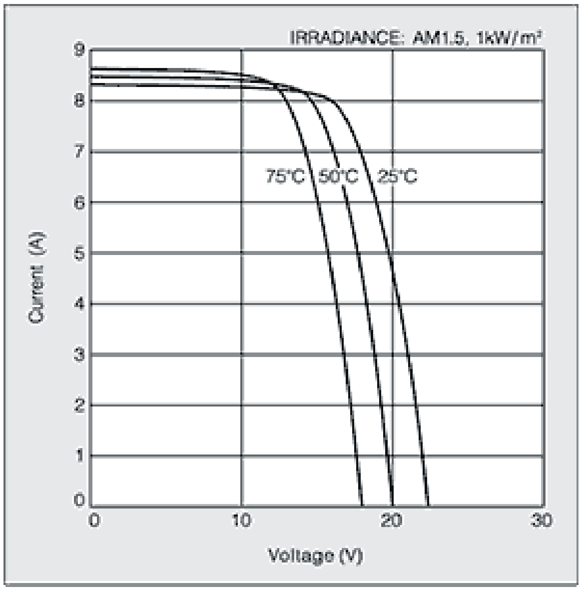

Fig. 5b. Current-Voltage characteristics of PV module KD 135GX-LPU at various cell temperatures [Courtesy of: www.wholesalesolar.com].

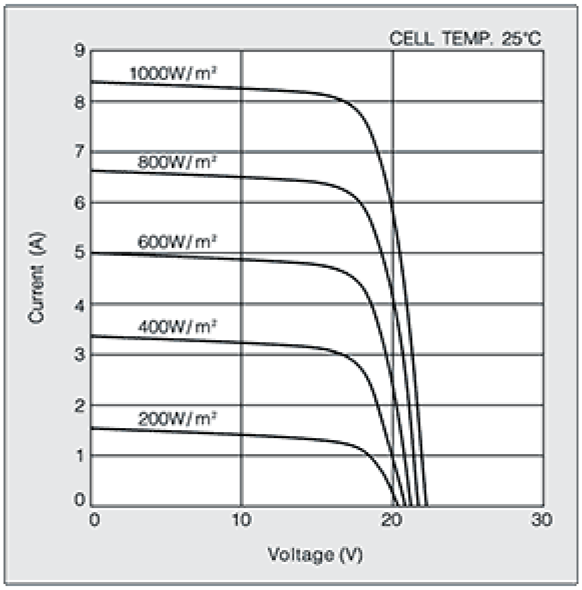

Fig. 5c. Current-Voltage characteristics of PV module KD 135GX-LPU at various irradiance levels [Courtesy of: www.wholesalesolar.com].

Fig. 6. The DEKA 8G34 PV Battery [Courtesy of: www.ecodirect.com].

E. Linear Actuators

The following system requirements are needed for the linear actuators (Fig. 7):

- Be able to apply a force to move 28lbs for East to West tracking and 40lbs for north to south tracking.
- Have the calculated minimum required stroke length of 22" to allow the solar panel to rotate 45 degrees east to west.
- Have the calculated minimum required stroke length of 18" to allow the solar panel to rotate 45 degrees north to south.
- Have a built in potentiometer for position feedback to know the current extended length so that the actuators are not commanded to extend or compress beyond their limits.
- Low Cost

Fig. 7. Linear Actuator w/Potentiometer (Stroke Size 24", Force 150 lbs., Speed 0.40"/sec) [Courtesy of: www.progressiveautomations.com].

There are 5 wires for the linear actuators with a built in potentiometer (Fig. 8). The first two wires are to supply power to the linear actuator; one for positive voltage and the other for ground. The polarity of the voltage supplied effects if the actuator extends or compresses. For this reason polarity switching is necessary. This can be accomplished by using a motor controller that can allow for bidirectional control of a DC motor hence switching the voltage polarity.

The next three wires are for the built in potentiometers in the linear actuators. They are a 5V input voltage (yellow), the ground for that voltage (white), and an output signal wire (blue). The analog output of the potentiometer was connected to analog input of Arduino. The signal wire outputs an analog value that indicates the linear actuators current position.

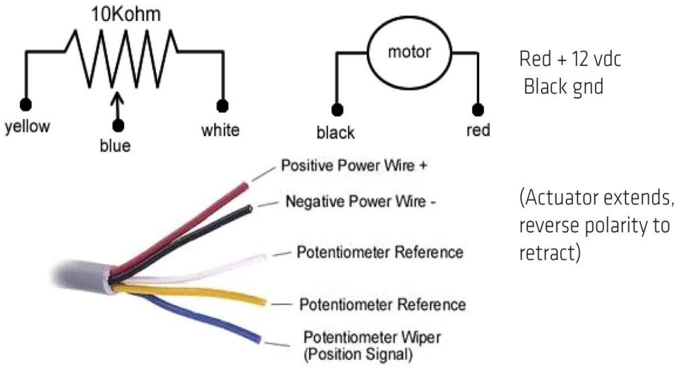

Fig. 8. Linear Actuator Wires [Courtesy of: www.progressiveautomations.com)].

F. Motor Controller

The Pololu Dual VNH5019 Motor Shield (Fig. 9) was used because it met the following requirements:

- Could control more than one linear actuator, since two were used.
- Can handle voltages well beyond the 14V that was supplied. This is done because if even for an instant the battery supplies a voltage more than the controller can handle it will do harm to the circuits.
- Can handle current well over the maximum current motors is intended to experience. For the preferred design, using two 24" linear actuators the maximum current those actuators will experience under full load is 5A. The motor controller must support well over 5A of continuous current.
- Low cost.

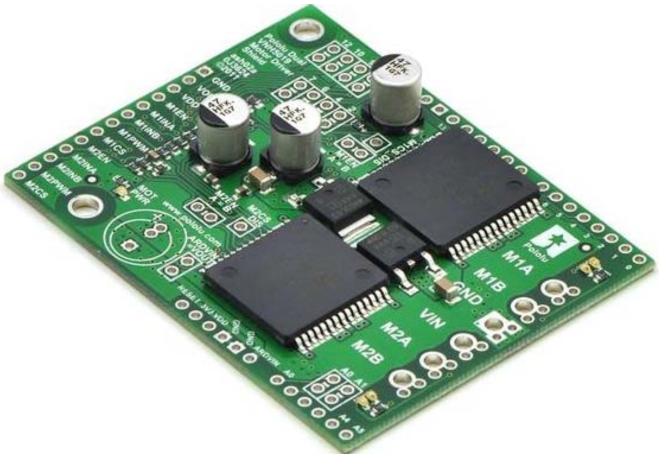

Fig. 9. The Pololu Dual VNH5019 Motor Shield [Courtesy of Pololu: http://www.pololu.com/product/2502/].

The Pololu Dual Motor Shield allows for controlling two DC motors with the use of an Arduino. Its motor drivers can operate motors that require 5.5V to 24V and can provide up to 12A of continuous current for each of the two motors connected to it. The linear actuator motors at most consume 5A of current and operate at 12V DC. This motor controller provides all of the requirements necessary to control the linear actuators effectively and efficiently. Since this controller can withstand up to twice the voltage and current the motors are expected to experience, the controller has no need to generate a lot of heat and it can last a very long time.

G. *Charge Controller*

In their article entitled “Development of a Microcontroller Based Maximum Power Point Tracking Control System”, the authors [9] prove that the Maximum Power Point Tracking (MPPT) can increase the efficiency of a photovoltaic system by 15%. They explain that MPPT is an intelligent feedback control based technique that tracks the input voltage of a solar panel and compares it to a constant reference voltage. The resulting difference signal (error signal) is used to drive a power conditioner which interfaces the photovoltaic panel to the load [10]. In this project, the JUTA MPPT-10 charge controller is used (Fig. 10) that implements MPPT. Moreover, the JUTA MPPT-10 also performs overcharge, over-discharge, battery reverse current, overloading, short circuit, and reverses polarity connection protections. Figure 11 compares the power output of a regular charge controller to the power output of a MPPT charge controller.

Fig. 10. JUTA MPPT-10 Charge Controller [Courtesy of manufacturer].

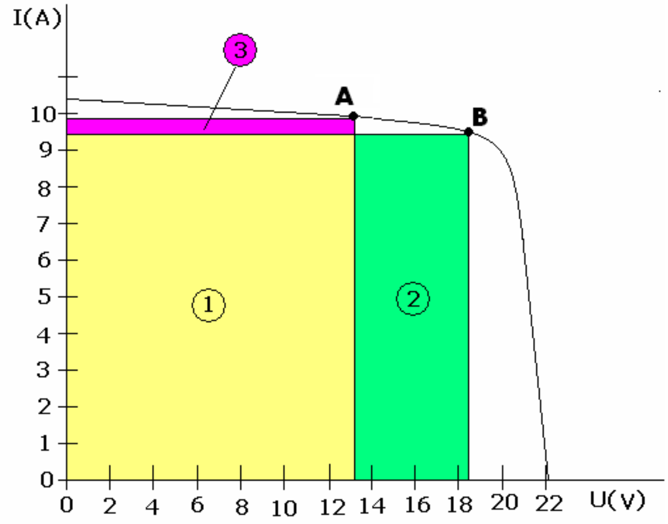

Fig. 11. Regular charge and MPPT solar charge controllers’ power output comparison [Courtesy of manufacturer].

The regular charge controller operates at point A while the MPPT solar controller operates at point B. The area under the curve represents the power output.
Different power output calculations:
Power output of A=13.2*9.8=129.36W
Power output of B=18.4*9.3=171.12W.
According to the manufacturer, the MPPT solar charge controller can yield a 32.28% increase in the power output.

H. *Current Sensor*

The Hall-Effect based ACS758 linear current sensor (Fig. 12) was used to measure the output current of the solar panel. The ACS758 is made up of a precision, low-offset linear Hall circuit with a copper conduction path located near the die. The manufacturer explains that “the applied current flowing through this copper conduction path generates a magnetic field which the Hall IC converts into a proportional voltage” [9]. The datasheet also says that “the device accuracy is optimized through the close proximity of the magnetic signal to the Hall transducer” [9].

Fig. 12. The Allegro Microsystem ACS758 current sensor [Courtesy of the manufacturer].

VIII. SOFTWARE DESIGN

As explained in the hardware architecture, there are two microcontrollers in this design. The first one is dedicated to the sun tracking system.

The dual-axis tracking system requires four light dependent resistors (LDRs) which provide the values needed to communicate to the Pololu Dual Motor Shield (Fig. 9), which drives the linear actuators. The system also needs two 24” linear actuators, a 12 VDC power supply, a 5 VDC power supply, two 10 kΩ resistors, and an Arduino Uno R3. Each LDR is connected in series with a 10 kΩ resistor. The five wires on each linear actuator are connected to a 12 VDC power supply, a 5 VDC power supply, and an analog port on the motor shield. The Pololu Dual Motor Shield (Fig. 9) is mounted on the Arduino Uno R3 (Fig. 4). The flowchart of the Arduino program is shown in Fig. 13.

The Arduino program imports the Dual VNH5019 MotorShield library. This library provides a set of functions that allows the program to control the motor shield, which controls the linear actuators. The program takes voltage readings from the four LDRs and compares their differences. The most important variable in the code is the deadband value. The deadband value provides a reference value for the calculated voltage difference to compare to. If the absolute value of the calculated difference is greater than the dead band, the program will adjust the linear actuators. If the absolute value of the calculated difference is less than and/or negligible compared to the deadband, the program will delay for one minute and re-run the program from the beginning. This method of polling satisfies the project specifications of providing a real-time system, despite the fact that the sun's azimuth does not change significantly in one minute. The daily motion of the sun is 360 degrees in 24 hours [11], which is 15 degrees every hour. Keep tracking the sun through a 12 hour period during which the system will check every minute for voltage difference between four LDRs. The motor controller will extend or retract the linear actuators until the voltage difference equals zero.

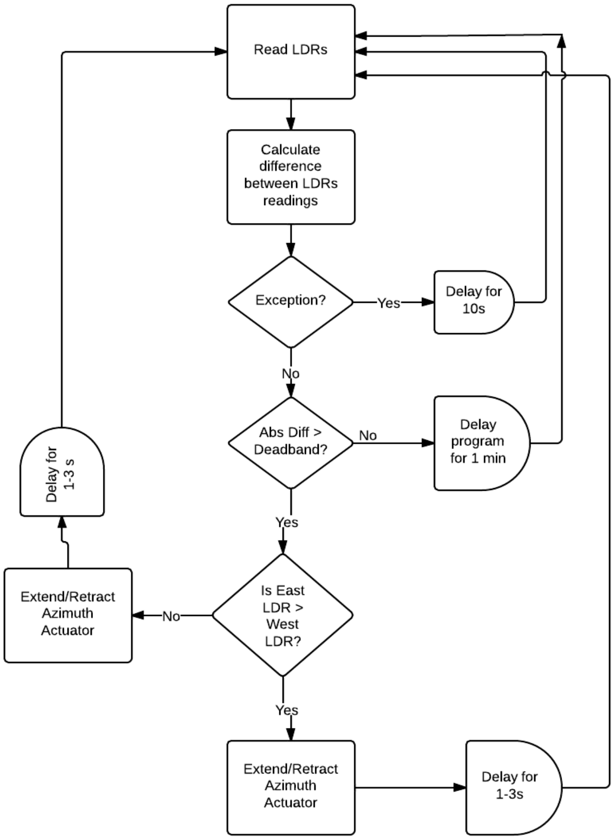

Fig. 13. Arduino program tracking flowchart.

IX. CONCLUSIONS AND RECOMMENDATIONS

The student team [12] has designed and built a solar tracking system that fulfills the requirements of a low cost but efficient solar energy system. The design costs less than five-hundred dollars for assembly and less than three-hundred dollars for the motors.

Among three design alternatives, design I proved to be the best. It has the lowest power consumption, which is crucial to the system because the maximum amount of output power was needed. It accomplishes flexibility in handling the necessary tracking by allowing a minimum of 45 degrees east to west and north to south rotation.

The key aspects of the product are that it is affordable, efficient, stand-alone, relatively easy to transport, and ready to use. The system is also designed to be autonomous so that the user does not have to do a lot of configuring once the system is set up. The design weighs less than 100 lbs, and consists of wheels for added portability.

The cost effect system built is functional and is kept in the Energy Systems Lab at MUSE. Series of tests will be conducted on the system at the end of the Spring Semester 2014. The solar tracking system will be available for data collection and be used as demonstration equipment for Electrical and Computer Engineering students at MUSE in the near future.

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