John Brown University

PROPOSAL FOR

Development of a Low-Cost Maximum Power Point Tracker for Low-Wattage Photovoltaic Systems

SOLARIS
POWER SYSTEMS

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I. Introduction

Photovoltaic (PV) systems are an increasingly popular source of power today, as they can be completely independent of an electrical grid, produce no emissions, and require only the sun as a fuel source. These advantages also make PV systems a viable way to alleviate energy poverty in the developing world. However, those lacking access to a reliable energy are often prohibited by the initial cost required by such PV systems. The use of a maximum power point tracker (MPPT) for PV panels can decrease this initial cost by increasing the efficiency of each panel up to 25%, thus necessitating fewer panels to achieve the required power budget. Most MPPTs on the market today are well over $100, making it more economical in small systems to purchase additional PV panels rather than investing in an MPPT. Our objective is to design, build, and test an efficient, low-cost MPPT appropriate for small PV systems in developing countries by utilizing inexpensive components and custom-designing components as needed to further reduce cost. The design we propose is intended to cost no more than $75, be contained in robust and durable housing, and have minimized usage complexity and maintenance requirements.

While PV systems are widely recognized as an optimal source of power in developing countries, communities in these countries are yet faced with two issues regarding the implementation of such systems: 1) the power provided by PV systems is inadequate to fulfill the total need for a community, thus necessitating kerosene or other fossil fuels as supplemental power, or 2) the community lacks the necessary funds to make the initial investment for a PV system. A PV system typically consists of one or more PV panels connected to a battery. By introducing an MPPT into a PV system, the efficiency of each panel is optimized, producing a power output up to 25% greater than a PV systems without maximum power point tracking. To a community presently possessing a PV system, adding an MPPT drastically increases the power produced by the system for the community, reducing the community's need for fossil fuels as supplemental power. To a community considering the purchase of PV panels, the addition of an MPPT reduces the initial investment required, as fewer panels are necessary to achieve the desired power budget.

The proposed project would decrease the cost of the MPPT to $75 by utilizing a low-cost microprocessor, low-cost sensing technologies, and by custom designing components as necessary. The MPPT will be designed with widely available, modular components, to allow for ease of maintenance and repair. Additionally, the MPPT will be designed to have a plug-and-play interface, so as to simplify installation and setup. As PV systems are necessarily outdoors, the MPPT will be housed in such a way as to withstand adverse weather conditions, such as rain and extreme temperatures.

II. Product Specifications

1. Target Markets

This project fits within the Environmental Technology market segment. The target market for this project is home and business owners in the developed and developing world who utilize low-wattage PV systems to provide electricity and reduce their environmental impact. This project is primarily focused on consumers in the developing world who cannot afford MPPTs on the market today. Table I shows the current costs of MPPTs on the market today.

From Table I it can be seen that most MPPTs on the market today cost over $100, which is out of the price range of many in the developing world. A high priced MPPT makes the purchase of an additional panel more cost effective than adding an MPPT. This project seeks to develop a more affordable MPPT to meet this market need. This device will be important for this market as it decreases the cost per watt of PV systems by increasing the power output of a PV system at a lower cost than adding the equivalent capacity by adding additional PV panels. This device will thus help to provide access to affordable electricity in developing regions. The project will also have a broader market toward any PV user desiring to maximize the efficiency of his or her PV system at the lowest cost.

Table I. Commercial MPPT Prices

Name	*Max Power Intake (W)*	*Price ($)*
BZ Products MPPT250	300	111
Blue Sky 2512i	300	213
Morningstar SunSaver 15 Amp MPPT Solar Charge Controller	180	250
Rogue MPT-3048	360	350
Morningstar TriStar 30 Amp MPPT Solar Charge Controller	360	355

2. Performance Requirements

Performance Criteria

The technical performance criteria for this project can be seen in Table II.

Table II. Technical Criteria

	Min	*Max*
V_{in}	5 V	38 V
V_{out}*	11.8 V	14.4 V
ΔV_{out}	-	2.5%
P	-	300 W
ΔP	+10%	-
Efficiency	90%	-
Self-Consumption	-	50 mW
Length	-	8"
Width	-	6"
Height	-	4"

The criteria of V_{in} was determined based on the minimum and maximum voltage outputs for PV panels in the 100 W to 300 W range. The criteria for V_{out} was determined based on the output needed to charge a 12 V lead-acid battery. This is the type of battery system expected to be used by the target market, as it is an affordable energy storage technology. The output voltage ripple was determined to be less than 2.5%, as this allows for a nearly constant output voltage, and is well within the range commonly specified by lead-acid battery manufacturers. The MPPT design we propose will be capable of handling 300 W. This is approximately the power needed to provide LED lighting and basic electrical appliances to a small home in the developing world. This power rating is also similar to the power rating for small-scale MPPTs on the market today. The minimum ΔP criteria of +10% means that the MPPT should increase the power output of the panel by at least 10%. The purpose of the MPPT is to increase the power output of the PV panel, thus this minimum is an important criteria for determining the success of the design. The criteria for minimum efficiency of the DC-DC converter within the MPPT has been set to be 90%. The goal of a MPPT is the increase of efficiency of the PV system, thus inefficiencies within the DC-DC converter must be minimized. The criteria for self-consumption, or the power taken to run the MPPT, will be less than 50 mW. This too is important because power used to run the controller and other components contributes to inefficiency of the MPPT, and thus should be minimized. Finally, the mechanical size constraint of 8” x 6” x 4” for the device was determined to reduce the footprint of the device where it is installed and to ensure that the device can be easily transported.

Constraints

a) *Production cost must not exceed $75.* As previously stated, a key goal for this project is to design an MPPT that is substantially lower in cost than comparable MPPTs on the market today, making this a primary constraint on the design.

b) *Prototype cost must not exceed $150.* Since electrical components and printed circuit board fabrication reduce significantly at production quantities, it is expected that the prototype will cost more than a production model of this MPPT. A $150 budget has been determined for this prototype based on the money provided by John Brown University as seed funding for this project.

c) *Prototype must be weather resistant.* PV panels are necessarily outdoors, thus making it highly likely that the MPPT will be outdoors as well. Without weather resistance, the MPPT will quickly break down and fail to function. The MPPT may be mounted inside of buildings to which power is supplied, but this is not guaranteed. In circumstances when this is not available, the product will be designed to be weather resistant.

d) *Design must prevent electric shock to users.* Users should not be shocked when installing the device, nor should technicians be shocked when servicing the device.

e) *Prototype must be able to be completed by May 1.* This deadline allows time for final testing of the device before the final presentation before the junior design class.

Design Alternatives

The decision matrix in Table III outlines the selection of a DC-DC converter topology. Four criteria were developed to evaluate the five alternatives. These criteria were cost, simplicity, inversion, and flexibility. The cost criteria involves the costs of components needed for the DC-DC converter design as well as the size of the PCB required, as this will increase the total cost. A higher score in this category signifies a lower cost. The simplicity criteria involves how difficult the design will be as well as difficulty in controlling the converter. Simplicity scores are higher for designs which do not require driver ICs for high-side switching, as well as for designs with fewer components. The inversion criteria grants higher points to converters which do not invert the output. Finally, the flexibility criteria grants higher scores to converters which are able to handle inputs which are both higher and lower than the output and lower scores to converters which can only increase or only decrease voltages. The points in the total column are highest for the best design, which in this case is the SEPIC converter, which is the converter topology which will be used.

Table III. DC-DC Converter Decision Matrix

DC-DC Converters	***Cost***	***Simplicity***	***Inversion***	***Flexibility***	Total
Buck	7	5	10	5	**20**
Boost	9	9	10	5	**24**
Buck-Boost	7	5	7	10	**22**
Cuk	5	7	7	10	**24**
SEPIC	5	7	10	10	**27**

The decision matrix in Table IV outlines the selection of a MPPT algorithm for the design. Six criteria were developed to evaluate the three alternatives. These criteria were simplicity, required sensors, computational resources, effectiveness, speed, and flexibility. The simplicity criteria measures the ease with which the algorithm can be implemented in code. The simplicity score is highest for algorithms which are easily implemented and lowest for algorithms which are more difficult to implement. The required sensors criteria involves the number and types of sensors required for the algorithm. Perturb and Observe and Incremental Conductance both score poorly in this area because they require a current sensor and voltage sensor, while Fractional Open Circuit Voltage only requires a voltage sensor. The computational resources criteria measures how much processing power is needed to implement the algorithm. This is measured by the number of operations which are necessary in each loop. A higher score in this category represents fewer operations needed. The effectiveness criteria represents how accurately the algorithm find the correct maximum power point (MPP). This score is highest for the Incremental Conductance method which finds and latches on to the MPP. The Perturb and Observe algorithm is next highest since it find the MPP but oscillates around it. Finally, the Fractional Open Circuit Voltage method is least effective as it only approximates the MPP. The speed criteria represents how quickly the algorithm is able to find the MPP. A higher score in speed means that the algorithm find the MPP faster. The flexibility criteria is rates the algorithms on their ability to work with different PV panels without calibration. Since the Fractional Open Circuit Voltage method relies on specifics about the panel, it scores poorly in this category, while the other two algorithms score well. From the total column in Table IV it can be seen that the Perturb and Observe method is preferable, however further research will be done as part of a SURF grant to determine if this algorithm is truly the best for this application.

Table IV. Algorithms Decision Matrix

Algorithms	*Simplicity*	*Required Sensors*	*Computational Resources*	*Effectiveness*	*Speed*	*Flexibility*	**Total**
Perturb and Observe	8	6	9	9	8	10	**50**
Incremental Conductance	7	6	7	10	9	10	**49**
Fractional Open Circuit Voltage	10	10	10	6	10	2	**48**

The decision matrices in Tables V and VI outline the selection of current and voltage sensors for the design. The criteria for both matrices are the same: cost, simplicity, reliability, and efficiency. The cost criteria relates to the cost of the sensor or components to build the sensor.

A higher score represents a lower cost. The simplicity criteria involves how difficult the sensor will be to design and implement, as well as the ease with which the sensor can be read by the controller. A higher simplicity score represents a simpler design. The accuracy criteria represents how accurate the sensor is relative to the actual value, with a higher accuracy score meaning that the sensor is more accurate. The efficiency criteria measures how much power is consumed by the sensor. A higher score in efficiency represents a lower power consumption for the sensor. From Table V it can be seen the both the Shunt Resistor and Hall Effect sensor have the same total score. The Shunt Resistor and Amplifier has been selected however, due to greater simplicity. From Table VI it can be seen that the Microcontroller ADC with Voltage Divider method received the highest score and will be used for this project.

Table V. Current Sensor Decision Matrix

Current Sensors	*Cost*	*Simplicity*	*Accuracy*	*Efficiency*	***Total***
Shunt Resistor and Amplifier	8	7	7	6	**27**
Hall Effect Current Sensor	7	4	8	8	**27**
Fiber Optic Current Sensor	1	1	10	8	**20**

Table VI. Voltage Sensor Decision Matrix

Voltage Sensor	***Cost***	***Simplicity***	***Accuracy***	***Efficiency***	**Total**
Microcontroller ADC and Voltage Divider	9	10	8	6	**34**
Voltage Measurement IC	7	7	9	9	**32**

The decision matrix in Table VII outlines the selection of a controller. The criteria for controller selection are cost, processing power, ease of programming, power consumption, and peripherals. For the cost criteria, a higher score in the represents a lower cost. The processing power criteria represents the amount of processing power the controller has, such as its clock speed and the ability to perform tasks in parallel. High scores in this category represent high processing power. The ease of programing criteria takes into account the ease with which the algorithm can be implemented on the controller. This includes the language which is used to program the controller, development environments available to be used when programming the controller, and availability of sample code. High scores in ease of programming correspond to simpler implementation, a strong development environment, and access to sample code. The power consumption criteria takes into account how much power each controller would require. Since self-consumption of the MPPT has been limited to below 50 mW, it is important that power consumption of the controller be kept low. A high score in power consumption relates to a low power consumption. Finally, the peripherals criteria takes into account the presence of peripherals available on the controller, including ADCs, PWM generators, etc. High scores in this category were given to controllers with these peripherals. From the total column of Table VII it can be seen that the MSP430 microcontroller received the highest score, and will be used as the controller for this project. This also aligns with the SURF grant which is providing additional funds for this project, as the grant specifies that an MSP430 be used.

Table VII. Controller Decision Matrix

Controllers	*Cost*	*Processing Power*	*Ease of Programming*	*Power Consumption*	*Peripherals*	Total
MSP430	10	6	9	9	9	**43**
Digital Signal Processor	8	8	7	7	10	**40**
FPGA	4	9	7	5	8	**33**
Arduino	6	6	10	7	9	**38**

The criteria for housing of the printed circuit board was shown previously in the constraints section, and includes weather resistance, durability, and prevention of electrical shock to the user. Additional desired characteristics of the housing design include affordability, ease of manufacture, use of common materials to provide for simple and quick maintenance, reversible component attachments, adequate heat dissipation for the PCB, and durable mounting into the PV array circuit. Since the project is still in the design phase, alternatives that match these constraints and goals are not available and additional research will be made that will affect design choices in the future. Housing design manufacture is scheduled for 20 March 2015. Testing is scheduled for 12 April 2015, and the results will affect the final prototype design for final presentation on 5 May 2015.

At the time of proposal submission, plastic is the favored material for circuit housing to minimize cost and weight. Metal housing would heat up in the summer, hindering heat dissipation from the circuit, and would need to be properly sealed to prevent rust. A hinged lid with O-ring sealing is an alternative that would allow for ease of access to the circuit while keeping the circuit weather resistant. Additional research and future design alternatives will be included in the online project notebooks.

Key Design Elements

The team consists of four engineering students: Kyle Crouse, Zach Lee, Austin Ricks, and Zeke Zumbro. As this project involves different fields of engineering, each member will have a specific role based on their major. Austin Ricks will be in charge of topics concerning the mechanical engineering components such as heat transfer and the housing of the MPPT. He will use thermodynamics along with materials science to perform these tasks. Zeke, with internship experience with Geometric Dimensioning and Tolerancing (GD&T), will assist Austin with the final housing design for the MPPT. Kyle will be in charge of the design of the DC-to-DC converter and charge control components, using his the concepts that he learned in Power Electronics. Zeke will then design the converter on a PCB to have it assembled at a factory. Zach will be developing the MPPT algorithm using Embedded Systems along with his understanding from Power Electronics. All students will help to design and implement the different test environments. In addition to the undergraduate students, Dr. Ted Song will be working with the team as the faculty advisor.

3. Production Cost

The primary cost involved in the creation of this prototype will be the electrical design, including the DC-DC converter components, controller, and printed circuit board manufacturing. Since component and PCB costs are reduced at production levels, the cost of the prototype is expected to be significantly more than final production costs. The second largest expense for this project will be the housing for the MPPT. It is expected that mass production of this housing will also reduce production costs relative to prototyping costs. Despite the challenge of higher costs at low quantities, since this project is aimed at reducing the cost of the MPPT, it is expected that the prototype will be able to be built for less than $150. An addition budget item which will increase the cost of this project is research and testing. Since the testing of this design will require PV panels as well as batteries to act as the load, significant funds will be needed to test the design. These funds will be provided by a SURF grant which Zach secured last semester. This will provide $600 to purchase PV panels, batteries, and other components needed for testing. The high cost of PV panels and deep cycle batteries pose some concern for staying within this budget, however by utilizing university resources and student discounts from manufacturers we expect to be able to stay within budget.

4. *Reliability Goals*

A Failure Mode Effects Analysis (FMEA) will be performed taking into account the probability, severity, detection, dormancy, and indication of failure modes. A concept design FMEA will be performed in the early design stages to determine potential failure modes inherent in the design. If any are found, adjustments will be made to the design. The final documentation will include a detailed design FMEA based on the Bill of Materials, listing the effects of probable catastrophic failures of components for every component in the design.

5. *Safety Considerations*

The product will be using electrical currents strong enough to cause harm, thus no live wires will be open to the user. Wires leading into the product housing will be made secure so that they cannot be pulled out accidentally. Leading and trailing wires will be insulated properly. The housing will be waterproof to withstand rain water and extreme conditions and will also provide proper heat dissipation from the circuit board to allow for stable operating temperatures. Electrical components will be selected with an appropriate safety factor based on the maximum expected voltage and current to be applied to each component. The User's Manual and Technical/Installation Manual will detail safety precautions and measures to take so as to ensure safety for the user and technician in installation, maintenance, and servicing.

6. *Performance Tests*

Testing will begin at the subsystem level. The DC-DC converter, controller, and mechanical subsystems will each be tested prior to assembling the entire system. The DC-DC converter subsystem will first be tested to determine proper functionality and an acceptable efficiency. The operation of the DC-DC converter will be tested by attaching the input side of the converter to a DC voltage source. The Arbitrary Waveform Generator (AWG) will be used to provide pulse width modulation (PWM) waveform to the DC-DC converter. The output of the DC-DC converter will be measured across a load resistor using the Digital Multimeter (DMM). Success of the DC-DC converter will be determined based on whether or not the output voltage is able to be controlled by the PWM signal provided by the AWG. The efficiency of the DC-DC converter will be tested by measuring the input voltage and current to the DC-DC converter using the DMM to find the input power. This will then be compared to the output power calculated by finding the output voltage and current measured by a DMM. The DC-DC converter should have as the highest efficiency possible, however a minimum of 85% efficiency will be required for the DC-DC converter to be considered successful.

The controller subsystem will be tested. The first elements of the controller subsystem to be tested are the voltage and current sensors. Each sensor will be evaluated by providing to it a known voltage or current using a DC voltage source and resistors. The output of the sensor will be compared to the reading from a DMM to determine the accuracy of the sensor. The level of accuracy deemed necessary for the design will be determined based on the algorithm used, thus lower accuracy sensors may be used if the lower accuracy can be accounted for in software. The other portion of the controller subsystem to be tested is the algorithm. The effectiveness of the MPPT algorithm will be evaluated by comparing it to a commercially available MPPT tracker. Two identical PV panels will be placed outside, one panel will be connected to the commercial MPPT and each of the others will be connected to a MPPT running the algorithms being tested. This MPPT will also consist of the DC-DC converter designed as well as the sensors selected. The time it takes the MPPT to arrive at the MPP, as well as the power extracted from the panel by each MPPT will be measured. Power will be measured at the input of the MPPT rather than the output in order to eliminate differences in efficiency of DC-DC converters. The panels connected to each MPPT will then be swapped so each MPPT is connected to each panel. The results of these tests will be compared to eliminate variations from different PV panels. An algorithm will be considered successful if it performs within 80% of the commercial MPPT in both tracking time and power extracted from the panel.

The mechanical case subsystem will be tested. The case subsystem will be primarily tested for weatherproofing. To do this the case will be sealed and water will then be poured over the case in a way which simulated heavy rainfall. The case will then be opened and examined to determine if water was able to penetrate the case. The casing will be considered successful if no evidence of leakage is found after testing for 1 hour.

Finally the integrated system will then be tested. This testing will be done in a way similar to the testing of the controller. During this test the MPPT will be connected between one PV panel and a battery. A second PV panel will be connected directly to the battery. The power dissipated by the load in each case will be measured by measuring the output voltage and current using a DMM. This test will be repeated after switching the PV panels to eliminate differences between the panels. Multiple tests will then be run by changing the temperature and solar insolation levels of the panels during the test. The MPPT will be considered successful if the average output power is at least 10% higher than the average output power of the PV panel connected directly to the load. The heat dissipated by the MPPT during these tests will be measured using thermocouples to determine the temperature rise within the case. This temperature rise will be compared to an acceptable value based on the thermal tolerances of the components used in the design. The design will be considered successful if the temperature rise plus 120°F does not exceed the thermal tolerances of any of the components. This will account for the high ambient temperatures which this device may be exposed to when used in the field.

7. Ergonomic & Aesthetic Considerations

The primary aesthetic considerations concern the housing. The overall shape of the housing will be a visually appealing small box made of a low-cost, durable material. The housing will be made in such a way that several options are available both for interior and exterior mounting. The final product will utilize a user interface that is intuitively understood and simple. Indicator LEDs will be clearly labeled visible at a quick glance of the MPPT.

III. Demonstration & Documentation Requirements

1. Documentation of Design Process

The team will use individual notebooks and a team notebook to record the steps and progress made on the design. The notebooks will include descriptions of research done, concepts learned, daily tasks accomplished, and project design specifics. Screenshots will be taken of circuit designs and mechanical drawings. Sketches will be made electronically for the circuit housing and uploaded to the online notebooks. The files for circuit designs made using SPICE software will be uploaded to the appropriate Google Drive folder for the project. Mechanical drawings will be made using SolidWorks. Electrical drawings will be made and simulated in LTSPICE while PCB designs will be created in Eagle. Software will be developed in Code Composer Studio.

2. Level of Prototype Capability

The prototype to be designed will be capable of finding and tracking the maximum power point of a PV panel in order to increase the power extracted from the PV array. The prototype will be capable of handling up to 25 A of current. The connection of the MPPT to the PV panel will be plug-and-play. The casing for prototype will be weather resistant and capable of dissipating the heat generated by the circuit. The prototype will not include an advanced user interface or user definable settings.

3. Market Packaging & Shipping

The market packaging will be a cardboard box with cushioning of some sort around the product to protect components during shipping. The box will display the product title, the general functions and specifications about the product, and the company logo. It is assumed that if shipped, the product will be placed in a more durable box to withstand harsh weather, and as such, the market packaging will not be made to withstand these conditions.

4. Product Manuals

The product will be accompanied by a User's Manual and a Technical/Installation Manual. The User's Manual will contain seven sections. The outline will be as follows:

a) Important instructions

b) Quick-start guide (it may be deemed later in the project that this section is not necessary and as such, it may be excluded)

c) Detailed installation guide

d) Basic maintenance

e) Basic troubleshooting

f) Actions to take if product needs servicing

g) Warranty

The Technical/Installation Manual will contain six sections. The outline will be as follows:

a) Important safety instructions

b) Important specifications and limitations of the product

c) Detailed installation guide

d) Maintenance

e) Troubleshooting (more detailed than User's Manual)

f) Servicing procedures

5. Final Report Submission

Documentation on the completed design will be submitted in the form of a final report. The final report will include test procedures and results for all specifications, tables showing cost calculations, tables showing all calculations for reliability predictions, a section on safe use, and completed drawings and schematics. The final report will be delivered as a bound notebook.

IV. Schedule

Several components in the schedule are dependent on others and as such, staying on schedule is extremely important for the design. A key component to finish is the DC to DC converter; once it is finished, algorithm design can begin, which is anticipated to be one of the most difficult components of the MPPT. After the DC-DC converter PCB is completed, calculations can begin on removing the heat within the system. The schedule can be seen in the Microsoft Project file located on the Google Drive.

V. Staffing

Kyle Crouse is a junior in engineering with an Electrical/Computer concentration at John Brown University. He is also the Head of Communications and Treasurer of the JBU IEEE Student Branch and is a two-time winner of the JBU Programming Competition. Kyle is passionate about engineering and music and aspires to work in the audio technology industry following graduation. Kyle has skills and background in power electronics, printed circuit board design, embedded systems, and programming.

Zach Lee is a junior Engineering major with a concentration in Electrical/Computer Engineering and an enhancement in Renewable Energy. He is the President of the JBU IEEE Student Branch, and is a former Resident Assistant and President of the JBU Wells Project. He is also a member of the JBU Honors Scholars Program and Leaders Scholars Institute and a recipient of the IEEE PES Scholarship, Utility Variable Generation Integration Group Scholarship, and JBU Presidential Scholarship. Zach is a three time winner of the JBU Programming Competition and tied for 1st Place in the 2013 Low-Power Microcontroller Competition. Zach has interned with Lexmark International as a Software Engineering Intern, where he received a Manager's Service Award and 1st Place Award at the Lexmark Emerging Leaders Symposium. Zach has also served as a Teaching Assistant for Power Electronics and Electronics I. Finally, Zach is the recipient of a SURF grant to study MPPT algorithms on low-cost microcontrollers such as the MSP430.

Austin Ricks is a junior engineering with a Mechanical concentration. He has studied physics at the University of Denver as well as Architecture at the University of Washington before transferring to JBU to finish his undergraduate with a B.S. in Mech. Engineering. He was worked as a valet attendant, engineering department lab assistant, and sub-contractor for construction companies at his home in Denver, CO. Austin has experience with heat transfer and thermodynamics through classes at JBU. The project responsibilities for Austin include PCB housing design, PCB heat dissipation, and mounting of the product into the PV array circuit.

Zeke Zumbro is a junior in engineering with an Electrical/Computer concentration at John Brown University. He has had two internships at the Dual Axis Radiographic Hydro Test facility (DARHT) in Los Alamos, New Mexico. During his first summer there, he assisted in manufacturing accelerator cells and also won the 2013 Student Symposium Engineering Category with his research on Resistance Thermal Device (RTD) outgassing rates. During his second summer, he learned how to use Creo Parametric (CAD software) and took a class in Geometric Dimensioning and Tolerancing for engineering drawings. Using this knowledge he created drawings of various components needed at the DARHT facility for the summer. At JBU Zeke has taken classes in Computing, Electronics, Circuit Analysis, and Mathematics. These courses and internships have aided to his understanding of the complex electrical world.

The whole team will be in charge of creating a MPPT. Austin Ricks will use knowledge gained through classes in Thermal Science and Thermodynamics as well as his skills in computer aided design to create the housing for the MPPT. Zeke, with internship experience with Geometric Dimensioning and Tolerancing (GD&T), will assist Austin with the final housing design for the MPPT along with creating the DC to DC converter PCB. Kyle will be in charge of the design of the DC-to-DC converter and charge control components, using the concepts learned in Power Electronics. Zeke will use skills learned in Power Electronics to design the PCB for this project with help from Zach who also has experience in PCB design using Eagle. Zach will be developing the MPPT algorithm using his experience in Embedded Systems along with his understanding from Power Electronics.

VI. Summary

A MPPT will be designed for a bulk production cost of $75 or less. While this is a challenging goal, since systems on the market currently range from $111 to $300, reduction in cost is the main goal of the project. This goal will be achieved by making a simple system consisting of widely available, modular components, which have a plug-and-play interface, and will be contained in durable housing capable of withstanding adverse weather conditions. When a user is servicing the device, it will not be too complicated to require a technician to perform basic service or shock the servicer. From preliminary research done on this design as well as examining current competing products, all of these criteria should be attainable. Given the outstanding skills of the team which were outlined in the staffing section, this project is well within the ability level of the group. Each member is well qualified for their respective role. In addition, many team members are also qualified to help in areas which are not their responsibility, which will aid in fixing problems which may arise. Budgetary concerns have been address and it is expected that the prototype will be able to be completed for well under $150. Supplemental funds have also been secured in order to pay for testing equipment. A realistic schedule of work has been created which will allow for the project to be completed on time, and leaves room to fix problems which may arise and for testing prior to the final presentation.