# GCC 3011 - Grand Course Challenge
# Pathways to Renewable Energy
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# Solar Testbed Master Plan

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## 1. Introduction

a. *Objective:* To build a solar testbed of 500W for demonstration of how a solar platform can generate electricity, while keeping the arrangement of devices and functionalities as simple as possible for public support and involvement in the solar power project at UMN.

b. *Motivation:* A solar testbed provides a platform for demonstrating the capabilities of a real solar platform in a reduced scale. It also illustrates the advantages, functionalities and challenges entailed in the transition to a photovoltaic (PV) energy generation method. As a whole, a platform of this kind provides a more tangible approach to how renewable energy can be generated.

## 2. Theory of Operation

Solar power generation is ranged according to the capacity of the output power. Since the solar testbed that we describe in this form is for educational and experiential purposes; we consider a structure capable of generating 500W. This structure will be composed of two solar panels, rechargeable batteries, an inverter, a controller and delta arrestors that provide protection in case of lightning. The list of components used for our implementation can be found in section 4 (Budget for Proposed System) and the connections are displayed on the next page.

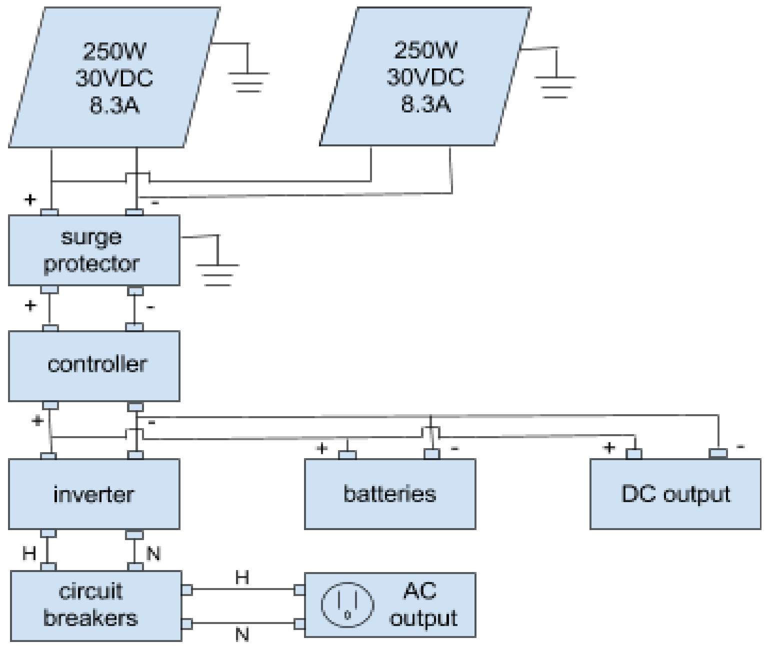


Figure 1. Solar generation platform. Panels are connected in parallel

a. *Solar Panels:* The two most commonly used PV panels are monocrystalline and polycrystalline silicon, with efficiencies of about 22% and 18%, respectively. The solar industry is aiming for higher efficiency with affordable cost, the reason being that monocrystalline panels are currently becoming more utilized. Solar panels of the model LG250S1C (see budget section) have been chosen for the analysis of the testbed shown above.

b. *Array Arrangement:* The options of parallel versus serial arrangement can define the capacity and functionalities of a solar platform. A parallel arrangement, as shown on figure 2, provides for a voltage output equal to the output voltage of each panel, while the current output adds up from panel to panel in a daisy-chain manner. For the purpose of the solar testbed described, a parallel panel arrangement is going to be used.

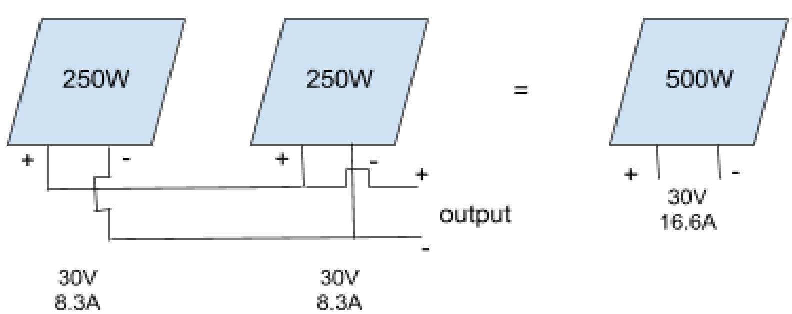


Figure 2. Solar panels connected in parallel.

Conversely, a set up of panels connected in series, as the arrangement shown below, provides for a voltage equal to the sum of voltages in a daisy-chain, while the current is equal to the average of the panels connected in series. The choice between serial and parallel arrangements is mainly based on the input that the voltage inverter can handle.

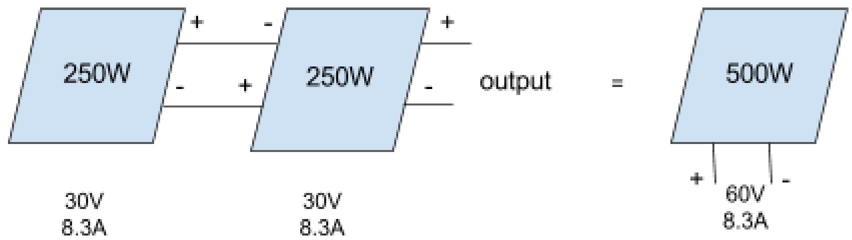


Figure 3. Solar panels connected in series.

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c. *Axes Adjustment:* Irradiation is a relevant factor during solar power generation due to the constant changes in the sun's position. Tracking the sun by adjusting the angle at which the sun's rays hit the panels becomes an important factor that can increase the energy obtained by as much as 20%, with the additional task of having to orientate the panels accordingly. In locations with reduced space where packing density is high, adjusting the angle of the panels plays a detrimental effect on neighboring panels. Therefore, it is not advised to use tilting tracking of the sun in such places.

Conversely, in ample generation fields, where panels can spread apart far enough to not block the sun's rays, panel tilting is recommended as a method of capturing as much sunlight as possible throughout the day. We leave this as an option for the implementation of the testbed.

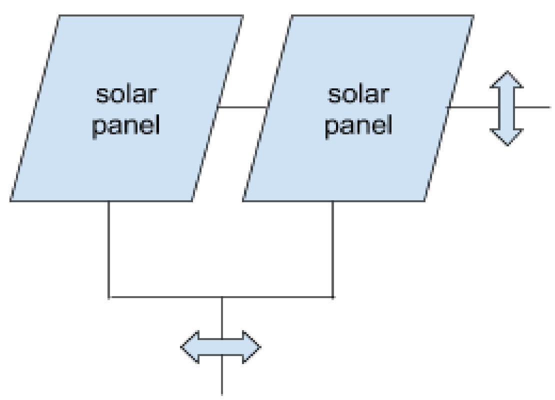


Figure 4. Axes adjustments.

d. *Controller with Data Logging:* The controller provides current flow to the battery and cuts the charging process once the batteries are fully charged in order to prevent damage on them. The TS-45, shown below, is not just a controller but it can also perform power logging throughout the day and output the data through its RS-232 port. This device is placed after the surge protector that serves as a connection to ground in the presence of lighting (see figure 1).


Figure 5. Morningstar Corporation TriStar TS-45 Charge Controller.
Source: http://www.wholesalesolar.com.

e. *Inverter*: This is the component that turns the DC output from the controller and outputs 120VAC at 50Hz in order to provide power for devices that are usually connected to a regular outlet at home. The inverter is placed before the circuit breakers that provide an interruption of current flow should a current excess occur (see figure 1). The device that we have chosen as an inverter for our solar implementation is shown below.

Figure 6. Solar PI15000X Inverter.
Source: http://www.solarproductspro.com.

## 3. Location

a. *Option A* involves collaboration with the CSG hosting team to obtain a segment for research and include a monitoring system. The viability of this option can be determined through coordination with the utility sector/other involved parties of the University.

b. *Option B* is the development of an independent small array for demonstration and research purpose.

   i. Short term plan: A portable trailer bed, to be built over the summer. This is a great option for outreach as it can be brought to events on and off campus to get students of all ages and disciplines involved.

   ii. Long term plan: A permanent site, to be established in the coming year. This requires space to be obtained through a living laboratory application, to be submitted during the fall application period. If a site is obtained on the ground, it could become an outdoor charging station. The dead solar array on top of Rapson Hall is another option. A site assessment of this is needed to determine if it can go live again.

## 4. Budget for Proposed System

| Qty | Item | Manufacturer | Model | Cost |
|---|---|---|---|---|
| 2 | Monocrystalline solar panel | LG | LG250S1C | $650 |
| 1 | Surge protector | Midnight Solar | MNSPD-600 | $100 |
| 1 | Controller | TriStar | TS-45 | $140 |
| 1 | Inverter | Solar | PI15000X | $250 |
| 3 | Rechargeable battery | Deka | Solar 8A22NF | $450 |
| 1 | Trailer* | Northern | TLK864 | $1,700 |
| | Miscellaneous accessories** | | | $700 |
| | | | **Total** | **$3,990** |

* Enclosed trailer found at http://www.northerntool.com/shop/tools/product_200329599.
** Tracking system, circuit breakers and other components.

Payment options: Class Funding, Student Group Support, CSE Small Grant and FUN Committee.

## 5. Outreach

The solar testbed will be set up to provide a place for collaboration, experimentation, and learning about solar and renewable technologies. There are many parties that may be interested in some of the resources that this testbed has to offer, so the goal will be to satisfy and accommodate as many of these parties as possible while staying within the scope of the design. Outreach will be necessary to understand who the potential customers/users of the testbed will be, in addition to finding what their interests are and how these can be met through the implementation of the project. Some of the important aspects of outreach are outlined below.

a. Initial outreach steps will include determining faculty and research departments across campus related to renewable energy or solar development in order to create a line of communication with them. Once this is achieved, interviews with researchers and faculty will help determine their needs and the needs of the University to better develop the testbed.

b. University of Minnesota and its adjacent community will receive the direct benefit from the solar testbed. The testbed will coordinate curriculums with local high schools and engage students with solar awareness. This effort has already been in process with Washington Technology Magnet School where a team of 9th grade teachers collaborated with the university students to bring an electrical engineering intensive curriculum to the high school class room. The solar testbed team has been deeply involved with the organization of the outreach program and is planning on developing a new curriculum to teach students in future semesters. Solar testbed will play a vital role in conveying a meaningful education about the renewable energy industry and encouraging the students to pursue a career in the solar industry at the University of Minnesota.

c. In addition to the outreach that will be completed at a local level at the University and surrounding community through the completion of this project, we hope that our efforts in the field of solar energy can have some degree of a global impact. Currently, there are plans underway to develop a research and demonstration site in Kenya, under the direction of Josphat Kariuki, the founder and director of Equator Fuelwood Energy Saving (EFWES). Such a site will provide community development, research opportunities, and, ultimately, a step further in worldwide renewable energy development.

   Paul Imbertson, a professor in the Department of Electrical and Computer Engineering at the University of Minnesota, who has also acted as a professor and mentor during our time in GCC: Pathways to Renewable Energies, has current and future plans to take students from the University to Kenya with plans of helping Josphat build and eventually bring to life his renewable energy service-providing site. We hope that our efforts in building a testbed at the University of Minnesota can be somehow incorporated or even mirrored during mentioned trips to Kenya's site to, ultimately, provide an ongoing research and learning experience between the two parties in years to come.

## 6. Moving Forward

To keep this project going we need to start out by organizing a group of students to build the testbed over the summer. Then we need to transfer the responsibilities of this project to an interested student group (Innovative Engineers most likely, possibly UMN Energy Club) and make sure they have all the information they need. Ideally at least one student from the class will continue working with the project to ensure its healthy transplant to new management.

## 7. Further Contacts

a. FUN Committee
    i. Michael Berthelsen - Committee Member
b. SIGHT (Special Interest Group on Humanitarian Technology)
c. Minneapolis St. Paul Public Schools
d. Solar Energy Lab. http://www.me.umn.edu/labs/solar/people/index.shtml
    i. Jane Davidson - Lab Head
e. Find Faculty researching solar energy: Potential Faculty
    - Sustainable and Responsible Energy Resources. http://www.cege.umn.edu/research/areas/sustainable-and-responsible-energy.html
        i. Michele Guala
    - Research Groups. http://www.ece.umn.edu/FacultyResearchGroups/index.html
        i. Dhople, Sairaj Vijaykumar - Modeling, Analysis, and Control of Renewable Energy
        ii. Campbell, Stephen - Photovoltaic Devices
        iii. Holmes, Russell (affiliated) - Organic Photovoltaics
        iv. Koester, Steven - Photovoltaic Devices
        v. Oh, Sang-Hyun - Photovoltaic Devices
        vi. Robbins, William - Energy Harvesting, Power Electronics
    - ME Dept. http://www.me.umn.edu/research/energy.shtml
        i. Jane H. Davidson - Director of the Solar Energy Laboratory
        ii. Xiaojia "XJ" Wang
        iii. James Van de Ven
        iv. William Northrop

v. Peter Bruggeman

f. Student Groups
    - NSBE (National Society of Black Engineers)
    - Innovative Engineers at UMN

## 8. Summary

In order to contribute to the University of Minnesota's ongoing commitment to utilizing solar energy and the ways in which we as a community can become more reliant on renewable sources of power; we propose the above plan to create, modify, and learn from a student-designed solar testbed on campus. By doing so, we will facilitate a physical opportunity for students, educators, and community members to engage with and learn the technicalities and proposed benefit of solar energy on campus. A plan of implementation for the testbed designed by our student engineers, once approved and financed, will provide a segue into what we hope will be an ongoing space for research, community outreach, and ultimately a foundation for future discovery in the realm of solar power.