University of Delaware
Department of Electrical and Computer Engineering
ELEG620: Solar Electric Systems

Photovoltaic Systems Design Project

The goal of this project is to specify, design, implement and test a simple, stand-alone photovoltaic system. Working in groups, you will:

- Decide on a load and design goal for your system
- Write a system design program and optimize your particular design for a selected location and then for Delaware
- Implement, trouble shoot and test the PV system

System Specification

The first step in the design of your system is to determine the type and size of the system. You are given substantial latitude in choosing the load to be powered, the location of the load, the design goals of the system, but you must be able to justify the system. The load should be one which can be implemented, or at least useful information obtained as an approximation to your design load, using 200W of solar panels. Existing loads which we have at the moment include a water pump, refrigerator, and fluorescent lighting.

Before starting on the design, come up with a set of design goals. These include addressing trade-offs such as the reliability required, the availability etc. You should then do a rough calculation to see if these criteria seem feasible. For example, if your design comes out to a 5kW system for a light bulb for a residence because you have specified 99.99% availability and reliability, a re-think of your design criteria would seem to be in order.

Design of the Photovoltaic System

The design of the photovoltaic system involves writing a program which: (1) calculates the power produced by the photovoltaic module based on incident solar radiation (from TMY data) as a function of the module tilt and azimuth angle; (2) determine how much energy reaches the battery and load and analyzes the energy flows in your system; and (3) calculates performance evaluation parameters. Since you will also need to calculate life cycle costs (LCCs) (since they are often a performance evaluation parameter), you may want to include this in your program. However, you can do these separately as well – your group's choice. Acceptable programming formats are MATLAB, C++, Java and Excel.

The program should include calculations that are used to design and analyze your photovoltaic system. This program should include as a minimum:

- The ability to change the tilt and azimuth angle of your array
- Change the location for the solar array/system
- Specify a load for every hour of the year, and determine yearly total and average load.
- Calculate energy flows and system performance parameters for a given number of panels and battery capacity.

- Correctly account for series and parallel connection of ideal PV modules and batteries (i.e. minimize mismatch)
- Correctly adjust the number of panels and batteries if the system voltage is changed.
- Determine the average, minimum and maximum Balance of System and Overhead Cost (BSOC).
- Determine relevant performance parameters for the system (you are strongly encouraged to find monthly as well as yearly performance parameters)
- Include one "advanced" effect. You may select which effect you include. A list of possible advanced effects includes:
    - Non-constant inverter efficiency
    - Effect of temperature on the array power
    - Non-constant battery voltage
    - Effect of mismatch losses in calculating the array power
    - Calculation of TMY data from world radiation data sets

Based on your program, you must write up in your report:

- The array size and battery size which best meets your system goals and how you decided this was the optimum.
- Justification of why this is the optimum design. This includes analysis of the performance parameters as well as a sensitivity analysis.
- Life cycle cost (LCC) of the system.
- Other necessary system specification, including: inverter size, charge controller current, which other components the system needs.
- Description of your program, showing approach taken, electronic copy of source code, and outputs of your program.

System Implementation

Your system will be implemented using solar panels on the roof of Du Pont Hall. For the system implementation, you need to re-run your design to account for the fixed tilt and azimuth of the roof panels as well as the location (use Wilmington DE solar radiation data set). You may also need to change the size of the load. You will then hook up your system to the panels and analyze the results to determine the performance of your system and how well it matched your predicted performance. You should aim to take data over one week.

Data Sources

Solar radiation data. In order to perform accurate calculations, particularly for battery sizing, you will need solar radiation data sets for your location. The US data is available to all and can be obtained from the site: http://rredc.nrel.gov/solar/old_data/nsrdb/. The TMY2 data files, and the manual that goes with it, can also be obtained from: http://rredc.nrel.gov/solar/old_data/nsrdb/tmy2/ .

Worldwide data is trickier. The site: http://wrdc-mgo.nrel.gov/ is a link to the World Radiation Data Centre. However, this data is not in TMY or similar format and accessing the data is interesting to say the least (http://wrdc-mgo.nrel.gov/html/data_access.html). Also most sites (like http://eosweb.larc.nasa.gov/cgi-bin/sse/sse.cgi?+s01#s01) will give

the data as average insolation per month or perhaps day and that is about it. If you find a way to get hourly data then please let me know. For the purpose of this project you may assume that the data for a year (if you can get it) is equivalent to the TMY data.

Module and Battery Information. You should get an idea of the modules and batteries available, and include these in your report. You may find information on panels at either the following site: http://www.solarbuzz.com/solarindex/CellManufacturers.htm as well as: http://www.solarbuzz.com/solarindex/ModuleManufacturers.htm. A more manageable site (though with limited selection) is http://www.solarhome.org/solarpanelscenter.html. http://www.wholesalesolar.com/products.html may also be useful to start off. Of course there are many other sites available, and you are free to use any you find, but they must give the price, maximum power point current and voltage and most importantly you must reference it. Most sites should also have battery information.

Assessment

Each person will be assessed for the overall project based upon the following:

- 65%: The overall grade of the final written report. The overall report mark consists of:
    - 10% system plan
    - 35% system design
    - 30% system implementation and measurement
    - 25% system analysis
- 25% Oral presentation. Each person in the group will be responsible for one section of the oral report and will be graded individually on this section.
- 10% Peer assessment: Each person in the group will be required to fill out a peer assessment table. This is handed in for each person individually and is not shown to other members of the group. Each person receives the aggregate from other team members.

Problems with individuals in groups should be brought to the attention of Dr Bremner or Dr Barnett, at least two weeks before the final report is due, for a resolution of the problem.