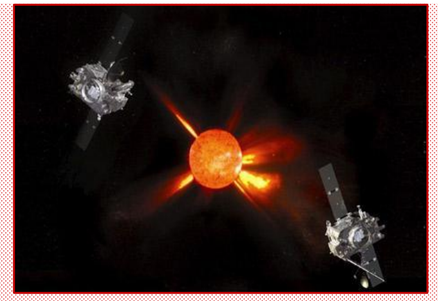
Maximum Power of a Solar Panel

Michael Miller (mmille11@mail.usf.edu)

Dr. Gerald Hefley, Mathematics and Statistics

Dr. Scott Campbell, Chemical and Biomedical Engineering



Abstract

Solar energy has become a promising alternative to conventional fossil fuel sources. Solar panels are used to collect solar radiation and convert it into electricity. One of the techniques used to maximize the effectiveness of this energy alternative is to maximize the power output of the solar collector. In this project, maximum power is calculated by determining the voltage of maximum power. These quantities are determined by finding the maximum value for the equation of power using differentiation. After the maximum values are found for each time of day, voltage of maximum power and maximum power are plotted as a function of the time of day.

Problem Statement

The current voltage relationship (I-V curve) for a particular photovoltaic solar module is represented by:

$$I=I_{PV}-I_0(e^{bV}-1) \qquad (1)$$

Where I_0=4.1x10^{-5} amps and b=0.5. The photovoltaic current I_{PV} is variable and depends on the amount of solar radiation, which in turn, depends on the time of day. For this solar module,

$$I_{PV} = 2.54\sin[\frac{\pi}{12}(t-6)] \qquad (2)$$

where I_{PV} is in amps and t represents the hour of the day (from t=6 ,which corresponds to sunrise, to t=12 which is solar noon). A controller has been designed to make the module operate at its maximum power where

$$P = IV \qquad (3)$$

is a maximum. The current and voltage that yield the maximum power will vary with the time of day. The objective is to determine these quantities so that maximum power can be achieved.

Mathematical Approach

•Mathematical analysis was carried out at each hour in the time interval.

•Combined equations (1) ,(2) and (3) so that the resulting equation is dependent on a single variable, voltage V.

•Calculated the value of V that yields maximum power, or *Vmax*.

•Differentiated the equation with respect to V and solved for *Vmax* using the optimization technique of differential calculus.

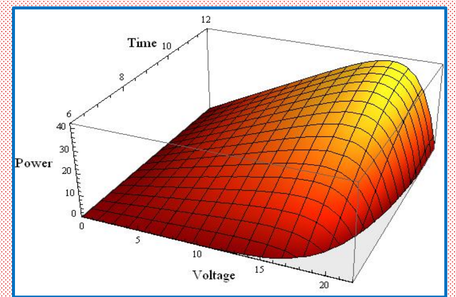


Figure 1- Three dimensional plot of Solar Module Characteristics

t	V_{max}
6	0.000
7	15.076
8	16.259
9	16.885
10	17.252
11	17.450
12	17.512

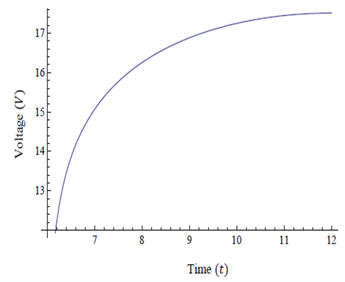


Figure 2- Voltage Vmax which yields maximum power for a solar cell at time t.

Discussion

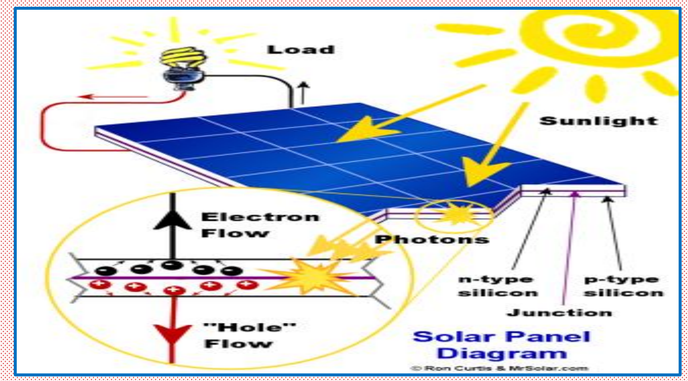
Figure 1 indicates that the maximum power increases as time progresses.

Figure 2 illustrates a similar trend with the voltage of max power. These results are not surprising since the times shown correspond to the period from sunrise to solar noon.

•Results show both the strength and weaknesses of using solar energy as a viable alternative energy.

•Sun provides energy for free, but the current focus is on technologies that collect energy during daylight hours in the visible spectrum of light.

•Devices only operate within earth's atmosphere, where reflection and absorption can reduce the amount of radiation that can be collected.



Conclusions

•The objective of this project was to use the given parameters of a certain solar module to derive the relationship between voltage and power so that the voltage applied at each time of day would consistently maximize power.

•It would benefit engineers involved in designing new solar technologies to also consider low impedance lines between the collector and the storage device.

•More accurate model of device behavior can be gained by also accounting for the effects of temperature.

•New research should be directed towards developing ways to put solar collectors in orbit, so the time of day does not impact max power output.

References

Anderson, Eric, Chris Dohan, and Aaron Sikora. *Solar Panel Peak Power Tracking System*. Rep. no. MQP-SJB-1A03. WORCESTER POLYTECHNIC INSTITUTE, 12 Mar. 2003. Web. <http://ece.wpi.edu/analog/mqps/SolarMQP.pdf>.

"As the Sun Awakens, NASA Keeps a Wary Eye on Space Weather." *NASA Science*. National Aeronautics Space Administration, Web. Photograph. <http://science.nasa.gov/science-news/science-at-nasa/2010/04jun_swef/>.

Curtis, Ron. Photograph. *About Solar Energy*. Terza Solar Power LTD. Web. <http://www.terzasolarpower.com/about.html>.

Emspak, Jesse. "Chasing Rainbows: Full-Spectrum Photovoltaics." *Scientific American* 23 Dec. 2008. *Scientific American*. Nature America, Inc, Jan. 2009. Web. <http://www.scientificamerican.com/article.cfm?id=chasing-rainbows>.

Fraas, Lewis M., and Larry D. Partain. *Solar Cells and their Applications [Electronic Resource]*. 2nd ed. Hoboken: John Wiley & Sons, Inc, 2010. Print.