IRBAS
www.irbas.academyirmbr.com
International Review of Basic and Applied Sciences
April 2016
Vol. 4 Issue.4

Design of a Solar Balloon Testing Facility

CHAN HAM
Kennesaw State University, Marietta, Georgia, USA
Email: chan.ham@kennesaw.edu
Tel: +16789157318

KUO-CHI LIN
University of Central Florida, Orlando, Florida, USA
Email: kurt.lin@ucf.edu
Tel: +14078230137

WEIWEI DENG
Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA
Email: weiwei@vt.edu
Tel: +15402317388

Abstract

Solar energy is the most abundant energy source on earth. The solar balloon in this paper is referring to a solar energy collection balloon. A testing facility is built and data are collected. The major objective is to prove that the surfaces that do not directly face the sun can still collect a fair amount of energy. The preliminary results have confirmed the technical approach.

Key Words: *Solar, Energy, Balloon, Collection Efficiency, Test Facility.*

Introduction

Most of the energy resources on Earth originate from the sun. Fossil fuels, wind and wave energies are indirect forms of solar energy. Therefore, there have been diverse technical schemes developed in order to efficiently produce energy from the sun.

The term “solar balloon” has two different meanings. One is a balloon that absorbs solar energy to heat the air inside the balloon and increase its buoyancy. It is just one type of the hot-air balloons and it has a long history. Recently, its usage has been expanded to space missions (Aliasi et al., 2012, Biggs et al., 2010, Blamont et al. 2002, & Jones et al. 1999). The second definition of solar balloon refers to a balloon that is used to collect solar energy for other applications. This type of balloon acts as a solar collector. The solar balloon in this paper is referring to a solar energy collection balloon.

Currently, photovoltaic (PV) based solar panels have been in the commercial-use phase for some time and are available in hardware stores. The history of PV module development started with rigid silicon solar cells. Therefore, flat-panel type solar energy collectors have their technology advantages in manufacturing and installation.

However, in city or residential areas, the flat-panel solar collector has its limitations. For example, the solar panels should always face true south if they are in the northern hemisphere, but the space for an ideal installation may not always be available. Even if they can face the right direction, nearby higher buildings may block the sunrays from that direction. Additionally, the sun's angles in the sky vary according to the days in the year and the inclination of the panel can only be made optimal in certain times during the year. To most solar collectors, the sun-tracking system is too expensive and impractical, and some cannot even adjust their inclinations manually.

Lin, et al, have proposed a new idea that can solve the above problems: forming the solar cells onto a spherical thin shell and enveloping it around a balloon (Lin et al., 2014). When the balloon is raised to a certain height, it will not be blocked by the surrounding buildings and can receive the sunrays from all directions in all seasons. Researchers have suggested various types of solar energy collecting balloons (Papageorgiou et al., 2007 & Online 2008). The concept Lin, et al, suggested is to wrap solar cells around a balloon, or "print" the solar cells directly on a surface of the balloon. This approach increases the areas of solar energy collection efficiency, compared with the solar balloon concepts suggested by other researchers.

The feasibility of direct printing solar cells is ensured by the rapid progress in discovering new semiconducting polymers and the development of polymer photovoltaic devices. Polymer solar cells (PSCs) are a light weight, flexible, and potentially a low cost form of organic photovoltaics (OPV). The energy conversion efficiency of OPV has increased steadily, with the record cell efficiency reaching 12% (Rohr et al., 2013). PSCs have followed a similar trend towards increased performance. Two major factors have been instrumental to the steady increase of efficiency in PSCs (Gao et al., 2010, Chen et al., 2019, Brabec et al. 2011, Yu et al., 2011, Huo et al. 2010, Price et al., 2009, & Mondal et al. 2010), namely, the bulk heterojunction interpenetrating network and development of novel low band gap materials (Yu et al., 1995, Liang et al., 2009, & Liang et al. 2010). These newly discovered semiconducting polymers can cover a wider range of the solar spectrum, improve interchain ordering, and possess increased stability at elevated temperatures. Most importantly, the liquid phase of such polymer solutions enable a wide range of processing methods such as screen printing (Shaheen et al., 2001), pad printing (Krebs et al., 2009), inkjet printing (Aernouts et al., 2008), spray coating (Hoth et al., 2009), and electrospray printing (Zhao et al., 2012). These new methods make it possible to fabricate flexible, stretchable, and low cost solar cells on curved surfaces.

Objective of the Testing Facility

Lin, et al, have compared the solar energy reception efficiency of the spherical- and flat-surface solar energy collectors (Lin et al., 2014). The main advantage of a spherical-surface collector is that its solar energy reception efficiency does not depend on the sun angles in different times during the day or in different seasons in a year. Therefore, no sun-tracking device is needed.

A flat-surface, with all solar cells having the same incident angle, is more efficient when facing the sun. However, the sun angle varies during the day and in a year. In a large solar farm, adding a tracking-device can improve the efficiency. But sun-tracking is not very practical for the smaller-scale applications. A spherical-surface, on the other hand, with only half of the surface area on the sunny side and the incident angle of each solar cell depending on its longitudinal position on the surface, is less efficient than the flat surface if the sun angle is the same.

Lin, et al, have argued that the spherical-surface collectors can have reasonable solar energy reception efficiency because, in addition to the direct sunray on the sunny side, they also receive the scattered and reflected solar energy from the environment in all directions. The objective of this research is to experimentally determine the solar energy receptions of the spherical surface in all positions.

Design and Implementation

Figure 1 shows the design concept of the test facility. The wireframe sphere on top, representing the spherical solar energy collector, will be covered by solar cells. Below it is a cubic housing unit that can store the sphere in bad weather. The hand crank on the side is a mechanism to raise or lower the sphere. The top cover of the housing unit can be slid to one side, supported by two rods, to allow the sphere to be cranked up.

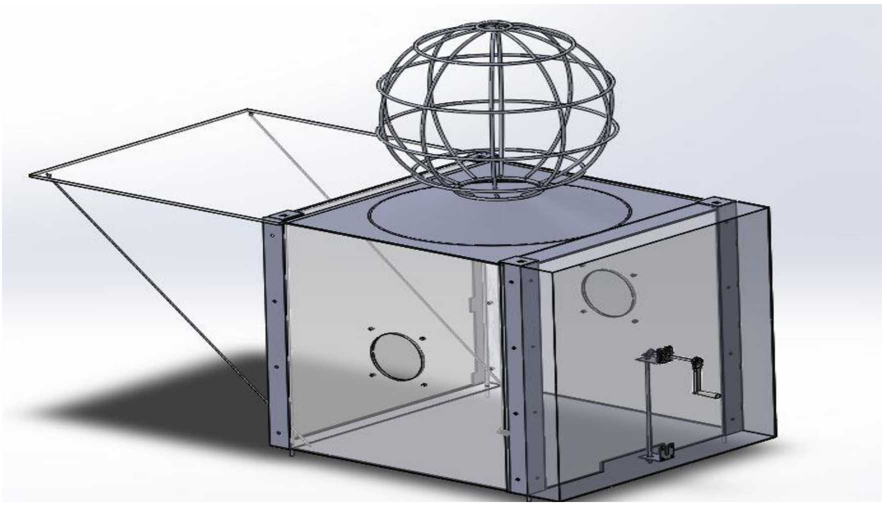

Figure 1 Conceptual Design

The hardware implementation are shown the following figures. Figure 2 shows the wireframe sphere. Figure 3 shows the housing unit with the lifting mechanism. The black plywood box on the side is the crank housing. Figure 4 shows the final assembly of the testing facility. There are 32 solar panels covering the wireframe sphere, which is sitting on the platform lifted up by the lifting mechanism. The top and bottom layers of panels are attached at a roughly 45 degree angle and in an overlapping pattern to provide complete coverage. The middle two layers are orientated horizontally, with 8 panels in each layer and with the overlap as even as possible. The data acquisition system with wirings are mounted below the platform.

Figure 2 Wireframe Sphere

Figure 3 Housing Unit with lifting mechanism

Figure 4 Final Assembly

Data and Results

The Arduino MEGA 2650 data acquisition system is used to record the data from the solar panels covering the sphere. Data are stored in an SD card to be read in a computer. The sampling rate is one data point per minute for each solar cell.

Figure 5 shows the output voltages versus time of a solar cell on the upper portion of the sphere. The higher "Sunny" curve represents the data taken when the cell directly faces the sun, and the lower "Shaded" curve represents the data taken when the cell is shaded by the clouds, trees, or in the case, the sphere itself. In other words, the lower curve is the output voltages when the solar cell is "on the dark side", which still can produce approximately 60% of the output voltage when it directly faces the sun.

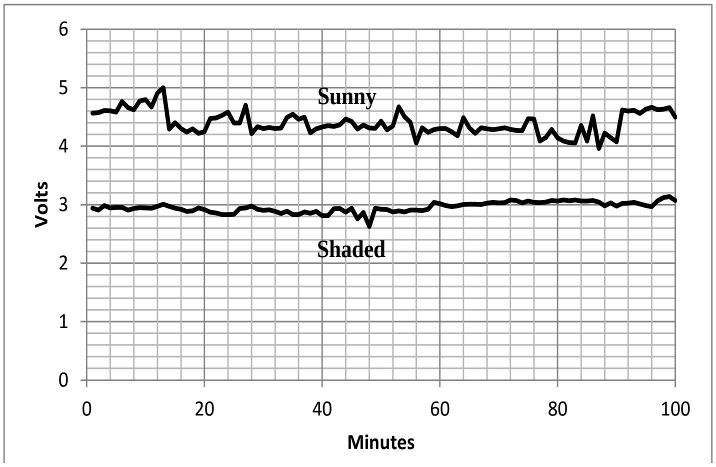

Figure 5 Output of a solar cell on the upper portion of the sphere and in the path of the sun.

Figure 6 shows the output voltages versus time of a solar cell that has a larger angle of incidence. The outputs are lower than the outputs shown in Figure 5; however, the outputs taken when the cell is shaded are still about 50% of the outputs when it is on the sunny side.

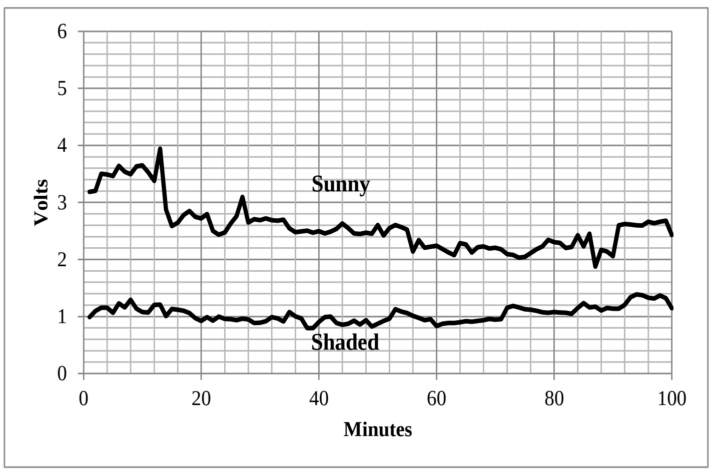

Figure 6 Output of a solar cell not in the path of the sun.

Figure 7 shows the output voltages versus time of a solar cell on the bottom of the sphere and not in the path of the sun. The outputs are very low even when it is in the sunny side. When it is shaded, the outputs are close to zero. The authors believe that it is due to the black-colored platform under the sphere that absorbs and blocks the lights.

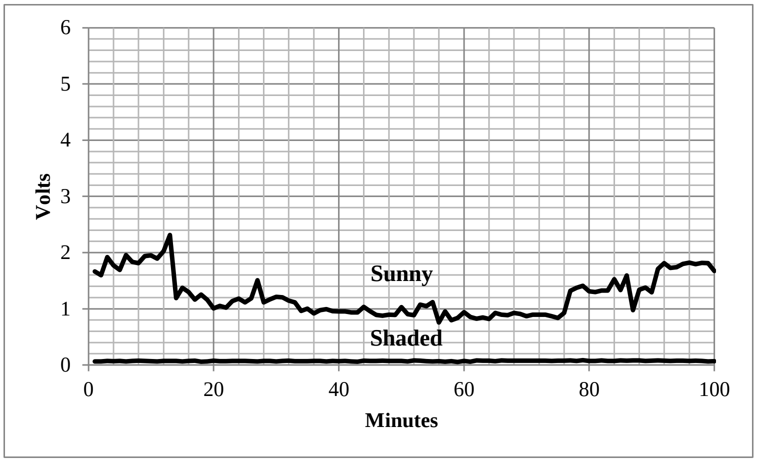

Figure 7 Output of a solar cell on the bottom and not in the path of the sun.

Discussion and Future Improvements

The data from this testing facility have partially proved that the dark side of a solar balloon can still harvest significant amount of solar energy, as suggested by (Lin et al., 2014). More data needs to be collected to better understand the overall efficiency of the solar balloons.

In addition, the design of the testing facility can be improved. The future improvement scheme is as follows:

1. Replace the platform with a sturdy pole to avoid blocking the radiation energy that the solar cells on the bottom of the sphere can receive. The sphere can be store indoor in bad-weather days.
2. The solar cells do not need to cover the whole sphere. The overlapping of the solar panels in the current design makes the accurate calculation of energy reception difficult.

Acknowledgements

This research is partially sponsored by Duke Energy.

References

Aliasi, G., Mengali, G., & Quarta. A. (2012). Passive control feasibility of collinear equilibrium points with solar balloons. *Journal of Guidance, Control, and Dynamics*, 35(5), 1657 - 1661.

Biggs, J. & Mcinnes, C. (2010). Passive Orbit Control for Space-Based Geo-Engineering. *Journal of Guidance, Control, and Dynamics*, 33(3), 1017 - 1020.

Blamont, J. & Jones, J. (2002). A new method for landing on Mars. *Acta Astronautica*, 51(10), 723 - 726.

Jones, J. & Wu, J. (1999). Solar Montgolfiere balloons for Mars. *International Balloon Technology Conference* (Paper No. AIAA-99-3852).

Lin, K., Deng, W., Gu, J., & Ham, C. (2014). Solar Energy Collection on a Spherical Surface, *Journal of Energy and Environmental Engineering*, 2, 48-54.

Papageorgiou C. (2007). Floating Solar Chimney versus Concrete Solar Chimney Power Plants. Clean Electrical Power, *2007 ICCEP '07 International Conference* (pp. 21-23).

Online Available (2008): http://cleantechnica.com/2008/09/13/cool-earth-solar-solar-power-from-balloons/

Rohr S. Heliatek consolidates its technology leadership by establishing a new world record for organic solar technology with a cell efficiency of 12%. Press Release: Heliatek GmbH, Dresden, Germany, January 16, 2013. Online available: http://www.heliatek.com/wpcontent/uploads/2013/01/130116_PR_Heliatek_achieves_record_cell_effiency_for_OPV.pdf

Gao, Y., Martin, T., Niles, E., Wise, A., Thomas, A., & Grey, J. (2010). Understanding Morphology-Dependent Polymer Aggregation Properties and Photocurrent Generation in Polythiophene/Fullerene Solar Cells of Variable Compositions. *The Journal of Physical Chemistry C*, 114(35), 15121-8.

Chen, Z., Zheng, Y., Yan, H., & Facchetti, A. (2009). Naphthalenedicarboximide- vs Perylenedicarboximide-Based Copolymers. Synthesis and Semiconducting Properties in Bottom-Gate N-Channel Organic Transistors. *J. of the American Chemical Society*, 131(1), 8-9.

Brabec, C., Heeney, M., McCulloch, I., & Nelson, J. (2011). Influence of blend microstructure on bulk heterojunction organic photovoltaic performance. *Chemical Society Reviews*, 40(3), 1185-99.

Yu, F., Wang, H., & Zou, S. (2011). Efficient and Tunable Light Trapping Thin Films. *The Journal of Physical Chemistry C*, 114(5), 2066-9.

Huo, L., Hou, J., Zhang, S., Chen, H., & Yang, Y. (2010). A Polybenzo [1,2-b:4,5-b′] dithiophene Derivative with Deep HOMO Level and Its Application in High-Performance Polymer Solar Cells. *Angewandte Chemie International Edition*, 49(8), 1500-3.

Price, S., Stuart, A., & You, W. (2009). Polycyclic Aromatics with Flanking Thiophenes: Tuning Energy Level and Band Gap of Conjugated Polymers for Bulk Heterojunction Photovoltaics. *Macromolecules*, 43(2), 797-804.

Mondal, R., Becerril, H., Verploegen, E., Kim, D., Norton, J., Ko, S., Miyaki, N., Lee, S., Toney, M., Brédas, J., McGeheec, M., & Bao, Z. (2010). Thiophene-rich fused-aromatic thienopyrazine acceptor for donor-acceptor low band-gap polymers for OTFT and polymer solar cell applications. *Journal of Materials Chemistry*, 20(28), 5823-34.

Yu, G., Gao, J., Hummelen, J., Wudl, F., & Heeger, A. (1995). Polymer Photovoltaic Cells: Enhanced Efficiencies via a Network of Internal Donor-Acceptor Heterojunctions. *Science*, 270(5243), 1789-91.

Liang, Y., Feng, D., Wu, Y., Tsai, S., Li, G., Ray, C., & Yu, L. (2009). Highly Efficient Solar Cell Polymers Developed via Fine-Tuning of Structural and Electronic Properties. *Journal of the American Chemical Society*, 131(22), 7792-9.

Liang, Y., Xu, Z., Xia, J., Tsai, S., Wu, Y., Li, G., Ray, C., & Yu, L. (2010). For the Bright Future—Bulk Heterojunction Polymer Solar Cells with Power Conversion Efficiency of 7.4%. *Advanced Materials*, 22(20), E135-E8.

Shaheen, S., Radspinner, R., Peyghambarian, N., & Jabbour, G. (2001). Fabrication of bulk heterojunction plastic solar cells by screen printing. *Applied Physics Letters*, 79(18), 2996-8.

Krebs, F. (2009). Pad printing as a film forming technique for polymer solar cells. *Solar Energy Materials and Solar Cells*, 93(4), 484-90.

Aernouts, T., Aleksandrov, T., Girotto, C., Genoe, J., & Poortmans, J. (2008). Polymer based organic solar cells using ink-jet printed active layers. *Applied Physics Letters*, 92(3), 3330-6.

Hoth, C., Steim, R., Schilinsky, P., Choulis, S., Tedde, S., Hayden, O., & Brabeca, C. (2009). Topographical and morphological aspects of spray coated organic photovoltaics. *Organic Electronics*, 10(4), 587-93.

Zhao, X., Lojewski, B., Yang, W., Zhu, T., Mi, B., Gao, Z., Huang, W., & Deng, W. (2012). Electrospray as a Fabrication Tool in Organic Photovoltaics. *Reviews in Nanoscience and Nanotechnology*, 1(3), 15.