International Journal of Advanced Research in
Engineering and Applied Sciences

ISSN: 2278-6252
Impact Factor: 5.795

SOLAR CELL HARVESTING: GREEN RENEWABLE TECHNOLOGY OF FUTURE

Jaya Pandey*

Richa Khare**

Smriti Khare**

Dheeraj Singh**

Abstract: *Solar energy which is a combination of light and heat is produced by sun. This energy moves from sun and reaches the earth where human collects it through solar collectors and convert it into any desirable form of energy. To convert sunlight into electricity solar panels, photoelectric technologies and thermoelectric technologies etc are used. This solar energy is running solar heater to supply hot water in homes. Through photovoltaic cell installed on the roof of the house energy is captured and stored on batteries to use throughout the day. These solar cells consist of silicon material and an electric field across the silicon drives the electrons away from the holes into a conducting metal material, where they then flow as current. Still work is going on that how can we utilize solar energy for different purposes.*

Key Words: *MSP, CCS, selenium, PV, silicon and AMO*

*Amity School of Applied Sciences, Amity University, Lucknow Campus, Uttar Pradesh

**Amity School of Engineering & Technology, Amity University, Lucknow Campus, Uttar Pradesh

INTRODUCTION

A solar cell is capable of converting light direct into electric energy. Most solar cells consist of silicon material. Light is often present for a longish period, during which the light energy can be accumulated in storage mechanisms and then used when needed.

Photovoltaic cells convert solar radiation directly into electricity. When photons of sunlight strike the cell, electrons are knocked free from silicon atoms and are drawn off by a grid of metal conductors, yielding a flow of direct current.Light creates electricity in silicon solar cells when each photon dislodges a single electron in the silicon, leaving behind a "hole" — an effective positive charge — where it once was. An electric field across the silicon drives the electrons away from the holes into a conducting metal material, where they then flow as current.

But silicon solar cells only absorb photons from some parts of the visible light spectrum. Sunlight at shorter blue and green wavelengths converts into heat, effectively wasting that light. Silicon solar cells only absorb photons from some parts of the visible light spectrum. Sunlight at shorter blue and green wavelengths converts into heat, effectively wasting that light

An article in *Science* magazine noted:“If there is a dream solar technology it is probably photovoltaic – solar cell. They have no moving parts and are consequently quiet, extremely reliable, and easy to operate. Photovoltaic cells are a space age electronic marvel, at once the most sophisticated solar technology and the simplest, most environmentally benign source of electricity yet conceived.”

HISTORY

In the 1860s, an electrician called Willoughby Smith was testing underwater telegraph lines for faults using a material called **selenium**. By chance, he discovered that electricity travelled through selenium very well when it was in light, but it didn’t if the selenium was in darkness.

In the late 1870s, two American scientists, William Adams and Richard Day, soon discovered that the sun’s energy creates a flow of electricity in selenium.

Then in the early 1880s, Charles Fritts invented the first **PV** cell by putting a layer of selenium on a metal plate and coating it with gold leaf. Placed in the sunlight, this cell made even more electricity but not enough to be useful.

The most productive and famous year in modern science, 1905 was the year when Einstein at the age of 26 years published four science shaking papers. This year later named as annus mirabilis (miracle year).[1-2]

One of those papers was on the Production and Transformation of Light which is today known as Photoelectric Effect which lead to the development of photovoltaic (PV) cell. Einstein explained how light was made of tiny packets of energy that wiggled like waves as they sped along. He called the energy packets photons.

EARLY DEVELOPMENTS

In the early 1950s, Calvin Fuller and Gerald Pearson, two scientists who worked at the Bell Laboratories in the USA, were trying to improve **silicon transistors** for electrical equipment. By accident they created a PV cell that also generated electricity when it was placed in light. It was made out of two different kinds of silicon that had different metals mixed in.

In 1953, another Bell scientist called Daryl Chapin was trying to make selenium cells better at generating electricity. But he wasn't having much success. After Pearson told Chapin about his accidental silicon PV cell, Chapin started to look into it straight away. The Bell scientists were excited to find that silicon PV cells made nearly five times more electricity than selenium cells.

After a year, by mixing tiny amounts of different chemicals into slices of silicon crystals, the PV cells they invented were 50 times more efficient at generating electricity than the selenium cells had been 20 years earlier.

In 1976, scientists began make silicon PV cells using silicon made from lots of small crystals joined together, called amorphous silicon. These types of PV cells are not as expensive to make as silicon cut from single crystals. But they can only create low amounts of electricity.

The first silicon cells were described by Ohl in 1941 using melt grown junctions. From the description of these devices, efficiency is assessed as less than 1%. The next step forward was reported in 1952 when Kingsbury and Ohl reported devices with junctions formed by helium ion bombardment. Cell efficiency then evolved rapidly with the introduction of diffused junctions. Bell Laboratories fabricated a cell with 4.5% efficiency in 195328 and 6% in 1954. The 10% efficiency mark was exceeded within 18 months. In 1961, a 14.5% terrestrial cell efficiency was measured for a commercial cell fabricated upon a phosphorus doped substrate.32 With the switch to boron doped substrates about this time, lower efficiency was obtained, but a higher radiation tolerance in space. It was not until the early 1970's that efficiencies on boron-doped substrates approached this 14.5% figure. The first cell to convincingly exceed this 14.5% figure was the 'violet' cell developed at Comsat Laboratories in the early 1970s introducing a second phase of cell development. This mark was soon exceeded by the Comsat non-reflecting cell using textured surfaces. These displayed efficiencies above 15% under the AMO spectrum. The next improvement was in 1983 when the UNSW MINP cell demonstrated 18% efficiency for the first time, introducing the modern period of cell development. From this date, Table I documents subsequent improvements, with the leading cell technology transitioning from MINP to PESC, to rear point contact cells, to PERC cells and ultimately to the PERL cell.[3-4]

Table I. History of silicon cell improvement (>1 cm2 area) over the modern era normalised to present standard test conditions (258C, 1000 W/m2, IEC 60904-3: 2008 global spectrum, equivalent to ASTM G173-03 global spectrum)

Date	Reported Efficiency (%)	Test Conditions*	Corrected efficiency (%)	Cell description
1/83	16.5	SERI 1 (t)	15.9	ORNL
5/83	17.1	SERI 1 (t)	16.5	ASEC
8/83	17.1	SERI 1 (ap)	16.5	Westinghouse
9/83	18.0	SERI 1 (t)	17.4	Spire textured
	18.7	SERI 1 (t)	18.1	UNSW MINP
12/83	19.1	SERI 1 (t)	18.4	UNSW PESC
5/85	19.8	SERI 1 (ap)	19.1	UNSW PESC
10/85	20.0	SERI 2 (ap)	20.2	UNSW µ g PESC
7/86	20.6	SERI 2 (da)	20.8	UNSW µ g PESC
4/88	21.4	SANDIA 2 (ap)	21.0	UNSW µ g PESC
9/88	22.3	SERI 2 (ap)	22.5	Stanford
6/89	23.2	SANDIA 2 (ap)	22.6	UNSW PERC
12/89	23.0	SERI 2 (ap)	23.2	UNSW PERL
2/90	24.2	SANDIA 2 (ap)	23.4	UNSW PERL
3/94	23.5	ASTM E892 (ap)	23.7	UNSW PERL
9/94	24.0	ASTM E892 (ap)	24.2	UNSW PERL
2/98	24.4	ASTM E892 (da)	24.7	UNSW PERL
11/98	24.5	ASTM E892 (da)	24.7	UNSW PERL
3/99	24.7	ASTM E892 (da)	25.0	UNSW PERL

*** (t)=total area, (ap)=aperture area, (da)=designated illumination area.**

Innovations And Developments To Increase The Solar Energy Harvesting Efficiency

1. Excitonic Dye Solar Cells

In this work solar cells based on the inorganic semiconductor titanium dioxide and hole-transporting dyes are investigated. These type of solar cells are categorized as hybrid solar cells and are conceptually related to both dye-sensitized solar cells and organic solar cells. Light absorption in the bulk of the hole-transporting dye layer leads to the formation of excitons that can be harvested at the organic/inorganic interface. Two design approaches were investigated: 1) utilizing a multilayer of a hole-transporting dye and 2) utilizing a hole-transporting dye as light harvesting antenna to another dye which is bound to the titanium dioxide surface. [5]

Using a multiple dye layer in titanium dioxide/hole transporting dye devices, leads to an improved device performance as light harvested in the consecutive dye layers can contribute to the photocurrent. In devices using both an inteface-bound dye and a hole-transporting dye, excitation energy can be transferred from the hole-transporting dye to the interface dye.

Maximum Power Point Tracking (MPPT)

One main limitation with many mobile and ubiquitous systems is the battery life. Battery replacement is not only inconvenient but also it adds to the bulk and cost. The design goals of an energy harvesting system for mobile and ubiquitous computing systems include high conversion efficiency, low overhead, low cost ,long operating life, and small size. An important problem that must therefore be addressed is that of maximum power point tracking (MPPT).

The maximum power point (MPP) is the load at which the transferred power (= I_V) is maximized for a given level of ambient power. By tracking the MPP, the system can harvest more energy using a smaller panel than one that uses a larger panel but does not perform MPPT. However, it is important to minimize overhead for MPPT, because the overhead may more than offset the gain. [6]

A key component associated with energy harvesting is energy storage. Energy storage is commonly used to sustain long periods of operation without steady supply of ambient power.

By default, rechargeable batteries are used, but more recently, supercapacitors are used either in addition to or instead of batteries because of many more recharge cycles and higher power density. However, unlike batteries, where the voltage remains relatively even over most of the battery's remaining charge levels, a capacitor's voltage scales linearly with the remaining energy. This means additional circuitry is required to make the energy usable. Another related issue with energy harvesting systems with storage is that of cold booting. This is a condition when the system starts running from zero stored energy. If the system starts booting up as soon as it has harvested enough energy, it is likely to drain the energy shortly after booting, forcing the system to reset and repeat the cycle of futile attempts to boot up. The better solution is to hold off booting until sufficient energy has been harvested, although being too conservative translates into increased latency.

MATERIALS AND COMPONENTS

The major materials in the CSP value chain are silica, iron and steel, concrete, plastic (or polyvinyl chloride), brass, synthetic oil, copper, aluminum, and molten salt. Figure 4-3 highlights the major country sources for these materials and their corresponding components. Table 4-1 highlights some CSP component manufacturing companies.5 A CSP plant has four major systems: the collector, steam generator, heat storage, and central control. The collector system components vary depending on the type of CSP plant. In addition to the components listed in Figure 4-3, concentrating solar power plants have many other elements not outlined here because they represent standard technology for generating electricity. These include a natural gas boiler, steam turbine, steam generator, condenser, and cooling tower. These components would certainly be a part of the production process for any CSP plant and would contribute to further manufacturing and construction needs.

One of the barriers to the wider adoption of solar energy is its high cost. One of the best ways to make the technology more affordable is to increase how efficiently the solar cells harvest energy from the sun.[7]

NEW DEVELPOMENTS

Emerging Nanopower Wireless

Sensor Applications

In the case of building automation,systems such as occupancysensors, thermostats and light switches can eliminate the power or control wiring normally required and use a mechanical or energy harvesting system instead. This alternative approach can also mitigate the costs of routine maintenance normally associated with wired systems in addition to eliminating the need for wiring to be installed in the first place, or for regular battery replacement in wireless applications.

Concentrated Solar Power

CSP plants concentrate beams of light from the sun to heat a fluid and produce steam. The steam rotates a turbine connected to a generator, producing electricity to run a traditional power plant. There are four types of CSP technologies: parabolic troughs, power towers, dish/engine systems, and linear Fresnel reflectors. The parabolic trough system was the first CSP technology, thus it is the most developed and most commonly replicated system. Deployment of the other technologies is relatively new and in some cases, as with the linear Fresnel reflector technology, projects currently being developed are the first to reach utility-scale magnitude. Parabolic trough technology uses parabolic reflectors to concentrate the sun’s rays into a receiver pipe along the reflector’s focal line. The receiver heats a liquid which generates steam for power. This collector system rotates with the sun’s movement to optimize solar energy generation (Solar Energy Technologies Program, 2008a). Power tower systems use flat mirrors to reflect the sun’s rays onto a water-filled boiler atop a central tower. The liquid is heated to a very high temperature and runs the turbine to create electricity (BrightSource Energy, 2007). Dish/engine systems use parabolic reflectors to direct the sun’s rays at a receiver placed at the reflector’s focal point.

The liquid in the receiver is heated and runs a Stirling engine to create power (Solar Energy Technologies Program, 2008b). Linear Fresnel reflector technology works much like the parabolic trough system, except that it uses flat mirrors that reflect the sun onto water-filled pipes that generate steam. This is a significant cost advantage because flat mirrors are much less expensive to produce than parabolic mirrors (Ausra, 2008b). Current advances in CSP allow these technologies to produce electricity several hours after sunset and on days with low intensity of solar radiation through heat accumulators and hybrid configurations.[8,9]

Solar Thermal vs. Photovoltaic

Solar thermal electric energy generation concentrates the light from the sun to create heat which is used to run a heat engine, which turns a generator to make electricity. The working fluid that is heated by the concentrated sunlight can be a liquid or a gas. Different working fluids include water, oil, salts, air, nitrogen, helium, etc. Different engine types include steam engines, gas turbines, Stirling engines, etc. All of these engines can be quite efficient, often between 30% and 40%, and are capable of producing 10's to 100's of megawatts of power.

Photovoltaic, or PV energy conversion, on the other hand, directly converts the sun's light into electricity, which are only effective during daylight hours and storing electricity is not a particularly efficient process. Heat storage is a far easier and efficient method, which is what makes solar thermal so attractive for large-scale energy production. Heat can be stored during the day and then converted into electricity at night. Solar thermal plants that have storage capacity can drastically improve both the economics and the dispatch ability of solar electricity. [10-12]

Other energy harvesting technologies

Piezoelectric

The piezoelectric effect converts mechanical strain into electric current or voltage. This strain can come from many different sources. Human motion, low-frequency seismic vibrations, and acoustic noise are everyday examples. Except in rare instances the piezoelectric effect operates in AC requiring time-varying inputs at mechanical resonance to be efficient.[13]

Pyroelectric

The pyroelectric effect converts a temperature change into electric current or voltage. It is analogous to the piezoelectric effect, which is another type of ferroelectric behavior. Pyroelectricity requires time-varying inputs and suffers from small power outputs in energy harvesting applications due to its low operating frequencies. However, one key advantage of pyroelectrics over thermoelectrics is that many pyroelectric materials are stable up to 1200 ^{o}C or higher, enabling energy harvesting from high temperature sources and thus increasing thermodynamic efficiency.[14]

Thermoelectrics

At the heart of the thermoelectric effect is the fact that a temperature gradient in a conducting material results in heat flow; this results in the diffusion of charge carriers. The flow of charge carriers between the hot and cold regions in turn creates a voltage difference. Today, due to knowledge of the Seebeck and Peltier effects, thermoelectric materials can be used as heaters, coolers and generators (TEGs).

Electrostatic (capacitive)

This type of harvesting is based on the changing capacitance of vibration-dependent capacitors. Vibrations separate the plates of a charged variable capacitor, and mechanical energy is converted into electrical energy. Electrostatic energy harvesters need a polarization source to work and to convert mechanical energy from vibrations into electricity. The polarization source should be in the order of some hundreds of volts; this greatly complicates the power management circuit. [15]

Magnetic induction

Magnets wobbling on a cantilever are sensitive to even small vibrations and generate microcurrents by moving relative to conductors due to Faraday's law of induction. By developing a miniature device of this kind in 2007, a team from the University of Southampton made possible the planting of such a device in environments that preclude having any electrical connection to the outside world. Sensors in inaccessible places can now generate their own power and transmit data to outside receivers.

These harvesters are now being supplied in large volumes to power wsn's made by companies such as GE and Emerson and also for train bearing monitoring systems made by Perpetuum. Overhead powerline sensors can use magnetic induction to harvest energy directly from the conductor they are monitoring.

Metamaterial

A metamaterial-based device wirelessly converts a 900 MHz microwave signal to 7.3 volts of direct current (greater than that of a USB device). The device can be tuned to harvest other signals including Wi-Fi signals, satellite signals, or even sound signals. The experimental device used a series of five fiberglass and copper conductors. Conversion efficiency reached 37 percent. When traditional antennas are close to each other in space they interfere with each other.[16]

CONCLUSION

Despite the sun’s enormous size, and because of its distance from the earth, it is not quite a point source. It actually occupies 1/2° in the sky. When making a concentrator, the architecture of the system needs to take into account this subtended angle of the sun.

The maximum theoretical concentration of line focus is 212:1. Line focus solar thermal plants are reporting 80-100x concentration, with some claiming 112x – in other words, people are achieving about half of the maximum theoretical concentration. It's hard to get more than this because of errors in the parabolic shape, thermal expansion and shifting of parts over time, and optical alignment of all the moving parts. At these concentrations a steam turbine can be run at roughly 25% efficiency. Even with great technological advancements, the ceiling is set at a maximum of 212:1, so there is not much room for growth.

Point focus, however, has a much higher maximum concentration ratio at 44,000:1. Current technology is reaching 1,000x concentration. Despite being a small fraction of the maximum concentration ratio, point focus' concentration can run a steam turbine at anywhere from 35-50% efficiency. Also, with point focus concentration, there is a lot of room to further improve and run at higher temperatures, and thus even higher efficiencies.

REFERENCES

1. Einstein A hundred years of relativity – Andrew Robinson Student Fact Sheet: A Short History of Photovoltaic (PV) Cells (schoolgen)
2. Geoffrey Jones Loubna Bouamane "Power from Sunshine": A Business History of Solar Energy" Working Paper XDSC : Excitonic Dye Solar Cells
3. Unger, Eva Uppsala University, Disciplinary Domain of Science and Technology. (Hagfeldt) 2012 (English)Doctoral thesis, comprehensive summary (Other academic) Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science and Technology, ISSN 1651-6214 ; 899
4. Martin a Green; "The Path to 25% Silicon Solar Cell Efficiency: History of Silicon Cell Evolution," Progress In Photovoltaics: Research And Applications Prog. Photovolt: Res. Appl. 2009; 17:183–189 Published online in Wiley Inter Science (www.interscience.wiley.com) DOI: 10.1002/pip.892.
5. Ohl RS. "Light sensitive electric device." US Patent 240252, filed 27 March 1941. "Light-sensitive electric device including silicon." US Patent 2443542, filed 27May 1941.
6. Kingsbury EF, Ohl RS. "Photoelectric properties of ionically bombarded silicon." Bell System Technical Journal1952; 31: 8092.

7. Chapin DM, Fuller CS, Pearson GL. “A new silicon p-n junction photocell for converting solar radiation into electrical power.” Journal of Applied Physics 1954; 8: 676.
8. Bell Laboratories Record, November 1954; 436. Bell Laboratories Record, May 1955; 166.
9. Mandelkorn J, McAfee C, Kesperis J, Schwartz L, Pharo W. “Fabrication and characteristics of phosphorus-diffused silicon solar cells.” Journal of the Electrochemical Society 1962; 109: 313–318.
10. Lindmayer J, Allison J. “The violet cell: an improved silicon solar cell.” COMSAT Technical Review 1973; 3: 1–22.
11. Haynos J, Allison J, Arndt R, Meulenberg A. “The Comsat non-reflective silicon solar cell: a second generation improved cell. International Conference on Photovoltaic Power Generation,” Hamburg, September, 1974; 487.
12. Green MA, Blakers AW, Osterwald CR. “Characterization of high-efficiency silicon solar cells.” Journal of Applied Physics 1985; 58: 4402–4408
13. Jacques and Pierre Curie (1880) "Développement par compression de l’électricité polaire dans les cristaux hémièdres à faces inclinées" (Development, via compression, of electric polarization in hemihedral crystals with inclined faces), *Bulletin de la Société minérologique de France*, vol. 3, pages 90 - 93. Reprinted in: Jacques and Pierre Curie (1880) Développement, par pression, de l’électricité polaire dans les cristaux hémièdres à faces inclinées," *Comptes rendus* ... , vol. 91, pages 294 - 295. See also: Jacques and Pierre Curie (1880) "Sur l’électricité polaire dans les cristaux hémièdres à faces inclinées" (On electric polarization in hemihedral crystals with inclined faces), *Comptes rendus* ... , vol. 91, pages 383 - 386.
14. *Yang; Divan, D.; Harley, R. G.; Habetler, T. G. (2006). "Power line sensornet - a new concept for power grid monitoring". 2006 IEEE Power Engineering Society General Meeting. pp. 8 pp. doi:10.1109/PES.2006.1709566. ISBN 1-4244-0493-2.*
15. K. MacVittie, J. Halamek, L. Halamakova, M. Southcott, W. Jemison, E. Katz, "From 'Cyborg' Lobsters to a Pacemaker Powered by Implantable Biofuel Cells", Energy & Environmental Science, 2013, 6, 81-86.
16. *McGarry, Scott; Knight, Chris (28 September 2011). "The Potential for Harvesting Energy from the Movement of Trees". Sensors 11 (10): 9275–9299. doi:10.3390/s111009275. Retrieved 30 November 2012.*