Energy 107 – Solar Cells I

Ken Johnson

This episode pertains to a different kind of solar energy electric power generator, the Photovoltaic Cell (PV), commonly called ‘solar cells’. But before we embark on that subject, a reference was made in the reader Comments of the last episode (ENERGY 106), about another Solar Thermal Energy system that has been getting some traction recently, i.e. the Parabolic Dish/Stirling (PD/S) unit.

As the name suggests, the solar energy input collector of this generator is a large parabolic dish reflector with a small collector panel mounted at the mirror’s focal point. The heat collection fluid passing through the panel may be either a liquid or an inert gas, which is fed to the thermodynamic ‘heat engine’ that drives an electric generator to produce the power output. This heat engine uses a gas as a working substance in an engine operating on the ‘Stirling Cycle’. This cycle was developed by Robert Stirling, in 1816. Its efficiency isn’t as high as the Rankine Cycle using water as a working substance, but it has fewer components and as a consequence, is lighter and less complex to control. Because of these attributes, it has been of interest to NASA for many years for power generation in outer space and has gone through many iterations by both NASA and Sandia National Laboratory (SNL), but its use for massive amounts of Grid power generation is impractical (compared to the Rankine type cycle). Think of the size/number of parabolic dish(s) required to compete with the multi-square mile parabolic trough type collector Solar-Rankine generators (discussed in the previous episode) . . . plus the additional collection area required to make up for the Stirling’s lower thermal efficiency.

There also seems to be some confusion about the ‘solar constant’. It is defined as the rate of solar radiation energy striking the outside of the Earth’s atmosphere at a right angle to its surface. It has a numerical value of 2 gcal/sq cm/min. Some years ago, an X-15 aircraft made a measurement at as high an altitude as possible and measured 1.95 gcal/sq cm/min. No where on the Earth’s surface does that value exist. It maybe approaches that in mid-summer on Mt. Everest’s crest. In English it is 7.43 Btu/sq ft/min. The highest Earth’s surface mean value in 80 selected cities within the US is in Inyokern, CA at 2.2 Btu/sq ft/min (daily average) or 3170 Btu/sq ft/day (The Passive Energy Book, by Edward Mazira, 1979)

So, on to the PV. Photovoltaics have been around for well over a hundred years.

They were thought to be a great approach to ‘green power’ production because this ‘direct’ energy conversion theoretically appeared not susceptible to the Laws of Thermodynamics or the limitations of the Carnot Cycle efficiency principles. However, after a hundred years of PV research, with the expenditure of billions of dollars, they appear to be limited by laws similar to those of thermodynamics and Carnot (Direct Energy Conversion, Stanley Angrist, 1965). I could find no evidence there has ever been a PV made that can convert more than 20% of solar energy into electrical energy . . . plus being severely limited in voltage and current capabilities as well as available sunlight hours. Those details, coupled with: a production cost of about $4 per watt, being susceptible to sun/wind/hail damage, and reduced output due to dust/snow coverage, make PVs very unlikely candidates for massive power generation projects that can in any way approach the low costs of fossil fuel/nuclear steam powered electric power plants and their output. The PVs do serve as excellent low power sources to charge batteries for: remote telephones, telecommunication repeaters, infrequently used vehicles, gate openers, alarms, emergency lighting, fire detectors, hand calculators, etc.

Somewhere, in my assorted junk collection, I have about 30 pounds of PVs made with various ‘thin film’ junction and substrate materials, along with a couple of 3 inch dia./4 inch long silicon ingots, from which thin wafers are sliced and diffused on one side into the p-n junction of a ‘solar cell’. I bought the lot for $0.10 per pound at my favorite junk yard in San Fernando Valley (CA). That’s right, it all cost $3.00 (plus tax). This was surplus material from ARCO when they closed their local PV facility in about 1990 . . . after losing a couple of million dollars on their ”Power of the Future” venture. My PVs were purchased to make a multi-voltage battery charging station for various batteries from autos, hand tools, flashlights, etc., but the task of making wiring connections to them was a bit formidable, to say the least, and a few months later I was able to buy a commercial one for about $10.00 at a local cut-rate tool store.

PVs have appeared to become the be-all end-all solution to the environmentalists as saviors of the planet. Massive grid connectable units are being designed, in construction, and some are in operation, mostly for development testing . . . and mostly at taxpayer expense of course, as we steadily move toward worldwide Socialism. Being driven by the IPCC, who are enforcing sanctions and imposing high fossil fuel CO2 taxes, European countries are well ahead of us in this regard, particularly Germany and most are on the verge of bankruptcy, probably because of having to rearrange their whole electric power generation structure to include ‘green’ technology.
The USA does have some experience, from the International Space Station (ISS), whose main power source is from PVs . . . about 265,000 of them (crystalline silicon) covering about one acre of solar panels. Connected in series/parallel, they provide a 120 VDC main power system with a separate 28 VDC bus to accommodate connections to the Space Shuttle. During their ‘day’ (55 minutes), they supply both buses and store energy in nickel-hydrogen batteries (mounted outside the ISS main pressurized envelope) for use during the ‘night’ (35 minutes).

A huge amount of money is being poured into research on different PV materials all around the world. Most operating cells are very thin crystalline silicon sliced off an ingot, which are then attached to a base material for physical strength. One goal is to be able to grow on or coat some substrate material (metal, plastic, etc.) by vapor deposition of the silicon onto the substrate, forming a 'thin film' of the p-n junction, hence improving the yield and survivability of the silicon, but this lowers the 'efficiency' of the solar energy conversion. There is also a whole potpourri of materials and alloys being tried to decrease the cell costs, improve their survivability, and increase conversion efficiency. One degradation problem is airborne contaminants which affect the viability of the p-n junction. This is partially eliminated by coating the cells with glass, and more recently corundum (sapphire) is being used, which of course raises the price considerably. Using cells in outer space shortens their life because of free protons floating around which strike the cell and nullifies small areas of the junction. Much of this information and more may be found at: http://en.wikipedia.org/wiki/Photovoltaics [1]

Although I am not a great proponent of that 'do-it-yourself' encyclopedia, this particular site has a long comprehensive bibliography, which lists some original works but understand that many of these are sales pieces to attract investors . . . even on some of the NASA sites.

In the next episode we will take a look at the economics of PV generation of electrical power.

- Prof. Ken Johnson, Ret.

Source URL (retrieved on *10/24/2014 - 9:31pm*):
http://www.ecnmag.com/blogs/2010/08/energy-107-%E2%80%93-solar-cells-i

Links:
[1] http://en.wikipedia.org/wiki/Photovoltaics