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Insight of fundamental solar power in India

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Abstract : It is well said that, "Necessity drives the technology". Many research works have been experimented on conventional alternatives of solar energy, which can prove to be a better, friendly and cost-effective option for the environment. The solar technologies hold significant promise for the present and the future generation of the world, and particularly for India, which has a high solar insolation of 4.5–5 kWh/meter^2/day as per the data collected from The Ministry of New and Renewable Energy, Government of India, for about 300 sunny days per year, as cited in Wikipedia. Being commercially viable and technologically mature, solar products have existed on earth for many years. However, the market share of solar energy fails to fulfill expectations of people. Hence, keeping in mind the way a customer thinks while buying a product, it can be said that if cost of solar products is minimized, along with the uninterrupted maintenance services offered by companies, the willingness of people to opt for solar products would have been more. However, this is not the case in the present. Hence, to provide a clear picture of basic solar technological knowledge, a detailed view has been provided in this piece of research review work.

Keywords: Solar cells, modules, HOMER software, solar insolation.

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1. Introduction

Most parts of India experiences a clear sunny weather for about 250 to 300 days a year, because of its location in the equatorial sun-belt of the earth, receiving fairly large amount of radiation as compared to many parts of the world especially Japan, Europe and the US where development and deployment of solar technologies is maximum. Whether accompanied with this benefit or not, usually we have to concentrate the solar radiation in order to compensate for the

attenuation of solar radiation in its way to earth's surface, which results in from 63,2 GW/m^2 at the Sun to 1 kW/m^2 at the Earth´s surface [1]. The higher the concentration, the higher is the temperature that we can achieve when converting solar radiation into energy.

India being world's 6th largest energy consumer, accounts for 3.4% of global energy consumption. Due to India's economic rise, the demand for energy has grown at an average of 3.6% per annum over the past 30years. In March 2009, the installed power generation capacity of India stood at 147,000 MW while the per capita power consumption stood at 612 KWh [1]. The country's annual power production increased from about 190 billion KWh in 1986 to more than 680 billion KWh in 2006. The Indian government has set an ambitious target to add approximately 78,000 MW of installed generation capacity by this year. The total demand for electricity in India is expected to cross 950,000 MW by 2030 [2].

This indicates that India's future energy requirements are going to be very high and solar energy can be one of the efficient and eco-friendly ways to meet the same. With this ever increasing demand for power in rapidly growing cities throughout the country, there stands a pressing need to look for sustainable and innovating technologies [3] of solar Photovoltaics to fulfill this effort. In 1838, Edmund Becquerel observed and published findings about the nature of materials to turn light into energy. They were considered interesting, but were not pursued. Again in 1860 – 1881, Auguste Mouchout was the first man to patent a design for a motor running on solar energy. From here onwards, the journey of Photovoltaics started to make difference towards creating an eco-friendly way of life.

The term "photovoltaic" comes from the Greek φῶς (phōs) meaning "light", and from "Volt", the unit of electro-motive force, the volt, which in turn comes from the last name of the Italian physicist Alessandro Volta, inventor of the battery (electrochemical cell). The term "photo-voltaic" has been in use in English since 1849 [4, 5].

Fig. 1: Solar Installed Panels

Photovoltaics is the field of technology and research related to the practical application of photovoltaic cells in producing electricity from light, though it is often used specifically to refer to the generation of electricity from sunlight [6]. Cells can be described as photovoltaic even when the light source is not necessarily sunlight (lamplight, artificial light, etc.). In such cases the cell is sometimes used as a photo-detector (for example infrared detectors), detecting light or other electromagnetic radiation near the visible range, or measuring light intensity.

The operation of a photovoltaic (PV) cell requires 3 basic attributes [4]:

1. The absorption of light, generating either electron-hole pairs or exciton.
2. The separation of charge carriers of opposite types.
3. The separate extraction of those carriers to an external circuit.

Utility-scale solar photovoltaic technologies convert energy from sunlight directly into electricity, using large arrays of solar panels.

Hence, the solar photovoltaic technologies convert solar energy into useful energy forms by directly absorbing solar 'photons' [6]—particles of light that act as individual units of energy—and either converting part of the energy to electricity (as in a photovoltaic (PV) cell) or storing part of the energy in a chemical reaction (as in the conversion of water to hydrogen and oxygen).

2. Solar Cells, Modules and Arrays

Solar cells are devices those utilize the energy from the sunlight to produce electricity [6, 4] by the application of photovoltaic effect. Solar cells are made of layers of semiconductor materials similar to those used in computer chips. When sunlight is incident on the solar cell and hence is absorbed by these semiconducting materials, the electrons become loose from their atoms, and thus electricity is produced as the electrons are allowed to flow through the material, without any external voltage source being attached to it [6]. A brief discussion on this topic is done by the Department of Energy Solar Energy Technologies.

Fig. 2: A Solar Cell

In contrast, a solar thermal collector collects heat by absorbing sunlight, for the purpose of either direct heating or indirect electrical power generation. "Photo-electrolytic cell" (photo-electrochemical cell), on the other hand, refers either a type of photovoltaic cell (like that developed by A.E. Becquerel and modern dye-sensitized solar cells) or a device that splits water directly into hydrogen and oxygen using only solar illumination [4].

Solar cells are generally very small, and each one may only be capable of generating a few watts of electricity. They are typically combined into modules of about 40 cells.

Fig. 3: A solar module [7]

The solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications [8]. Each panel is rated by its DC output power under standard test conditions, and typically ranges from 100 to 320 watts. The efficiency of a panel determines the area of a panel given the same rated output - an 8% efficient 230 watt panel will have twice the area of a 16% efficient 230 watt panel. Because a single solar panel can produce only a limited amount of power, most installations contain multiple panels. A photovoltaic system typically includes an array of solar panels, an inverter, and sometimes a battery and or solar tracker and interconnection wiring [8].

The solar modules formed with the combination of solar cells, are in turn assembled into PV arrays up to several meters on a side [6]. These flat-plate PV arrays can be mounted at a fixed angle facing south, or they can be mounted on a tracking device that follows the sun, allowing them to capture more sunlight [6]. For utility-scale electricity generating applications, hundreds of arrays are interconnected to form a single, large system.

A system is made up of one or more photovoltaic (PV) panels, a DC/AC power converter (also known as an inverter), a racking system that holds the solar panels, electrical interconnections, and mounting for other components [9]. Optionally it may include a maximum power point tracker

(MPPT), battery system and charger, solar tracker, energy management software, solar concentrators or other equipment. A small PV system may provide energy to a single consumer, or to an isolated device like a lamp or a weather instrument. Large grid-connected PV systems can provide the energy needed by many customers. The electricity generated can be either stored, used directly (island/standalone plant), or fed into a large electricity grid powered by central generation plants (grid-connected/grid-tied plant), or combined with one or many domestic electricity generators to feed into a small grid (hybrid plant) [10]. Systems are generally designed in order to ensure the highest energy yield for a given investment. A typical solar array is shown in the figure below:

Fig. 4: A solar Array [11]

3. Solar Resource Calculation Using Homer

The location of Bhubaneswar, India is latitude 20.3^0 North & 85.8^0 East; IST (GMT +05:30). The software Homer evaluates PV array power for the year in hourly basis and uses latitude value to calculate the average daily radiation from the Clearness index & vice-versa [12]. Homer, Hybrid Optimization Model for Electric Renewable application was developed by National Renewable Energy Laboratory, USA. In early 1993, internal DOE (Department Of Energy) developed software for the understanding of trade-offs among various energy production configurations. After few years the particular tool was developed for the use of Renewable energy system designers [13]. Homer is typically used for the purpose of design & analysis of hybrid power systems particularly for the sustainable energy sources. In Homer, user can input hourly data of load

consumption & match the generation to this required load. It helps to calculate the Micro-Grid potential, peak renewable penetration, ratio of renewable sources to total energy, stabilization for medium to large scale projects. It takes a cost-effective analysis, environmental impacts into consideration which is a necessary issue of the time. In very less time it generates reports of the designed system. It works for on-grid, off-grid and standalone system as well, which makes it useful for rural to urban applications. User can directly input data to the solar resource or Homer acquires solar resource data from NASA Atmospheric Science Data Centre for the provided coordinates.

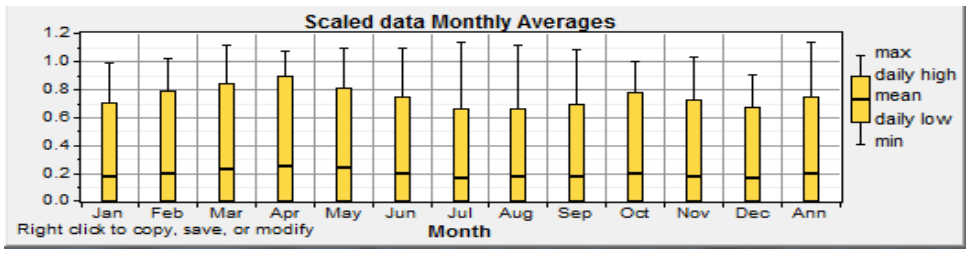

Fig. 5: Scaled data monthly averages of solar radiation

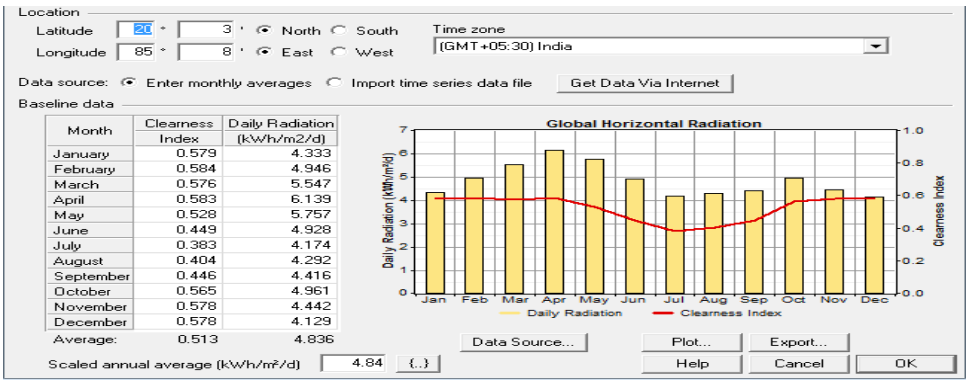

Fig. 6: Solar radiation & Clearness index

4. Conclusion

When photons from the sunlight strike a PV cell, the transfer of energy to an electron in the atom of the cell takes place. This cell is actually a semiconductor. Possessing this energy, now the electron becomes capable enough to become part of the current in an electrical circuit by escaping from its normal position associated with that specific atom. The built-in electric field, which is a special electrical property of the PV cell, provides the required voltage in order to drive the current through an external load (such as a light bulb). After the discussion

about solar cells, the application of solar technologies in rural places was taken into consideration and hence, the required data were provided to the HOMER software, in order to obtain the outputs.

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