Photovoltaics (PV) – A Sustainable Energy Alternative

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Abstract: **Solar energy is the most abundant energy resource on earth. The solar energy that hits the earth's surface in one hour is about the same as the amount consumed by all human activities in a year. There is a pressing need to accelerate the development of advanced clean energy technologies in order to address the global challenges of energy security, climate change and sustainable development. PV probably offers the best deal for the environment among non-conventional sources of energy which directly convert solar energy into electricity with reasonable efficiency. This paper provides an overview of PV cells including its working principle, features, technology and new developments. Also, the aim of this paper is to present the future potential of the PV technology in various application domains.**

Keywords: Photovoltaic, Non-conventional energy sources, sustainability, HCPV

I. Introduction

The combination of rising energy costs and our insatiable appetite for technology advancements will lead to significant environmental impact unless aggressively addressed by a unified strategy. Due to recent innovations and research endeavors, the cost of Renewable Energy Sources (RES), particularly Photovoltaics (PV), is constantly decreasing. Moreover, solar power uses a free renewable energy source i.e. Sun, which means there is no re-occurring cost from consuming power and it does not produce any negative environmental effects by way of pollution to the air, land or water [6]. PV probably offers the best deal for the environment among non-conventional sources of energy which directly convert solar energy into electricity with reasonable efficiency. In this paper we have discussed the working principle, features and future potential of PV technology.

II. Photovoltaics – Energy from sand

The word 'photovoltaic' comes from the two words 'photo' and 'Volta'. In 1954, the first silicon solar cell was launched. Silicon, the raw material for computer chips and solar cells, is the second most common element in the earth ' s crust after oxygen. The current increases with the size of a solar cell, whereas the voltage remains constant. The electric voltage of a solar cell is only 0.6 to 0.7 volts. Many cells are interconnected in series to form solar modules. The front contacts of a cell are connected to the back contacts of the next cell using soldered - on wires (see Figure 1). It takes 32 to 40 cells connected in series to produce a sufficiently high voltage to charge 12 - volt batteries. Higher voltages are needed to feed into the grid through inverters. Solar modules with an even higher number of cells interconnected in series are available for this purpose. Today silicon cells in mass production reach a maximum efficiency of over 20%. Close to 25% efficiency has already been reached in laboratories [1]. Solar PV power is a commercially available and reliable technology with a significant potential for long-term growth in nearly all world regions. This roadmap estimates that by 2050, PV will provide around 11% of global electricity production and avoid 2.3 gigatonnes (Gt) of CO_2 emissions per year [4]. Among various renewable energy resources, India possesses a very large solar energy resource which is seen as having the highest potential for the future. The first, recently announced, the very ambitious Jawaharlal Nehru National Solar Mission with a target of 20,000 MW grid solar power, 2000 MW of off-grid capacity including 20 million solar lighting systems and 20 million sq.m. Solar thermal collector area by 2022 is under implementation. The main objectives of the mission are to help reach grid parity by 2022 and help set up indigenous manufacturing capacity [5].

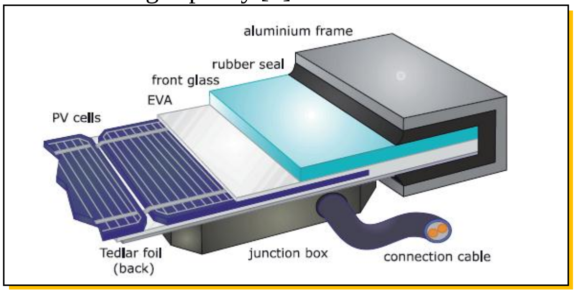

Figure 1. Structure of Photovoltaic Module [1]

III. Working Principle

The small applied model shown in Figure 2 explains roughly the principle involved. There are two horizontal levels. The second level is located a bit higher than the first one. The first level has a large number of small hollows filled to the top with water. The water here cannot move by itself. Now someone starts to throw small rubber balls at the first level. If a ball hits a hole, the water splashes upwards and ends up on the second level. Here there are no hollows to contain the water. The second level is therefore inclined so that the water runs off and reaches the draining groove on its own. This groove is connected to the second level through a pipe and as the water flows through, it drives a small waterwheel with a dynamo. When the water reaches the lower level, it fills up the hollows again. The cycle can start all over again with new rubber balls.

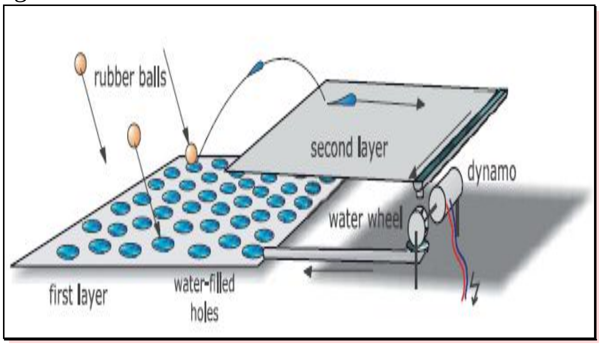

Figure 2. Model illustrating Principle [1]

However, we want to use solar cells not to produce a water cycle but to generate electric current to run electrical appliances. Electric current is created from the flow of negative - charge carriers, called electrons. These are the same as the water in our simple model. The solar cell needs a material in which two levels can be found: one level in which the electrons are firmly affixed like the water collecting in the hollows, and a second level where the electrons are able to move freely. Semiconductor materials normally have precisely these properties. Tiny particles of light, called photons in physics, correspond to the rubber balls and are able to raise the electrons to the second level.

IV. New Developments

PV has emerged as inevitable choice to address our ever increasing energy needs with some astonishing applications in various domains. Some of new developments in PVs and their applications are discussed below.

A. Solar Panel Powers for Notebook Computer through smart Adaptors

The pair of 10 watts modules provides enough power to run and add some charge to most notebook computers. It will power most available Macintosh portables computers and 60% of available PC notebooks. The Smart Adaptor converts the 16 volt output of the solar module to anywhere from 10 to 30 volts to power your computer. This adaptor can also be used to power or charge your computer directly from a car cigarette lighter socket or any 12 volt battery with a cigarette lighter socket wired to it. The output voltage is determined by the Smart-Cord output cord that is attached to it the Smart Adaptor. If you have more than one Notebook Computer, or if you change your computer model, you just need to order another plug-in Smart-Cord to have the right voltage.

B. Solar Energy-based telecom towers

According to SESI, as many as 400 telecom towers will soon be powered by panels that will sit on them, reflecting light from the sun to produce electricity that will be used by the towers. Solar energy use in cell towers can cut CO_2 emission. Use of diesel generators in cell phone towers leads to a staggering five million Tonnes of annual carbon emissions in India and there is a need to replace them with solar panels, says a new study. According to a study released by 'Future Energy' periodical published by Maharashtra Energy Development Agency (MEDA), with the number of mobile phone users in the country swelling rapidly, telecom operators are going in for more high-intensity cell phone towers for better network efficiency entailing a massive consumption of diesel, about two billion litres every year, for power generation to run them. This is resulting in carbon emissions totalling over five million tonnes, it said. The country at present has about 250,000 cell phone towers each of which use 3-5 kilowatts of power depending on the number of operators using them.

C. HCPV Highly Concentrated PV

The Sunflower highly concentrated photovoltaic system integrates photovoltaic modules, advanced tracking, unique power optimization, an embedded controller and wireless communication, into one elegant solution to produce cost-competitive solar power while reducing installation and maintenance costs. The Sunflower system uses proprietary Micro-Converter technology to improve energy delivery by conditioning modules' power output and optimizing maximum power point. A Micro-Converter optimizes Maximum Power Point Tracking (MPPT) over only 5 modules versus up to several thousand modules in traditional single inverter MPPT architecture. This provides more precise and effective MPPT and therefore more usable energy. In addition, this architecture reduces electrical losses within the array and increases the energy produced. This occurs when both shaded modules and unshaded modules are present, and under low light conditions such as sunrise and sunset when traditional inverters would shut down due to under voltage conditions [2].

D. Sun in the Grid

As solar modules produce direct voltage but the public grid works with alternating voltage, an inverter is also required (see Figure 3). An inverter converts the direct voltage of a photovoltaic module into alternating voltage. Modern inverters have high demands placed on them. They are required to have a high level of efficiency to ensure that only very little valuable solar energy is lost during the conversion into alternating voltage. Modern photovoltaic inverters achieve efficiency of close to 95% or even more. What is important is that efficiency is high even with a partial load, such as in cloudy weather. European efficiency describes average inverter efficiency based on Central European climate conditions, while CEC efficiency is for Californian conditions.

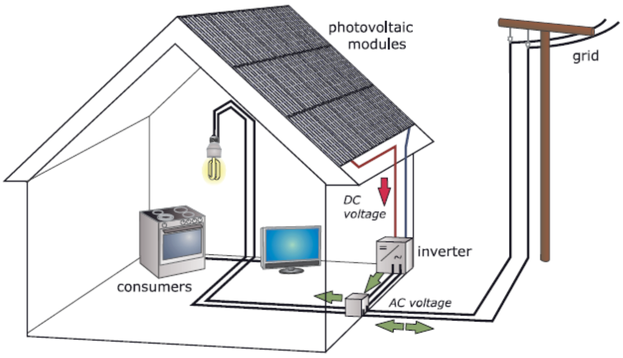

Figure3. Principle of grid connected photovoltaic system.

V. Future of PVs

PV technology has a bright future to become a potential candidate to achieve energy sustainability. The Graph in figure 4 shows the costs of different resources of energy out of which most economical is renewable energy resources, which justifies the potential of various RESs including PVs.

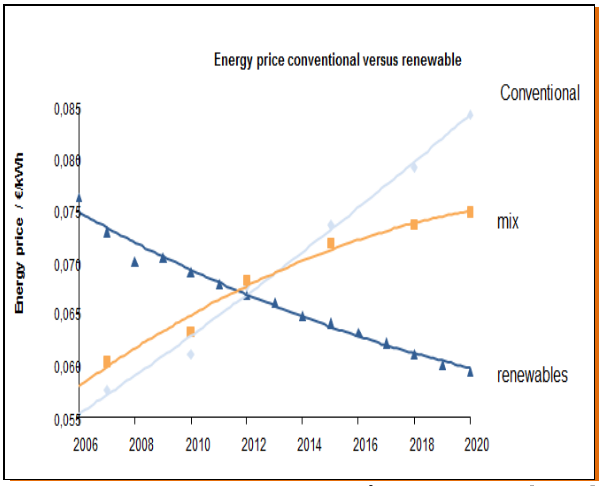

Figure 4. Cost comparison of Conventional and Renewable Sources of Energy [3]

Efficiency of PVs is a major bottleneck in the adoption of the technology. Hence, it is the only concerned area to make the PV technology, an unavoidable choice to meet the future energy needs. The higher the efficiency, the more electric power the solar cell can generate per square metre. In addition to the type of materials used, the quality of the manufacturing also plays a major role. Today silicon cells in mass production reach a maximum efficiency of over 20%. Close to 25% efficiency has already been reached in laboratories. PV technology fills a significant need in supplying electricity, creating local jobs and promoting economic development in rural areas, avoiding the external environmental costs associated with traditional electrical generation technologies.

We can sum-up the Pros and Cons associated with PV technology as follows:

A. Pros

- Distributed energy source
- No moving parts hence reliable
- Green power
- Low maintenance
- Unlimited energy source

B. Cons

- Capital intensive
- Low capacity utilization (<20%)
- Low efficiency and large area is required
- Security of panels in some locations

VI. Conclusion

A fast growing world population, increasing prosperity and the hunger for fuel, has led to a rapid rise in the need for energy. Overconsumption of energy is the main trigger for the global warming that is now threatening to cause devastation in many areas of the world. Use of renewable energy sources is the only way to end our dependence on energy sources like oil and uranium, which are so costly both in financial terms and in the havoc they wreak on our environment, and satisfy our hunger for energy in a way, that is sustainable and compatible with the climate. Among the renewable energies that currently exist, photovoltaic (PV) offers the most possibilities for different uses. The potential reductions in cost, combined with the simplicity, versatility, reliability, and low environmental impact of PV systems, should help them to become increasingly important sources of economical premium-quality power over the next few years [6].

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