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A Comprehensive Review of Solar Energy and its Applications

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ABSTRACT

The various forms of solar energy e solar heat, solar photovoltaic, solar thermal electricity, and solar fuels offer a clean, climate-friendly, very abundant and in-exhaustive energy resource to mankind. Solar power is the conversion of sunlight into electricity, either directly using photovoltaic (PV), or indirectly using concentrated solar power (CSP).Solar energy has experienced phenomenal growth in recent years due to both technological improvements resulting in cost reductions and government policies supportive of renewable energy development and utilization. This paper presents a review of solar power generation and its related applications.

Keywords: concentrated solar power (CSP), photovoltaic (PV), GaAs.

INTRODUCTION

A solar cell is a PN junction device which is used for converting optical radiation (sunlight) into electrical energy. There is no voltage directly applied across the junction. The solar cell converts photon power into electrical power and delivers it to a load. The generated electrical voltage is proportional to the intensity of incident light. Due to their capability of generating voltage, they are called as photovoltaic cells. For example silicon solar cell which converts sunlight into electrical energy. Selenium, gallium arsenide, and cadmium sulphide are also used for solar cell. Such types of devices are used for the power supply of space , vehicles and satellites. A group of series and parallel connected solar cell operating as a battery charger.
Today's continuously increasing energy demands but the fast depleting conventional energy sources in the context of environment that encouraged intensive research for new, more efficient and green power plants with advanced technology. Figure 1 shows the basic construction of a solar cell.

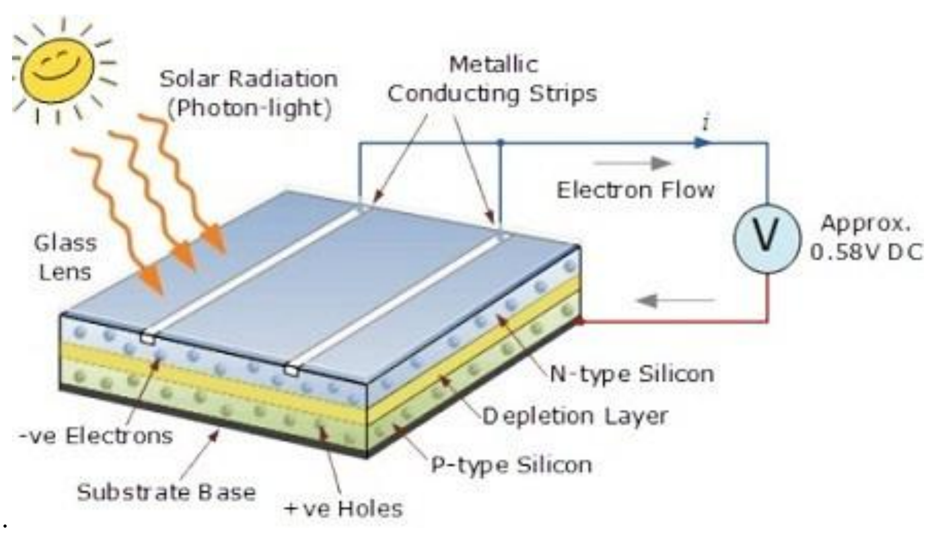

Figure1: Basic Construction of a solar Cell

2. EVOLUTION OF SOLAR ENERGY

Now energy and clean fuel technologies are being investigated since environmental protection are increasing in the world today. Most of the renewable energy from wind, biomass, tidal geothermal and solar are converted into electrical energy. Solar energy technologies include solar heating, solar thermal electricity, solar photovoltaic cells. For generating electricity in far area at reasonable cost, solar power supply system plays key role. These are excellent choices in remote areas for low to medium power supply.

The main attraction for the photovoltaic systems is that there is no harmful effect on environment in production of electric power as it directly transforming the solar energy into electrical energy. In the future, the continue decreasing in cost of solar cell arrays and increasing in their efficiency plays an important role. The efficiency of energy conversion depends on solar panels that generate power. The main drawback is that practical systems have low overall efficiency. It is relatively an expensive technology, the cost for PV systems are coming down and markets are expending. Costs of solar cell production have been reduced in recent couple of years and technological advances and are set to fall further.

Solar energy has experienced an impressive technological shift. While early solar technologies consisted of small-scale photovoltaic (PV) cells, recent technologies are represented by solar concentrated power (CSP) and also by large-scale PV systems that feed into electricity grids. The costs of solar energy technologies have dropped substantially over the last 30 years. For example, the cost of high power band solar modules has decreased from about $27,000/kW in 1982 to about $4,000/kW in 2006; the installed cost of a PV system declined from $16,000/kW in 1992 to around $6,000/kW in 2008. The rapid expansion of the solar energy market can be attributed to a number of supportive policy instruments, the increased volatility of fossil fuel prices and the environmental externalities of fossil fuels, particularly greenhouse gas (GHG) emissions.

Solar energy technologies are not yet competitive with conventional technologies for electricity production. The economic competitiveness of these technologies does not improve much even when the environmental externalities of fossil fuels are taken into consideration. Besides the economic disadvantage, solar energy technologies face a number of technological, financial and institutional barriers that further constrain their large-scale deployment.

3. TECHNOLOGIES AND RESOURCES

Solar energy refers to sources of energy that can be directly attributed to the light of the sun or the heat that sunlight generates. Solar energy technologies can be classified along the following *continuum*: 1) passive and active; 2) thermal and photovoltaic; and 3) concentrating and non-concentrating. Passive solar energy technology merely collects the energy without converting the heat or light into other forms. It includes, for example, maximizing the use of day light or heat through building design.

In contrast, active solar energy technology refers to the harnessing of solar energy to store it or convert it for other applications and can be broadly classified into two groups: (photovoltaic (PV) and (ii) solar thermal. The PV technology converts radiant energy contained in light quanta into electrical energy when light falls upon a semiconductor material, causing electron excitation and strongly enhancing conductivity. Two types of PV technology are currently available in the market: (a) crystalline silicon-based PV cells and (b) thin film technologies made out of a range of different semi-conductor materials, including amorphous silicon, cadmium-telluride and copper indium gallium diselenide1.

Solar thermal technology uses solar heat, which can be used directly for either thermal or heating application or electricity generation. Accordingly, it can be divided into two categories: (i) solar thermal non-electric and (ii) solar thermal electric. The former includes applications as agricultural drying, solar water heaters, solar air heaters, solar cooling systems and solar cookers ; the latter refers to use of solar heat to produce steam for electricity generation, also known as concentrated solar power (CSP). Four types of CSP technologies are currently available in the market: Parabolic Trough, Fresnel Mirror, Power Tower and Solar Dish Collector.

A solar cell is a non-linear device and can be represented as a current source model as shown in Fig. 2

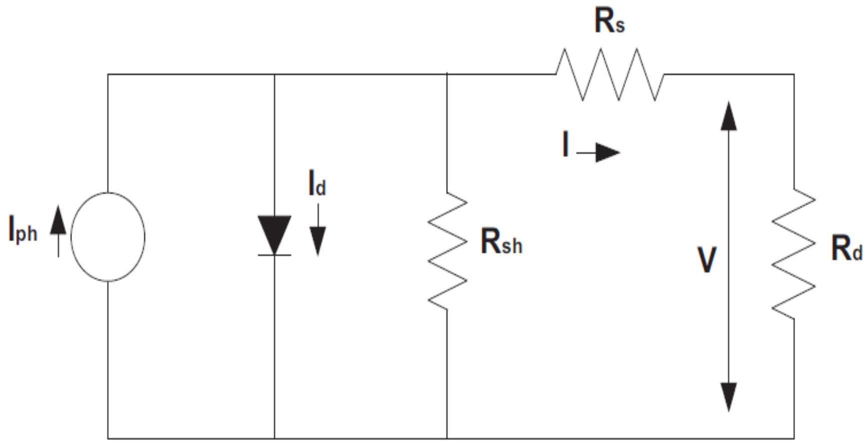

Figure 2: Equivalent circuit of a solar cell

$$I = N_P I_{PN} - N_P I_D \left[EXP\left(\frac{QV}{KTAN_S} - 1\right)\right] \quad (1)$$

where, I is the PV array output current (A), V is the PV array output voltage (V), Ns is the number of cells connected in series, N_P is the number of modules connected in parallel, q is the charge of an electron, k is the boltzman's constant, A is the PN junction ideal quality factor, Id is the cell reverse saturation current. T is the cell temperature. The factor 'A' determines the cell deviation from the ideal pn junction characteristic.

Now, The cell reverse saturation current Id varies with temperature is given by

$$I_D = I_C \left[\frac{T}{T_C}\right]^3 EXP\left[\left(q\frac{E_g}{KA}\right)\left(\frac{1}{T_C} - \frac{1}{T}\right)\right] \quad (2)$$

where, T_C is the cell reference temperature, I_C is the reverse saturation current at T_C, and E_g is the band gap energy of the semiconductor used in the cell. The photo current I_{PH} depends on the solar radiation and the cell temperature as given by:

$$I_{PH} = [I_{SCR} + K_I\,(T - T_C)]\left[\frac{S}{100}\right] \quad (3)$$

The PV array power can be calculated by

$$P = N_P I_{PH} V - N_P I_D V \left[EXP\left(\frac{qV}{KTAN_S} - 1\right)\right] \quad (4)$$

$$V = \left(\frac{AKT}{q}\right) IN \left[\frac{(I_{PH} + I_D - I)}{I_D}\right] - R_S I \quad (5)$$

The current source I_{PH} represents the cell photo current, Id is reverse saturation current of diode, R_{sh} and Rs are the intrinsic shunt and series resistance of the cell respectively. Usually the value of R_{sh} is very large and that of Rs is very small, hence they may be neglected to simplify the analysis. PV cells are grouped in larger units called PV modules, which are further interconnected in a parallel-series configuration to form PV arrays or PV generators. The typical 1eV characteristic of a PV array is given by the following equation [5]:

Photovoltaic system for power generation A basic photovoltaic system integrated with utility grid is shown in Fig. 2. The PV array converts the solar energy to dc power, which is directly dependent on insolation. Blocking diode facilitates the array generated power to flow only towards the power conditioner.

4. BENEFITS AND APPLICATIONS

Solar energy has become a promising alternative source due to its advantages: abundance, pollution free and renewability. Some of the key advantages are: direct use of heat resulting from the absorption of solar radiation, direct conversion of light to electricity through a simple solid-state device, absence of moving parts, ability to function unattended for long periods as evident from space program, modular nature in which desired currents, voltages and power levels can be achieved by simple integration, low maintenance cost, long effective life, high reliability, rapid responses in output to input radiation changes, high power handling capabilities from microwatt to kilowatt and even megawatt, high power to weight ratio, which is more important for space applications than terrestrial (may be favorable for some terrestrial application), amenable to onsite installation, decentralized/dispersed power; thus the problem of power distribution by wires could be eliminated by use of solar cells at the site where the power is required. They can be used with or without sun tracking, making possible a wide range of applications.

The major factors that limit the use of solar energy for various applications is that, it is cyclic time dependent energy source. Therefore, solar system requires energy storage to provide energy in the absence of insolation. Comprehensive research and advancement in energy storage technologies offers benefits for solar in energy application. There is considerable work being done on fuel cell technology, which should offer a cheaper and more efficient mechanism for storing energy. Solar systems, which when not connected to the grid, store energy in conventional lead acid battery. Similarly, hydrogen offers considerable potential as a major power source, and tests are being done to use solar to produce hydrogen as a power source . The stand-alone system does not supply power to the grid.

Without a blocking diode, the battery would discharge back through the solar array during low insolation. Power conditioner contains a maximum power point tracker (MPPT) a battery charge and a discharge controller. The MPPT ensures that the maximum power generated by the solar PV array is extracted at all instants while the charge discharge controller is responsible for preventing overcharging or over discharging of the battery bank required to store electricity generated by the solar energy during sunless time. Figure 3 shows the basic block diagram of a photovoltaic system.

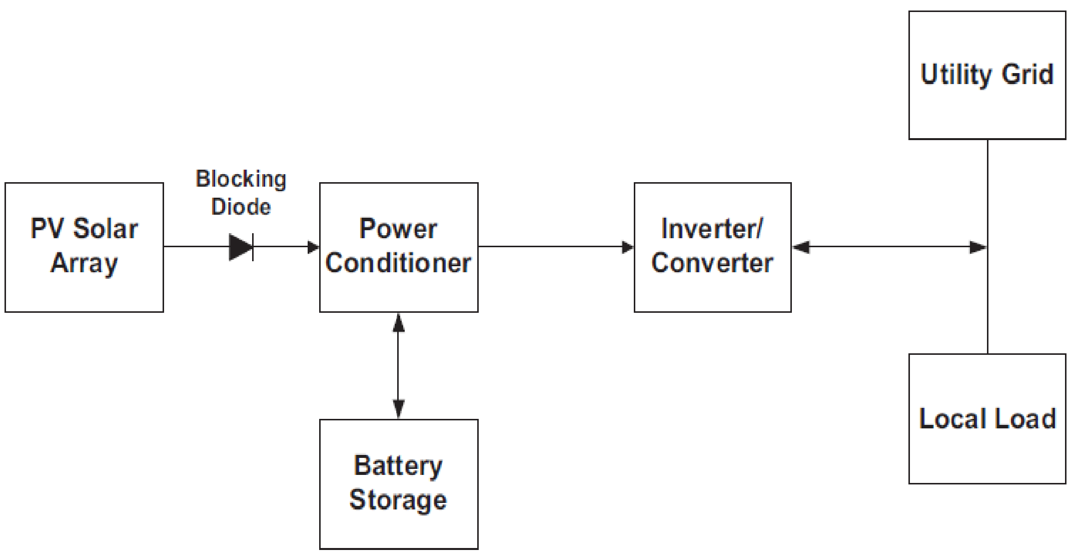

Figure 3: Basic Photo Voltaic System

In simple PV systems, where PV module voltage is matched to the battery voltage, use of MPPT electronics is generally considered unnecessary, since the battery voltage is stable enough to provide near-maximum power collection from PV module. A stand-alone system does not have a connection to the grid.

Block diagram of a typical photovoltaic system the maximum power generated by the solar PV array is extracted at all instants while the charge discharge controller is responsible for preventing overcharging or over discharging of the battery bank required to store electricity generated by the solar energy during sunless time. In simple PV systems, where PV module voltage is matched to the battery voltage, use of MPPT electronics is generally considered unnecessary, since the battery voltage is stable enough to provide near-maximum power collection from PV module.

CONCLUSION

In this era, there is a lot of inclination towards clean and renewable energy. Solar energy is a suitable and everlasting solution to the ever increasing energy demands. In this paper we have presented a comprehensive review of solar energy and its related applications. This paper will be beneficial for the researchers to pursue their research in this field in an efficient manner.

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