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An understanding of the operation of silicon Photovoltaic panels

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Abstract

As the photons of the solar irradiance fall on the free electrons of the PV cell, it mobilizes the electrons and causes an electric current flow. It has been found that the electrical current from a silicon PV cell is proportional to the incident solar irradiance such if there is no limit for the generated electrical current. The performance of a PV cell is a very confusing phenomenon, because the number of free electrons within a silicon PV cell is limited, while the generated electric current from a PV cell is unlimited. It has been shown that considering the electric current as a flow of electrons is contradicted by many experimental arguments. On the other hand, the postulated nature of electric current as a flow of an electromagnetic wave of a negative electric potential solves such conflicts. The PV cell is a device that transforms the incident solar energy, i.e. zero potential electromagnetic waves, into an electromagnetic wave but with a negative potential, which is known as the electrical current. Therefore, more input solar energy to the PV cell means more electrical output from the PV cell without any limitations.

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Keywords: Photovoltaic; electric current; PV cells; electromagnetic waves

1. Introduction

The growing demand of energy [1, 2] and the depletion of fossil fuels worldwide urges all governments to depend on renewable sources of energy [3, 4]. Solar photovoltaic energy conversion is a one-step conversion process which

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generates electrical energy from solar energy. Silicon PV cells are composed of two layers, i.e. a layer of free electrons (or n junction) and layer of holes (p junction). The n-junction is made by embedding atoms that have five valence electrons, e.g. phosphorus (P) atoms, in the silicon crystal lattice, in which the silicon atoms have just four valence electrons. The fifth electron of the embedded atom cannot participate in electron pair binding with the silicon atoms, thus, this electron is bonded very loosely. Little energy is required to separate this electron from the atom and thus create a free electron. The embedding of an atom of five valence electrons is known as n-doping, and these atoms are called donor atoms. The positive junction of a PV cell is made by embedding atoms of three valence electrons, e.g. boron (B). Each boron atom can only form full bonds with three neighboring silicon atoms and a broken bond with a fourth silicon atom, such that each boron atom introduces a deficiency of an electron in the silicon structure, and a consequently positively charged layer, i.e. the P-junction. The embedding of an atom of three valence electrons is known as n-doping, and these atoms are called acceptor atoms. Viswanathan [5] stated that the solar irradiance consists of corpuscles of energy, i.e. photons, and as these photons fall on the free electrons of the PV cell. So, it mobilizes the electrons to make a flow of current between the positive and negative layers of the cell, as indicated in Fig. 1. However, it is found that not all the photons of the incident solar irradiance can mobilize the free electrons within the cell, but only photons with a specific energy level, i.e. the band gap energy, can free the electrons and allow a flow of current. The above theory of operation of PV panels has been proposed by Einstein and many other researchers [6–9]. This indicates that a PV cell is a device that “takes photons and delivers electrons”.

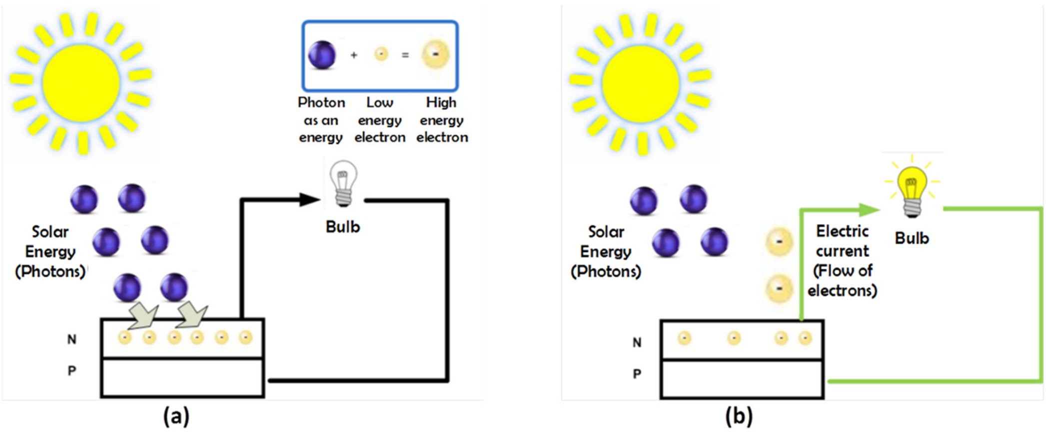

Fig. 1. Working principal of solar cells according to current hypothesizes. Incident solar energy on the PV cell (a) and generation of an electrical current, i.e. freeing of electrons from the PV cells (b).

The performance of PV panels is characterized by an I-V characteristics curve, which is the relation between the output photoelectric current, I, from the panel versus the potential difference, V, across the panel, in case of a solar irradiance of 1000 W/m^2 at an operating panel temperature of 25 °C. An example of an I-V curve is shown in Fig. 2. Three points on the I-V curve are important in defining the performance of a PV panel; (i) the short-circuit current, Isc, which is the maximum photoelectric current generated by the panel, and it occurs when the load resistance RLoad is zero, i.e. V = 0, (ii) the open-circuit voltage, V_{oc}, which is the maximum load voltage at which the panel can operate, and it occurs when the load resistance is infinite such that I = 0 and (iii) the maximum power point, MPP, which is the point on the I-V curve at which is the maximum possible electrical power is generated. The power output from a PV panel is calculated by multiplying each output current by its corresponding load voltage. The power output from the PV panel is depicted on the I-V characteristics curve as shown in Fig. 2. It can be clearly seen from the I-V characteristic curve that the PV cell is a hard source, i.e. it has a limited output current even if the load resistance is zero. The hard source characteristic of a PV cell indicates that a PV cell has a limited number of free electrons, that can’t be exceeded. The limited number of free electrons “n” can be calculated from the following equation [10]: