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Power loss due to soiling on solar panel: A review

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ABSTRACT

The power output delivered from a photovoltaic module highly depends on the amount of irradiance, which reaches the solar cells. Many factors determine the ideal output or optimum yield in a photovoltaic module. However, the environment is one of the contributing parameters which directly affect the photovoltaic performance. The authors review and evaluate key contributions to the understanding, performance effects, and mitigation of power loss due to soiling on a solar panel. Electrical characteristics of PV (Voltage and current) are discussed with respect to shading due to soiling. Shading due to soiling is divided in two categories, namely, soft shading such as air pollution, and hard shading which occurs when a solid such as accumulated dust blocks the sunlight. The result shows that soft shading affects the current provided by the PV module, but the voltage remains the same. In hard shading, the performance of the PV module depends on whether some cells are shaded or all cells of the PV module are shaded. If some cells are shaded, then as long as the unshaded cells receive solar irradiance, there will be some output although there will be a decrease in the voltage output of the PV module. This study also present a few cleaning method to prevent from dust accumulation on the surface of solar arrays.

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1. Introduction

Solar energy, which comes from the sun in the form of solar irradiance, can be directly converted to electricity by using photovoltaic (PV) technology. PV technology uses solar cells made of semiconductors to absorb the irradiance from the sun and convert it to electrical energy. Currently, solar energy has drawn worldwide attention and is playing an essential role in providing clean and sustainable energy [1]. However, the research related to the nature of semiconductors, which are used in solar cells, has limited the efficiency of PV systems to 15–20%. Thus, in order to increase the efficiency of the PV system, some improvements such

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as applying sun trackers and maximum power point tracking controllers have been made to the PV system installation.

Solar panels are normally expected to be designed to produce the most ideal output or optimum yield. The factors that influence the determination of the ideal output or optimum yield can be classified into two categories, namely, changeable variables and unchangeable variables. The variables that can be changed provide design flexibility to respond to varying installation requirements, while the variables that are unchangeable need to be adapted to by default. The various changeable and unchangeable variables influence the configuration and design of a solar panel, the installation and operation of a solar panel and play an important part in solar panel generation. However, as more and more PV power plants are built in the upper MW and GW power ranges in the future, there is a need for more attention to be paid to this problematic area, which directly affects the efficiency of the power generation.

The characteristics of a PV module can be demonstrated by power–voltage or current–voltage curves. Fig. 1 shows the power–voltage curve of a PV module for different conditions of solar irradiance and cell temperature. As the figure shows, the PV output power is dependent on solar irradiance and cell temperature. Low irradiance leads to low power, and high temperature causes a reduction in output power. Furthermore, for each curve of the PV module, there is a point on the curve at which the PV module delivers maximum power to the load. This point is known as maximum power point (MPP) [2].

Solar irradiance and cell temperature are two factors, which affect the performance of a PV module. In addition to these factors, the amount of energy delivered by a PV module is dependent on other factors such as the reliability of other components of the overall system and other environmental conditions. This section provides a description of these factors [3,4].

A. ***Nameplate DC Rating***: Also known as the sticker DC power rating is the maximum power output under Standard Test Conditions which solar module manufacturers indicate on their modules. However, there might an error between the Actual field performance and nameplate rating that can result from two issues. Measurement inaccuracy is one of potential source of error that can happen by the manufacturers while testing. Furthermore, first time exposition to sunlight can cause some modules to suffer from the light-induced degradation while becoming stable during the first few hours of their operation [3].

B. ***Diode and Connection loss***; *the* primary application of bypass diodes is PV system is to preserve PV modules in partial shading conditions. Such a protective component can cause one form of connection loss known as power loss in the system. The other type connection loss in PV system happens where PV modules and other electrical components are connected together to form PV arrays, known as resistive loss [3]. Herrmann et al in 1997 did an investigation on hot spots in solar cells with respect to bypass diode. Because the series connection of the PV generator forces all the cells to operate having the same current (string current), the shaded cell within a module becomes reverse biased which leads to power dissipation in the form of heat [4].

C. ***Mismatch losses***: When PV modules with different characteristics (*I* & *V*) are connected together they provide a total output power less than the power achieved by summing the output power provided by each of the modules. PV modules with same ratings coming out of one production line in a factory do not possess identical current–voltage characteristics for many reasons. This inequality causes PV modules to compromise on common voltage and current when they are connected in series or parallel in an array. This compromise results in a type of power losses known as mismatch losses which is recognized by several research works. Samad et al in 2014 studied mismatch loss minimization in photovoltaic arrays and suggested a solution based on arranging PV modules in arrays by genetic algorithm. Findings of this study show that a genetic algorithm-based arrangement of modules reduces mismatch losses more effective than classical modules sorting techniques do [5].

D. ***DC and AC Wiring:*** DC and AC wiring loss comprises of the resistive losses of the cables and wires used throughout the whole PV plant from the PV including the whole route from the PV module to the main power grid.

E. ***Sun-Tracking loss:*** Sun is moving across the sky during the day. In the case of fixed solar collectors, the projection of the collector area on the plane, which is perpendicular to the radiation direction, is given by function cosine of the angle of incidence. Sun tracking loss occurs when the single or dual axes of tracking solar panels are not set at the optimum orientation, or are misaligned due to a mechanical failure. In a study by Hossein Mousazadeh et al. in 2009, they reviewed principles of sun-tracking methods for maximizing PV output. They considered different types of sun-tracking systems. The most efficient and popular sun-tracking device was found to be in the form of polar-axis and azimuth/elevation types [6].

F. ***Shading losses:*** Shading loss occurs when PV modules are shaded by buildings, trees or other objects in proximity to PV modules. Since the output current of the PV module is a function

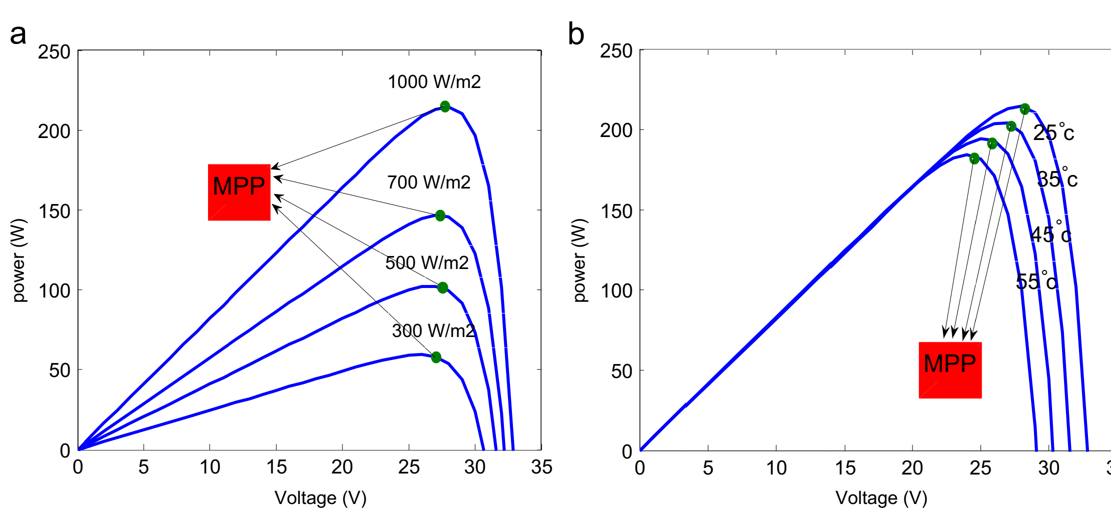

Fig. 1. *P–V* characteristics of a PV and location of the MPP for different irradiances at 25 °C, and (b) different temperatures at an irradiance of 1000 W/m^2.