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Comparison of Solar Photovoltaic Module Temperature Models

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Abstract: This paper presents the comparative study of the different models that used to predict the solar photovoltaic module temperature, which is one of the most important factors responsible for lowering the performance of photovoltaic modules. The approach of the different models was examined in order to evaluate the estimated behavior of module temperature increase with respect to ambient temperature and solar radiation. A total of 16 models have been reviewed by employing monthly mean daily meteorological data of Kuching, Sarawak. The most models showed similar trend of increase or decrease of solar photovoltaic module temperature due variation of solar radiation intensity. However, the results of reviewed models were quite different under constant solar radiation and ambient temperature conditions. It was found that the variation in the results was due to the use of different variables, climatic conditions, configuration of photovoltaic modules and the approach used by various researchers in their models.

Key words: Photovoltaic modules · Cell temperature models · Solar photovoltaic systems · Solar radiation · Sunshine hours

INTRODUCTION

Photovoltaic module operating temperature is one of the most important parameters for the evaluation of long term performance of PV systems, as it modifies the power output and system efficiency. Its affect varies with characteristics of module encapsulating material, thermal absorption and dissipation properties, types of PV cells, configuration, installation and operating point of module and climatic conditions of locality such as solar irradiation level, ambient temperature and wind speed [1-3].

Photovoltaic module performance or efficiency is usually inversely proportional to the operating temperature of cell. Two challenging factors are playing the conflicting role in the power output of PV modules. Firstly, as temperature increases, the band gap of the intrinsic semiconductor shrinks, the open circuit voltage (V_{oc}) decreases following the p-n junction voltage temperature, which contains diode factor. It is equivalent to the charge (q) divided by the product of cell temperature (T) and a constant (k), in which the q is electronic charge (1.602×10^{-19} Coulomb), k is Boltzmann's constant (1.381×10^{-23} J/K) and T is cell temperature (°C). Hence, the PV cells have a negative temperature coefficient of open circuit voltage (βV_{oc}). Likewise, that caused a lower power output at a given photocurrent, because the charge carriers are liberated at a lower potential. Thus, the reduction in V_{oc} results lower theoretical maximum power ($P_{max} = I_{sc} \times V_{oc}$) at a particular short-circuit current I_{sc}. Secondly, as temperature increases again the band gap of the inherent semiconductor shrinks, which results more absorption of incident energy. The greater percentage of the incident light has sufficient energy to raise charge carriers from the valence band to the conduction band. A larger photocurrent result the increase of I_{sc} at a definite solar insolation. The PV cells have a positive temperature coefficient of short circuit current (αI_{sc}). This effect alone would raise the theoretical maximum power by the relationship above [4-7]. Consequently, at a fixed solar radiation level increasing temperature leads to decreased open circuit voltage and slightly increased short circuit current, eventually it reduces the power output [6]. Thus it requires lowering the operating temperature of modules but with high irradiance. Since, the temperature of cells is very difficult to measure, because the cells are firmly enclosed for moisture protection. Therefore, in most cases, the back side temperature of a PV module is

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