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Experimental Analysis of Conditions Based Variations of Characteristics and Parameters of Photovoltaic Modules

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Abstract–This paper presents an experimental determination of the main and advanced characteristics of photovoltaic (solar-PV) modules as affected by variations in the solar irradiance and temperature. In addition, the effects of connecting modules in series, and in parallel are inspected. The measured main characteristics are the current/voltage (IV), and power/voltage (PV) relations, while the advanced characteristics include the form factor (FF), shunt resistance (Rsh), series resistance (Rs), characteristic resistance (Rch), and efficiency (η). The impacts of the various levels of partial shading on the performance of the modules are also presented. Two identical 10 Wp modules are used in the tests. The sun's energy is simulated using two lighting sources: One 1 kW halogen floodlight and four 100 W incandescent lamps. These light sources offer spectral which is very close to that of the black body radiation; however, they provide a lower color temperature in comparison with the sun. Therefore, they closely match the requirements of the IEC 60904-9 Edition2 and ASTM E927-10 standards of solar simulators. The electrical load is represented using two wound rheostats of 1200Ω, and 500Ω. The temperature is measured by a remote temperature sensor, while the electrical variables are measured using digital multi-meters. For cost reduction, the solar irradiance is estimated based on the linear relation between the short-circuit current, and the solar irradiance. The results are presented within the main text, and summarized in the conclusions section. It is found that the parameters such as Rs, Rsh, Rch, FF, and η are not constant, but they are highly dependent on the variations in the irradiance, and the temperature. The salient conclusion is that the standard equivalent circuit model of solar-PV modules that includes constant parameters needs to be significantly enhanced by considering the variations of the circuit parameters as affected by the variations in the solar irradiance and temperature.