
# PV Cell Electrical Model Parameter Extraction Methodology for Low Illuminance Scenarios

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Electrical equivalent models of photovoltaic (PV) cells, panels and modules are used to estimate performance as well as to emulate the energy source of an energy harvesting system. Different types of PV cell models are proposed, and although the diode equivalent circuit is relatively simple, its non-linear and implicit nature makes estimating its parameters a challenging task. This has led to numerous studies proposing and evaluating different methods to extract and estimate diode model parameter. Even though there is much research on the implementation and evaluation of these models for outdoor conditions, their performance indoor is largely unknown due to low illuminance levels. This is of special interest for energy harvesting for IoT circuits, since most of them are located indoor. Light conditions play an important role in estimating available energy levels for ambient light energy harvesting systems. A particular interest is increasing for indoor light energy harvesting for IoT applications. This scenario is characterized by low illuminance levels generated by artificial light sources. The same illuminance levels can be generated by different types of light sources, which radiate different spectral components. This means that photovoltaic cells can produce different output powers even though identical lighting levels are observed, depending on the light source. However, LED lamps are dominating the market for home and office illumination, and can be considered the main artificial light source. Indoor ambient conditions are more predictable and controllable when compared to outdoor counterpart. Illuminance level, light duration and temperature, for example, can be easily modeled for a given indoor scenario. Even with low illuminance levels, it is possible to harvest energy for powering an ultra-low power circuit. For the development of these circuits it is necessary to accurately model the energy source in terms of output load and illuminance level. This work describes the setup to measure I-V characteristics and a method for extracting parameters of a 20 x 40 mm PV cell for the 1D2R electrical model at indoor conditions. This modeling is fundamental for emulating the electrical behavior of PV cells under indoor conditions and can be used as input for characterization of energy harvesting circuits, is also composed of five free parameters. The five parameters of the 1D2R PV cell model were extracted for illuminance levels. These electrical models are used to compare the properties of PV cells and solar panels and to predict the characteristics of their I-V curves. The I-V measurement was performed by the PV cell illuminated by a cold LED lamp (model MTX mini floodlight 50 W). To avoid interference from natural lighting, tests were conducted at nighttime. The ambient temperature was approximately 27°. To guarantee the precise measurement of the I-V characteristics for different loads, the cell output was connected to an SMU of a B1500A semiconductor parameter analyzer, which acted as a voltage source varying from 0 to 1 V. With this configuration it is possible to emulate a variable load resistance (RL) ranging from 0 to infinite. An Instrutherm LD-550 luxmeter was placed close to the target PV cell in order to measure the illuminance level. In view of this, it was evaluated an optimization-based method n an algorithm that was implemented for extracting parameters for illuminance levels from 1.05 to 1119 lux of the 1D2R model. Results demonstrated good accuracy of the electrical model with respect to measurement data regardless lighting condition. As explained in this work, photovoltaic cell was modeled under low illuminance conditions. The behavioral model was investigated and the measurement results were compared to an equivalent circuit model. The five parameters of the 1D2R PV cell model were extracted for illuminance levels from 1.05 to 1119 lux with the use of the Differential Evolution optimization method. Results demonstrated a good correlation between analytical and measured I-V curves, with root mean square error below 4.2µA, even for ultra-low illuminance levels.

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