



Comparative analysis between provided values and measured values on photovoltaic modules

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1. Introduction

At a global level, technology is developing faster and faster, in recent years a series of new technologies have been introduced aimed at the use of renewable energy, such as solar energy and wind energy. [1] Going deeper into solar energy, we find the photovoltaic effect that is the basis of this system, which consists of converting the Sun's electromagnetic radiation into electrical energy through potential difference. Photovoltaic modules are responsible for generating of energy, its function is to collect photons from sunlight. The photovoltaic effect occurs when these photons collide with the atoms and semiconductors of the modules, the electrons are displaced, thus generating the current. [2] The material of its constitution determines the mode of energy generation, with the main types of modules being Monocrystalline Silicon and Polycrystalline Silicon. In addition to the material constitution of the module, another point to be highlighted is the power of these modules, thus determining the energy capacity of the system. However, the calculation basis is linked to the nominal demand made available by the manufacturer, but the main issue is to consider whether the module delivers what is assured, thus questioning all previously established predictions.

2. Methodology

The method used in the present study is based on the analysis of the power of the modules, where a curve of their current is established as a function of the applied voltage, thus it is possible to measure the analysis parameters through the I-V characteristic curve, a curve which provides detailed data on the electrical factors of a photovoltaic system. [3] In the proposal in question, the I-V characteristic curve is carried out using a Solar Simulator from the company Pasan installed at IEE (Institute of Energy and Environment - USP). Two modules with different cellular compositions were used for the case study, they are: Polycrystalline Module from Resun, model RSM-100P; and the Resun Monocrystalline Module, model RS6E-155M.

In order to compare the power values, which are the basis of the study, the curve is simulated with the module still unused so that there is no interference in the initial value due to degradation or something similar. The reference value used is that which appears in the datasheet provided by the manufacturer, thus starting from this premise to maintain parity between the described value and the real value.

In order to approve the real values of the polycrystalline modules (model RSM-100P) and the monocrystalline module (model RS6E-155M), the flash test on the Solar Simulator HighLIGHT from Pasan Measurement Systems, version R2.4.0, is carried out at IEE - Institute of Energy and Environment, located in São Paulo, set in an air-conditioned laboratory at 25°C.

Tests are carried out individually, where the module is sanitized in order to eliminate impurities and particles that could affect the incident irradiance. The module is then attached to the support inside the

simulator, in order to isolate it against the passage of light through a black cotton curtain. After these procedures, the operator starts the simulation, where a flash of light is emitted generated from a Xenon gas lamp, in a short duration that varies from 1 to 30 milliseconds. This action is performed in duplicate, as the measurement occurs directly and reversely in order to attest to the values produced, ensuring the reliability of the measurement. Figure 1 shows the environment where the simulator performs measurements in the IEE building in São Paulo.

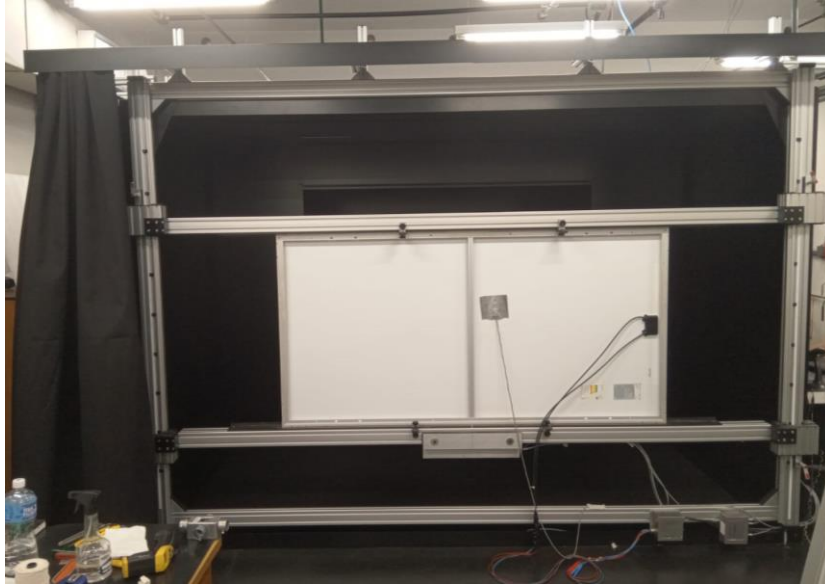


Figure 1: Pasan simulator installed at IEE/SP

The I-V Characteristic Curve is generated automatically using the Simulator's own software, Pasan software version 2.3. A file is provided containing information relating to the measurement that contains data from the module in simulation, as well as its various measured parameters, including cell temperature, incident irradiance, cell efficiency, fill factor, etc. In addition to electrical parameters such as Open Circuit Voltage (V_{oc}), Short-Circuit Current (I_{sc}), Maximum Power Voltage (V_{mp}), Maximum Power Current (I_{mp}) and Maximum Power Point (P_{mp}).

3. Results and Discussion

According to the data provided by the module manufacturer, the following values are found in accordance with Table I:

Table I: Measurements provided in the modules datasheet.

	Polycrystalline Module	Monocrystalline Module
Power	100 W	155 W
Open circuit voltage	21,58 V	24,46 V
Short-circuit current	6,04 A	8,31 A
Maximum Power Voltage	17,40 V	20,64 V
Maximum Power Current	5,75 A	7,51 A
Module efficiency	15,44%	18,05%

To obtain the simulation values of the I-V Characteristic Curve, its measurement are carried out three times in each method (direct and reverse), in order to ensure the values found through an uncertainty of 2.2% of the simulator's percentage error. In this way, the average values of each parameter are used to manipulate the data. In this way, the next step presents the real values that the modules can reach, based on the simulation carried out, it is possible to obtain the following values presented in Table II below.

Table II: Measurement carried out on the Pasan Simulator.

	Polycrystalline Module	Monocrystalline Module
Power	95,83 W	111,61 W
Open circuit voltage	23,77 V	22,96 V
Short circuit current	5,15 A	5,98 A
Maximum Power Voltage	19,59 V	19,30 V
Maximum Power Current	4,89 A	5,77 A
Module efficiency	16,82%	13,00%

It is possible to observe a considerable divergence in the values found, mainly in the Monocrystalline module, which exceeds the specified tolerance, reaching around 28% below what was reported, while the Polycrystalline module presents around 4% below. According to the datasheet, it is mentioned in both modules that the tolerance is from -0 to +5W. In addition to the values, the I-V Characteristic Curve is also simulated, which presents these values graphically as shown in Figure 2.

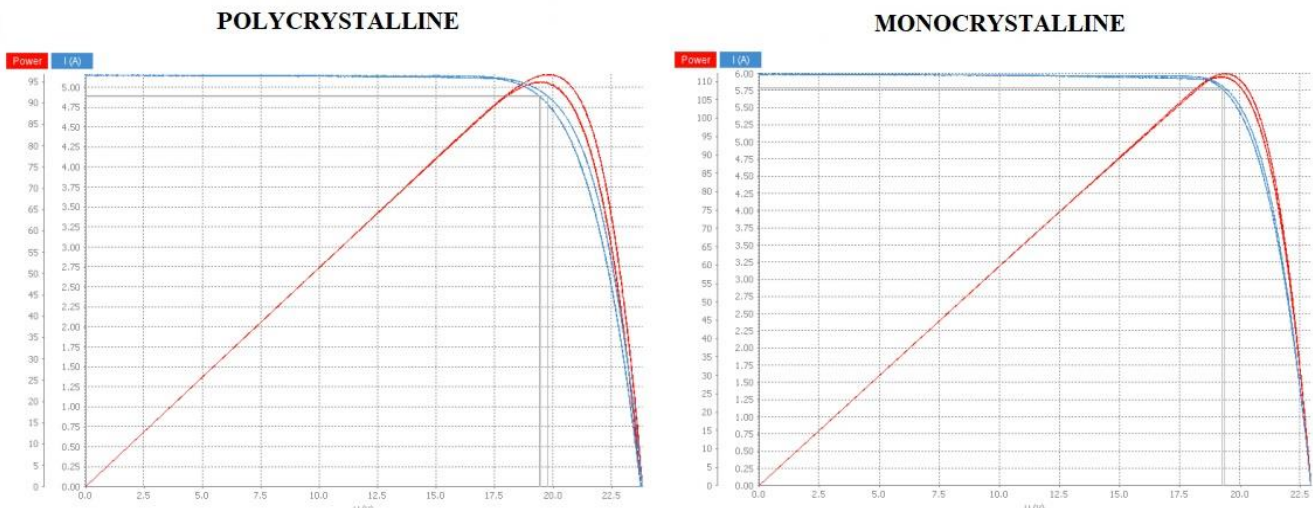


Figure 2: I-V characteristic curve of both modules

4. Conclusions

According to the results above, it is clear that the relationship between manufacturer and consumer needs to have greater transparency. The simulation carried out by IEE had no costs as it was an academic study, however for a regular consumer this simulation has a high cost, in addition to being limited to individual modules and not the entire batch. As a result, many modules may not meet the stipulated minimum

tolerance, causing problems in system sizing, as well as a significant financial impact, as in the case study in question, where some of the modules affect 28% below the nominal measurement.

INMETRO (National Institute of Metrology, Quality and Technology) is the body responsible for regulating these values for manufacturers of photovoltaic modules, however, as mentioned above, the conformity test is carried out in batches, that is, the measurement is carried out in a module that serves to regularize all modules that have passed the same manufacturing process over a given period of time. This causes some modules to be validated without being within the desired tolerance. It is therefore necessary to provide details to determine the best means of studying this validation, as well as an analysis to establish whether this failure is restricted to some manufacturers or whether it is applied generally.

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