DTU Fotonik

Characterization of photovoltaic modules at STC and Several Irradiances

34553 Applied Photovoltaics

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Abstract: In this exercise, we will investigate the performance at different light intensities of a c-Si photovoltaic panel.

References and links

- Slides from lecture (Block 2), course 34553.
- Lecture Week 3 from course 34552 "I-V Curves, Parameters and Equivalent Circuit Models"
- IEC 60891:2010: Procedures for temperature and irradiance corrections to measured I-V characteristics.
- https://www.pveducation.org/pvcdrom/solar-cell-operation/iv-curve

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1. Introduction

In this exercise you will configure a solar simulator to characterize a photovoltaic Device Under Test (DUT) at several irradiances. This test allows to measure the variation in efficiency value of the device due to irradiance level. This variation becomes relevant when assessing the power output of the device being exposed to outdoor irradiance conditions, whose average value can vary significantly due to the seasons and the different locations. Additionally, effects of parameters like series resistance become more relevant at lower irradiances. This exercise will also guide you for the steps to configure the sensors and the measurement parameters that compose and IV curve: Irradiance, temperature, current and voltage.

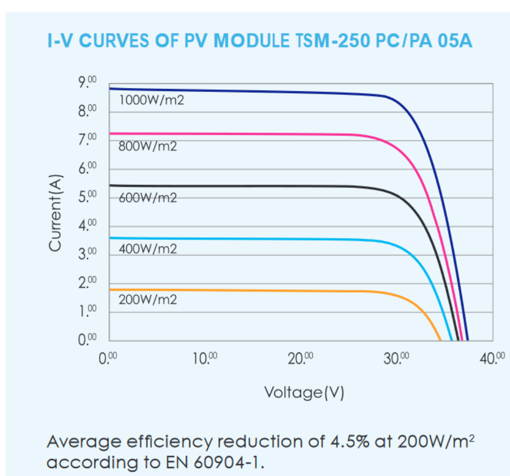

Figure 1: Example of IV Curves at several irradiances as presented on the datasheet of the Trina Solar TSM-PC05A / TSM-PA05A 60 cell module.

2. Experimental setup

The system you will be working with is used by DTU Fotonik's Applied Photovoltaics (APV) team for measuring I-V curves on PV panels up to 1.2 m x 2.0 m in size. The light source consists of many LEDs that are controlled by eight addressable channels. The spectral distribution and intensity of the light can be customized via the computer interface, but for this exercise the spectral distribution is set to be similar to AM 1.5G with a broadband intensity that will be varied according to the desired irradiance level. When the DUT is illuminated, an I-V curve will be made using a single quadrant load and a 4-wire measurement. Temperature of the device will be measured with a contact PT100 probe attached at the back of the DUT. A trained staff member from DTU Fotonik's APV team will assist you with the measurements.
The irradiance levels of interest and their power configuration are shown in the table below:

Irradiance [W/m^2]	Light Intensity Power Level [%]
1000	75%
800	58%
600	43%
400	28%
200	15%

3. Experimental Methods

A trained DTU staff will assist you with the initial familiarization of the solar simulator and with the steps to be followed.

1. You will need the electrical and physical parameters of the manufactured PV device ready for input into the simulator software. These will be:
   a. Module Dimensions (external borders).
   b. Cell dimensions and number of cells.
   c. Amount of cells connected in series and/or parallel.
   d. Expected electrical parameters Isc, Voc, Impp, Vmpp will be provided.
   e. The following values of the temperature coefficients for the cell technology employed will be used:
      T. coefficient for Isc: $\alpha = 0.05$ %/°C
      T. coefficient for Voc: $\beta = -0.34$ %/°C
      T. coefficient for Pmpp: $\gamma = -0.4$ %/°C
2. You will get familiarized with several aspects of the solar simulator, as listed below:
   a. The configuration of sensors for temperature and irradiance measurements.
   b. Light intensity control.
   c. Differences between calibration at Isc and Pmpp.
   d. Use of the working reference module to correct values measured by the pyranometer through the Calibration Factor (Cf) obtained.
   e. Software IV curve correction procedures at STC. At several irradiances, software correction is made only for temperature at 25 °C and no irradiance correction is made.
   f. The 1-quadrant electronic load employed for the voltage sweep and 4 wire connection principles.
3. A calibration module of the same technology as the DUT will be used for irradiance calibration before testing the device under test. Select the appropriate light intensity power level and IV curve correction procedure from the software menu. Perform IV measurement of the calibration module at each desired irradiance.

4. Adjust the internal rails of the simulator to the size of the DUT to be measured. Before sliding the DUT in, attach the temperature sensor to the back of the module, close to the center. Connect the 4-wire cables to the leads of the DUT.
5. Select the desired light intensity power level, software IV curve correction, and calibration file at the desired irradiance.
6. Repeat step 5 for all desired irradiances.
7. Repeat step 3 (measurement of working reference module at desired irradiances) to verify light stability deviation before and after measurements.

4. Presentation

The measured I-V curves corrected to STC and to 25 °C without irradiance correction will be uploaded to the Learn platform as a .csv file. Prepare a short presentation showing plots of the measured I-V curves following the tasks detailed below, and responses to the following questions.

The presentation should fit in around 6 slides and should include:

- Background and purpose/motivation of the method/exercise (1 slide)
- Description of the experimental setup and procedure (1 slide)
- Results and conclusions (4 slides)

Questions and tasks for presentation:

1. Correct the IV curves to the appropriate irradiance level using the use Correction Procedure 2 (i.e. equations 4 and 5 on page 7 of IEC 60981). The curve at 1000 W/m^2 is already corrected to STC and does not need to be processed. Use ($T_2 - T_1$) = 0, Rs´= 0 and a = 0.06.

2. Calculate the efficiency [%] for each IV curve. The area should be the calculated using the measurements of the outside borders of the DUT. The irradiance should be the desired one (200 W/m^2, 400 W/m^2, etc.)

3. Prepare a table with the summary parameters for each IV curve using the template given below.

Corrected Irradiance [W/m^2]	Measured T_{DUT} [°C]	Isc [A]	Voc [V]	Impp [A]	Vmpp [V]	Pmpp [W]	FF [%]	Efficiency [%]
1000								
800								
600								
400								
200								

4. Calculate the relative efficiency (η_{rel} , in %) using the equation below:

$$\eta_{rel} = \frac{P(G)/G}{P(G_{STC})/G_{STC}}$$

Where:

$P(G)$ = Power output of the DUT at the corrected irradiance [W].

G = Corrected desired irradiance [W/m^2].

$P(G_{STC})$ = Power output of the DUT at STC conditions [W].

G_{STC} = Corrected irradiance at STC = 1000 W/m^2

5. Calculate the Series Resistance (Rs, Ω) with a linear regression using values of I-V close to Voc for each irradiance level. Take the range of points between 0.9*Voc to Voc. If we take a typical value for c-Si of 5-10 mΩ/cell, how would your estimated value for the whole module compare? (beware number of cells and interconnection)
6. How does the efficiency at lower irradiance levels compare to the efficiency at STC? Could this affect energy yields estimations on a PV installation model?
7. What was the maximum deviation of irradiance between the values before and after the measurements?
8. The IV curve test is done in a non-controlled lab environment, which temperature can vary around 25 °C ± 10 °C. Which irradiance calibration parameter would be more advisable to use and why?
9. A manufacturer may decide to use the ambient temperature of the room for the DUT temperature measurement. What would you advise regarding test/environmental conditions (e.g. light exposure duration, sample handling and/or environment monitoring) to minimize the error when using such an assumption?
10. A 4 wire measurement is used for acquiring the I-V curve. Why is that?