Measurement of Temperature Coefficients

34553 Applied Photovoltaics

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Abstract: In this exercise you will measure the I-V curve's dependency on cell temperature. You will use the measurements to derive temperature coefficients for the main points on the I-V curve.

References and links

- Slides from class (Block 3)
- K. Mertens Chapter 4.4.6
- https://www.pveducation.org/pvcdrom/solar-cell-operation/effect-of-temperature

Safety

- The pulsed-light source is very bright. Avoid looking at it when flashing (during measurement).

1. Introduction

Temperature coefficients of PV devices describe the change of electrical output (current, voltage and power) with respect to cell temperature. You will measure this effect on either a 36 cell panel (outdoor system) or a single c-Si cell (indoor system). If there is stable direct beam light available (clear skies), we will do the experiment outdoors on the panel. If the solar irradiance is mostly diffuse, we will conduct our testing indoors on a single cell. You will compare your measured temperature coefficients to the values published on the datasheets of commercially available c-Si modules.

2. Theory

As shown in class the voltage and power of PV panels decreases with increasing temperature, while the short circuit current I_{SC} increases slightly with increasing temperature. Increases in temperature decrease the bandgap of the semiconductor. When the bandgap decreases, lower energy is needed to break the Si bond, and longer wavelength photons can create charge separation. This phenomenon results in a higher I_{SC} with increasing temperature.

A more pronounced temperature effect on electrical output is observed in the voltage. The open circuit voltage V_{OC} of a PV device decreases with temperature because of the intrinsic carrier concentration n_i dependence on the bandgap energy; Subsequently, the increase of electron movement (n_i) in the conduction band leads to a higher saturation current I_0 and thus a lower V_{OC}.

3. Experimental Setup

Figure 1 shows a block diagram of a commercially available Pasan cell tester that is capable of measuring temperature coefficients. This system consists of a Xe arc lamp that is powered by high a voltage generated from the capacitor bank. The light intensity during the 10 ms long flash is stable via closed-loop feedback control. Inside the lamp housing are a series of baffles that improve the spatial uniformity of light on the test plane and minimize light dispersion. Cell temperature is varied by Peltier elements underneath the mounting plate, which are capable of controlling cell temperature between ~20 - 55 °C. Note that the reported temperature comes from a probe inside the mounting plate. We will assume that this temperature is equal to the cell temperature.

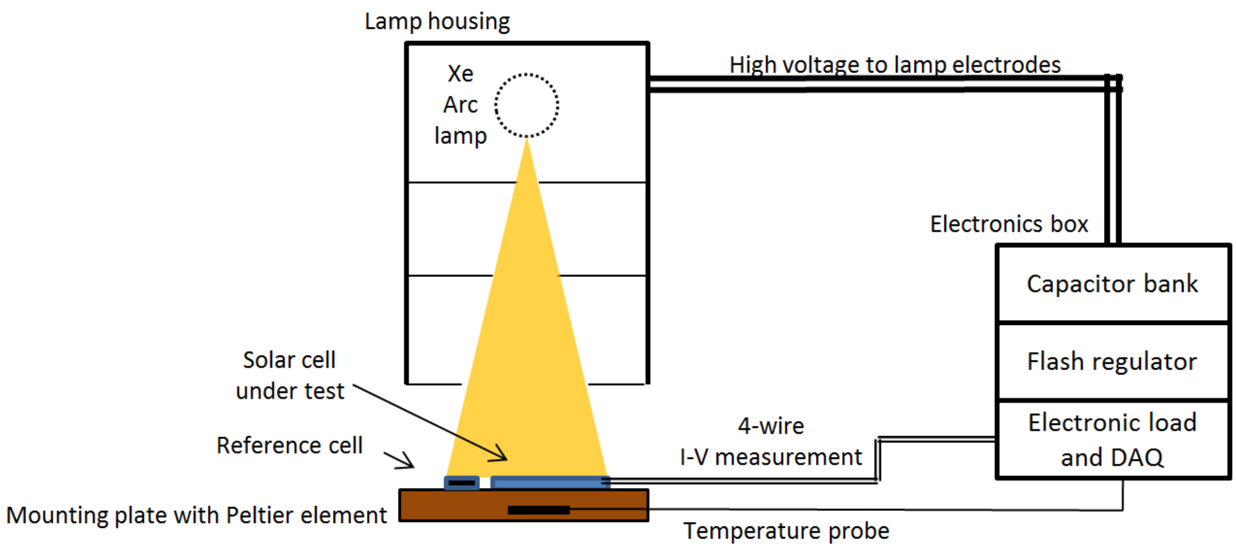


Figure 1: Block diagram for temperature coefficient measurement of single cells.

4. Experimental Methods

Your task is to change the cell temperature from 25 to 55 °C while taking I-V measurements every 5 °C. The instructor will walk you through the following procedure to accomplish this task:

1. Turn on the Dell laptop located on the desk.
    a. Make sure the laptop is charging via power supply.
2. Turn on the Pasan flasher electronics located under the desk (Figure 2)

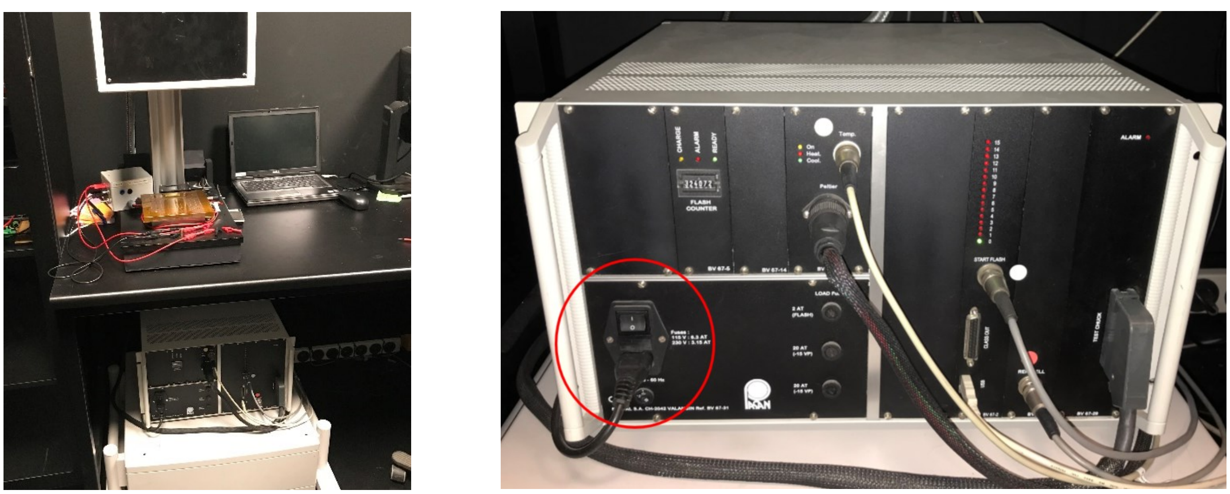


Figure 2: Left) Picture of Pasan cell tester setup. Right) Picture of electronics box with on/off switch circled in red.

3. Mount the single cell PV device on the gold plate with the “sunny side” facing up. Make sure the edges of the cell (i.e. active area) are completely within the gold plate (Figure 3, Right).
4. Attach four banana plug cables (≥ 2 mm^2) to the enclosure as shown, make sure that both the “sense SW” and “source SW” toggle switches are in the left-most position (Figure 3, Left).

5. Attach the 4-wire measurement to the appropriate PV polarity with the sense leads on the inside of the source leads

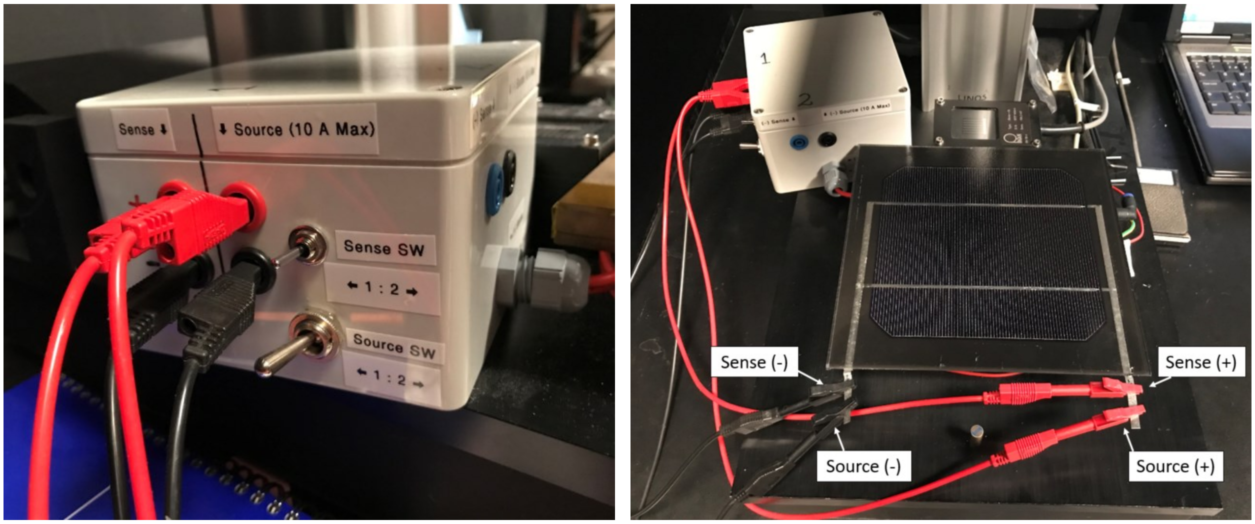


Figure 3: Left) Junction box and toggle switches shifted to left-most position. Right) PV device aligned on gold plate and 4-wire connection made with crocodile clips.

6. Open the "Pasan SLAB" application on the desktop. Figure 4, Left shows a screenshot of the main interface and highlights the menus you will use.
7. Select "**Config**" -> "modules" to see the available PV device configuration files.
    a. These files contain device-specific information such as manufacturer, bill of materials and the expected electrical characteristics.
    b. Select the "Gaia, Mono 156, Albarino T" device, then click "use".
8. For each temperature step, select the "**Mde**" box to configure the temperature control settings. Do the following:
    c. Make sure the "T compensated results" box is <u>unchecked</u>.
    d. In the "Temp control" section select the "Set to" radio button and input the target cell temperature (Table 1). See Figure 4, Right for an example of a target temperature of 25 °C
    e. Click "Apply" then click "Save".

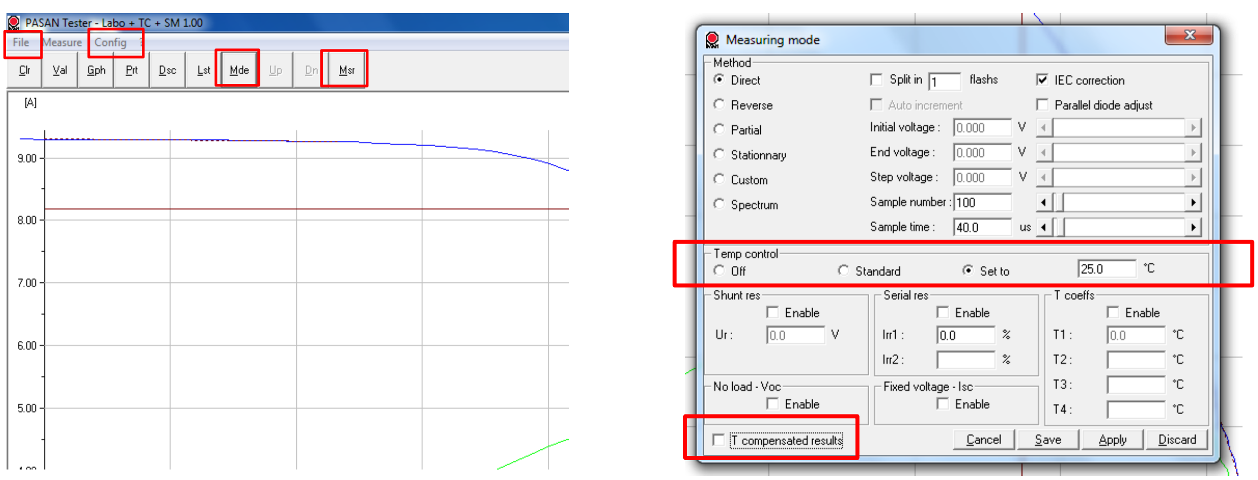


Figure 4: Left) Screenshot of main screen within the Pasan SLAB software. The menus to be used in this exercise are boxed in red. Right) Screenshot of the 'Mde' menu with temperature control and flash settings for 25 °C.

Table 1: Test steps and expected wait times. Note you can insulate the top of the device with blankets or other material to potentially improve temperature homogeneity and speed up the ramp time.

Step	Target Cell Temperature	Expected wait time between previous step
1	25 °C	-
2	30 °C	10 min
3	35 °C	10 min
4	40 °C	10 min
5	45 °C	15 min
6	50 °C	30 min
7	55 °C	30 min

9. Click the "**Msr**" box.
    a. The Peltier element will now heat the plate to your target temperature.
    b. The measurement will not be taken until the target temperature is reached. You can monitor the "Panel temperature" in the bottom right of the GUI.
10. When the "Panel Temperature" is within 1 °C of your target temperature, turn off room the lights (the measurement will soon take place and you don't want them on with this happens).
11. IMPORTANT! After each measurement you need to click "**File**" -> "Export" (.asc) and save each measurement. If you take another measurement without saving, the previous measurement will be lost. For each file give a descriptive name e.g. Date_SampleName_Temperature_Flash#.asc)
12. It is a good practice to take three I-V measurements at each temperature step and average them.
13. Proceed to the next temperature step. When all steps are complete save your data to a USB drive.
14. Shutdown the PC and turn off the Pasan flasher.

Notes on troubleshooting:

If you receive an error message upon measurement it may be because the electrical characteristics of the device have changed and are no longer within the settings specified in the configuration files. To check the PV device parameters, click **Config** -> modules -> modify. The most common parameter you may need to modify is "Start scanning voltage". Adjust this value in steps of about 0.2-0.3 V and repeat the measurement as necessary.

5. Presentation (~3 slides)

From the I-V curves, extract the I_{SC}, V_{OC}, I_{MP}, V_{MP} and P_{MP}. Plot these characteristics as a function of the cell temperature. Construct a least-squares-fits to the data. The slope of the regression line gives the temperature coefficient in absolute units (i.e A/ °C, V/ °C or W/ °C). Divide each slope by the respective value at 25 °C to obtain the temperature coefficients in units of %/ °C. You may need to extrapolate or interpolate to obtain the value at 25 °C.

Points to mention in your presentation:

1. Measurement concept and purpose.
2. Show the measured temperature dependency of I_{SC}, V_{OC}, I_{MP}, V_{MP} and P_{MP}.
3. How do your temperature coefficients for I_{SC}, V_{OC} and P_{MP} compare to the datasheet values of a typical c-Si module? Refer to the thermal characteristics in the datasheet below (Figure 5). Why do you believe there are differences, if any?
4. Provide suggestions for how to improve the testing you did in this lab. Think about the different aspects of the test such as the electronics (load), the methods used to heat the cell/module, the temperature measurement etc.

SOLVIS
PHOTOVOLTAIC MODULES

Electrical parameters at Standard Test Conditions (STC)				
MODEL		SV36-150	SV36-155	SV36-160
Peak power P_{MPP}	[W]	150	155	160
Peak power tolerance	[W]	-0/+4,9		
Short circuit current I_{SC}	[A]	8,62	8,82	9,05
Open circuit voltage V_{OC}	[V]	22,8	23,0	22,9
Rated current I_{MPP}	[A]	8,13	8,29	8,47
Rated voltage V_{MPP}	[V]	18,5	18,8	18,9
Current and voltage tolerance	[%]	± 3		
Module efficiency	[%]	14,91	15,41	15,91

STC: 1000W/m² irradiance, 25 °C cell temperature, AM1,5 g spectrum according to EN 60904-3
Average relative efficiency reduction of 3,4 % at 200 W/m² according to EN 60904-1

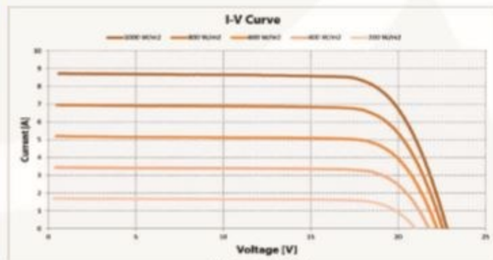
Electrical parameters at Nominal Operating Cell Temperature (NOCT)				
MODEL		SV36-150	SV36-155	SV36-160
Peak power P_{MPP}	[W]	109,11	112,98	116,12
Peak power tolerance	[W]	-0/+4,9		
Short circuit current I_{SC}	[A]	6,92	7,09	7,27
Open circuit voltage V_{OC}	[V]	21,0	21,2	21,1
Rated current I_{MPP}	[A]	6,44	6,56	6,71
Rated voltage V_{MPP}	[V]	16,9	17,2	17,3

NOCT: module operating parameters at 800 W/m² irradiance, 20 °C ambient temperature, 1 m/s wind speed

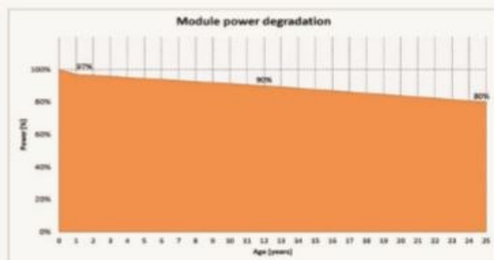
MECHANICAL DATA		
Dimensions (H x W x D)	[mm]	1014 x 992 x 35
Weight	[kg]	14,0
Solar cells		36 cells, polycrystalline Si, 156 x 156 mm
Cells encapsulation		Ethylene vinyl acetate (EVA)
Front		Tempered solar glass, 3,2 mm
Back		Composite polyester Film
Frame		Anodized aluminium frame with twin-wall profile and drainage holes
Junction box		IP67 with 3 Bypass diodes
Cable and connectors		Solar cable 4 mm², length1000 mm, MC4 compatible connectors

OPERATING CONDITIONS		
Temperature range	[°C]	-40 to +85
Maximum system voltage	[V]	1000
Max. series fuse rating		15A
Limiting reverse current		15A
Maximum surface load capacity		5400 Pa (Snow load)
Resistance against hail		Maximum diameter of 25 mm with impact speed 23 m/s

THERMAL CHARACTERISTICS		
Temperature coefficient of P_{MPP}	[%/K]	-0,41
Temperature coeffcient of I_{SC}	[%/K]	0,05
Temperature coeffcient of V_{OC}	[%/K]	-0,31



I - V Curve for SV36-150



NOTE: For extended models, SV36 YYY, voltages and currents can vary where YYY is optional based on the chosen YYY variant (YYY = letter(s), F for black frame, B for silver frame and black backsheet, BC for full black module)

Figure 5: Datasheet from a 36-cell multicrystalline PV module manufactured in 2016.