

Exercise 2a

Developing a PV Circuit Model from a Datasheet

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1 Introduction

Fundamental to power electronics design for photovoltaic (PV) systems is the inherent variability of a PV cell. We must capture this behavior if we wish to develop useful models of PV systems. However, PV cells vary not only with irradiance and temperature, but with the specific construction and technology used by a particular manufacturer. In this exercise, we'll learn how to create a circuit model from a PV panel's datasheet values using a popular algorithm proposed by Villalva et al. in [1].

We'll consider a popular residential PV panel by LG Electronics, the "LG NeON2 Black" model LG325N1K-V5 [2]. The datasheet for this panel accompanies this exercise. However, once you complete and this exercise, you will be equipped to model any PV panel from its datasheet parameters.

2 Identify Key PV Panel Parameters

The most important points on the I-V characteristic of a solar PV cell are the open-circuit voltage, short-circuit current, and the maximum power point (MPP) voltage and current. However, we are also interested in how these parameters change under different irradiance and temperature conditions. These parameters are always provided by the panel manufacturer.

1. Use the provided datasheet to find and record the MPP Voltage, MPP current, open circuit voltage, and short circuit current of the panel under standard test conditions.
2. Find and record the % change in open circuit voltage and short-circuit current with temperature.
3. Convert the parameters in part (2) to $V/^{\circ}C$ and $A/V/^{\circ}C$ by multiplying by the open circuit voltage and short circuit current under nominal module operating temperature conditions.
4. Find the number of cells used in the panel.
5. Determine the series/parallel configuration of the panel's cells. Typically these panels have all of their cells wired in series, and this is the case in the panel we're studying. Although it is not told to us directly, we can roughly confirm this by noting that a typical solar cell has a nominal open-circuit voltage around 0.55-0.76V. If all of the cells in this module are in series, does the panel's open circuit voltage reasonably match with this expectation?

6. Digitize the provided I-V characteristics (assumed to be collected under the standard test condition¹) so that you can plot them in MATLAB. A tool like “WebPlotDigitizer” is excellent for doing this [3]. For your convenience, this data accompanies this exercise.

3 Review and Run the Accompanying MATLAB Script

The accompanying MATLAB script implements the algorithm in [1], which describes how all of the unknown model parameters can be determined via a numerical iterative search. The algorithm is rooted in making the computed and estimated short-circuit current, open-circuit voltage, and maximum power point equal to the datasheet values in the nominal conditions. These “remarkable points” are the most important features and it is argued that if these details are well-captured, then the model is sufficiently good for most purposes.

First, open the file and enter the PV datasheet values you determined in the first part of this exercise. Then, the one tuning parameter which must be determined is the ideality constant a of the diode in the PV circuit model. The script is set up so that once you enter the values obtained from the datasheet, you simply need to tune a to achieve the best matching between the datasheet values and the estimated values. In the script, dashed lines are data extracted from the datasheet while solid lines are the data from the model. Data is plotted for the five irradiance curves provided on the datasheet.

An important note is that the manufacturer’s I-V curve data may not exactly match the datasheet specifications of open-circuit voltage, short-circuit current, or maximum power point. There is innate variation between any two panels, and most manufacturers will indicate this by specifying a percent variation in the listed quantities. For example, our panel says that open-circuit voltage and short-circuit current in nominal conditions can vary by $\pm 5\%$. You will notice that we do not get perfect matching between the computed and experimental curves because of this reason (in particular, the maximum power point extracted from the datasheet I-V curve is higher than the maximum power listed in the datasheet). You should choose the ideality constant which most closely matches the manufacturer’s data.

Record the value of a you used to get best matching, and the values of R_p and R_s computed from the script. These, along with the known datasheet parameters, define our complete PV circuit model.

4 Defining the Circuit Model

Draw the circuit schematic of a practical PV device as described in lecture. Write out the equations for I_{pv} and I_d in terms of the datasheet values you recorded in the first part of this exercise, with these equations being functions of the input irradiance G (in W/m^2) and the cell temperature (in degrees Kelvin). Also write out the values of a , R_p , and R_s obtained in part (2) on this schematic. *Hint: The MATLAB script describes these items in detail.* We now have a circuit model of the LG325N1K solar panel which we can employ in simulation for future PV system studies.

¹Irradiance $1000 \text{ W}/\text{m}^2$, Cell temperature 25°C , AM 1.5

References

- [1] M. G. Villalva, J. R. Gazoli, and E. R. Filho, “Comprehensive Approach to Modeling and Simulation of Photovoltaic Arrays,” *IEEE Transactions on Power Electronics*, vol. 24, no. 5, pp. 1198–1208, May 2009.
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- [3] A. Rohatgi, “Webplotdigitizer: Version 4.5,” 2021. [Online]. Available: <https://automeris.io/WebPlotDigitizer>