

Figure S1. Actual Simulink model diagram of the solar cell.

- **MATLAB/SIMULINK setup**

A mathematical model representing a physical system can be easily expressed and simulated in Simulink. These models are graphically represented as block diagrams. The user can select blocks from the provided libraries to represent various phenomena and models in a number of different formats. As shown in Figure S2 below, one of the models available in the Simulink library is a solar cell. Furthermore, current and voltage sensors are used to read measure the current and voltage under the effect of solar irradiance of (1000 W/m^2). The block diagram of a solar cell is derived from the equivalent circuit Equation 1 presented in the main text of the paper, and the block parameters are depicted in Figure S3. In addition, other block diagrams are used to run the mathematical calculations, such as ramp and solver configuration.

Solar cell model characteristics in Simulink software provide three different block parameterization settings named by s/c current and o/c voltage, five parameters, by equivalent circuit parameters, five parameters, and by equivalent circuit parameters, eight parameters. The first two parameterization settings provide only a few parameters to be adjusted; thus, a parameter such as shunt resistance is unavailable. However, the third parameterization settings allow the user to have complete control of the parameters and, most notably, the series and shunt resistances of the solar cell model.

After connecting the blocks in to create the solar cell model, the data could be extracted directly from workspace in MATLAB main page. As can be seen in Figure S4, the value of voltage and current are displayed as column data. The same Figure is also showing the simple code written to draw the I-V curve.

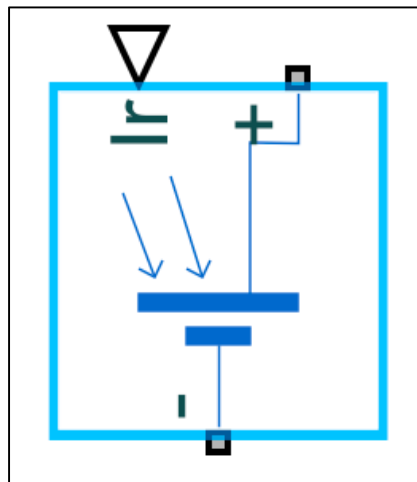


Figure S2. Solar cell block diagram in MATLAB/SIMULINK.

Block Parameters: Solar Cell15

Solar Cell

This block models a solar cell as a parallel combination of a current source, two exponential diodes and a parallel resistor, R_p , that are connected in series with a resistance R_s . The output current I is given by:

$$I = I_{ph} - I_s \left(e^{\frac{V+I R_s}{N V_t}} - 1 \right) - I_{s2} \left(e^{\frac{V+I R_s}{N_2 V_t}} - 1 \right) - \frac{V+I R_s}{R_p}$$

where I_s and I_{s2} are the diode saturation currents, V_t is the thermal voltage, N and N_2 are the quality factors (diode emission coefficients) and I_{ph} is the solar-generated current.

Models of reduced complexity can be specified in the mask. The quality factor varies for amorphous cells, and typically has a value in the range of 1 to 2. The PS input I_r is the irradiance (light intensity) in W/m^2 falling on the cell. The solar-generated current I_{ph} is given by $I_r \cdot (I_{ph0}/I_{r0})$ where I_{ph0} is the measured solar-generated current for irradiance I_{r0} .

Settings

Cell Characteristics Configuration Temperature Dependence

Parameterize by: By equivalent circuit parameters, 8 parameter

Diode saturation current, I_s : A

Diode saturation current, I_{s2} : A

Solar-generated current for measurements, I_{ph0} : A

Irradiance used for measurements, I_{r0} : W/m^2

Quality factor, N :

Quality factor, N_2 :

Series resistance, R_s : Ohm

Parallel resistance, R_p : Ohm

OK **Cancel** **Help** **Apply**

Figure S3. Solar cell block parameters in MATLAB/SIMULINK.

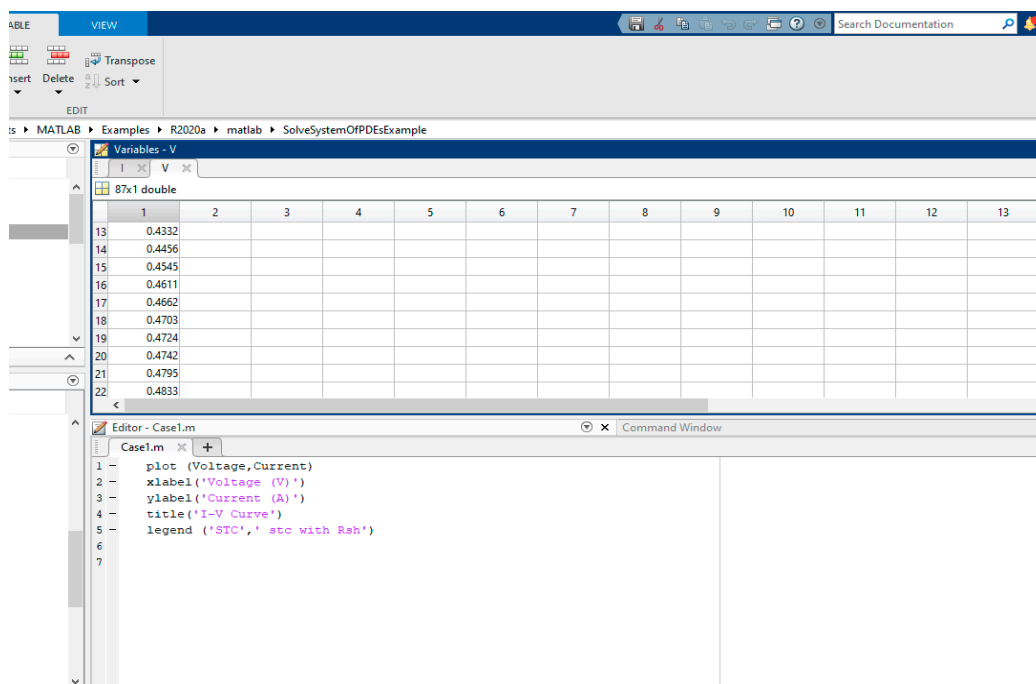


Figure S4. Simple code for drawing the I-V curve.