Formulate a single-diode model (SDM) in terms of—
- parallel conductance
- parameter SDM is given by—
- Under certain homogeneity assumptions, a six-spectrally dependent temperature coefficient (TC).

The SDM is calibrated by measuring observables
- current-voltage (I-V) curves
- short-circuit current & open-circuit voltage
  point pairs: $I_{sc}$ & $V_{oc}$

The SDM-calibrated PV device becomes an irradiance and temperature sensor by re-tasking the parameter fitting problem solved with PVfit in Fig. 1.

Knowing the six SDM parameters and at least two distinct points on an I-V curve measured at constant irradiance and temperature, one can fit the remaining two unknown parameters $F$ and $T$ in the SDM.

$I_{sc}$ and $V_{oc}$ are a minimal number of easy-to-observe points, which are particularly sensitive to changes in $F$ and $T$, respectively. (Cf. TC-based methods.)

**Technical Foundation**

Formulate a single-diode model (SDM) in terms of—
- Effective Irradiance: $F = I_{sc} -$ prevailing
- Cell Temperature: $T \leftarrow$ prevailing (at junction)

$I_{sc0}$, the PV device’s short-circuit current at standard test conditions (STC), does not depend on a spectrally dependent temperature coefficient (TC).

Under certain homogeneity assumptions, a six-parameter SDM is given by—

$$0 = I_{ph} - I_{sc} \left( \frac{G_{p0}}{G_{p0sc}} - 1 \right) - G_{p} (V + i R_{s}) - I,$$

with auxiliary equations—

$$I_{ph} = I_{sc} \left( \frac{G_{p0}}{G_{p0sc}} - 1 \right) + G_{p} i R_{s} + I_{sc}.$$ 

$$I_{sc0} = \frac{T_{sc}}{T_{sc0}} e^{\frac{b_{sc}}{T_{sc0}}},$$

$$n = n_{sc}, \quad R_{s} = R_{s0}, \quad G_{p} = G_{p0}, \quad I_{sc} = FI_{sc0},$$

where the subscript 0 denotes a value at STC [2, 3].

The SDM is calibrated by measuring observables (green) and inferring model parameters (blue) [2].

Other auxiliary equations for series resistance $R_{s}$ and parallel conductance $G_{p}$ are readily handled.

**PV-Based Sensing of $F$ and $T$**

Two PV-based sensors were tested on various PV modules in the (m)PERT outdoor I-V curve data set from the National Renewable Energy Laboratory (NREL) [4], which included $I_{sc}, V_{oc}$, plane-of-array (POA) irradiance, and module back-surface temperature with each I-V curve, and an IEC 61853-1 calibration for each module.

Fig. 2 shows one day of results for the module in Fig. 1 with I-V curves at 5-minute intervals in Cocoa, FL. Discrepancy between the two sensors is largest at low $F$ and may be related to larger SDM inaccuracy there.

**Demonstration of PV-Based Sensing of $F$ and $T$ Using PVfit**

**Key Result**

Diode-based performance models calibrated using IEC 61853-1 enable new PV-based irradiance and temperature sensors that do not rely on temperature coefficients.

**Key Idea**

Photovoltaic (PV) devices measure effective irradiance ($F$) and cell temperature ($T$) more directly than meteorological (MET) stations. This PV-based sensing approach requires—

- A field-deployable PV device, e.g., cell/module
- A good performance model, e.g., 1 or 2 diodes
- A calibration “matrix”, e.g., IEC 61853-1 [1]
- A measurement time series of—

- current-voltage (I-V) curves
- short-circuit current & open-circuit voltage
  point pairs: $I_{sc}$ & $V_{oc}$

**References**


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