PV Module Single-Diode Model: Operating I–V Point and Maximum Power

Five-parameter single-diode PV model: parameters at operating cell temperature and irradiance, short-circuit current, open-circuit voltage and maximum power point.

Input parameters

Unit system: SI

Parameter	Value	Unit
Modified ideality factor at reference (n k T N_s/q)	0.93520	V
Light current at reference	4.5490	A
Diode reverse saturation current at reference	4.7820e-10	A
Series resistance	0.56700	Ω
Shunt resistance at reference	52.400	Ω
Short-circuit current temperature coefficient, A/K	2.6000e-04	
Open-circuit voltage temperature coefficient	-85.000	mV/K
Cell temperature	25.000	°C
Reference cell temperature	25.000	°C
Absorbed radiation ratio	1.0000	
Module area	0.63300	m^2
Incident radiation on the module	1,000.0	W/m^2
Cell material	Silicon (E_g 1.12 eV)	

Calculated results

Parameter	Value	Unit
Modified ideality factor	0.93520	V
Light current	4.5490	A
Reverse saturation current	4.7820e-10	A
Shunt resistance	52.400	Ω
Short-circuit current	4.5003	A
Open-circuit voltage	21.399	V
Current at maximum power	3.9502	A
Voltage at maximum power	16.501	V
Maximum power	65.180	W
Module efficiency at maximum power	10.297	%
Maximum power at reference conditions (1000 W/m^2, T_c,ref)	65.180	W
Efficiency at reference conditions	10.297	%
Fill factor	67.683	%
Efficiency temperature coefficient estimate η_ref μ_V,oc/ V_mp,ref, 1/K	-5.3043e-04	

Notes for this case

• De Soto, Klein and five-parameter model: a ∝ T_c, I_L ∝ S/S_ref with μ_I,sc, I_o from the band gap, R_sh ∝ S_ref/S, R_s constant. The reference parameters come from fitting datasheet I_sc, V_oc, I_mp, V_mp and μ_V,oc.

Formula and method

$$I = I_L - I_o \left[\exp\left(\frac{V + IR_s}{a}\right) - 1\right] - \frac{V + IR_s}{R_{sh}}$$

$$\frac{a}{a_{ref}} = \frac{T_c}{T_{c,ref}}, \quad I_L = \frac{S}{S_{ref}}\left[I_{L,ref} + \mu_{I,sc}(T_c - T_{c,ref})\right], \quad \frac{I_o}{I_{o,ref}} = \left(\frac{T_c}{T_{c,ref}}\right)^3 \exp\left[\frac{E_{g,ref}}{kT_{c,ref}} - \frac{E_g}{kT_c}\right]$$

Variables

a_{ref}	Modified ideality factor at reference (n k T N_s/q)	V
$I_{L,ref}$	Light current at reference	A
$I_{o,ref}$	Diode reverse saturation current at reference	A
R_s	Series resistance	Ω
$R_{sh,ref}$	Shunt resistance at reference	Ω
$\mu_{I,sc}$	Short-circuit current temperature coefficient, A/K	-
$\mu_{V,oc}$	Open-circuit voltage temperature coefficient	V/K
T_c	Cell temperature	K
$T_{c,ref}$	Reference cell temperature	K
S/S_{ref}	Absorbed radiation ratio	-
A_c	Module area	m²
G_T	Incident radiation on the module	W/m²
E_g	Cell material	-
a	Modified ideality factor	V
I_L	Light current	A
I_o	Reverse saturation current	A
R_{sh}	Shunt resistance	Ω
I_{sc}	Short-circuit current	A
V_{oc}	Open-circuit voltage	V
I_{mp}	Current at maximum power	A
V_{mp}	Voltage at maximum power	V
P_{mp}	Maximum power	W
η_{mp}	Module efficiency at maximum power	-
$P_{mp,ref}$	Maximum power at reference conditions (1000 W/m², T_c,ref)	W
$\eta_{mp,ref}$	Efficiency at reference conditions	-
FF	Fill factor	-
$\mu_{\eta,mp}$	Efficiency temperature coefficient estimate η_ref μ_V,oc/V_mp,ref, 1/K	-

Method and standards

Single-diode equivalent circuit with temperature and irradiance scaling of its five parameters.

Assumptions and limits

- Crystalline silicon or GaAs cells; R_s constant, R_sh ⍰ 1/S.

Report details

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Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

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Reopens the calculator with the inputs of this report.