

Supplementary Information

Modeling and Simulation of Photovoltaic Modules Using Bio-Inspired Algorithms

Lucas Lima Provensi, Renata Mariane de Souza, Gabriel Henrique Grala,
Rosângela Bergamasco, Rafael Krummenauer and Cid Marcos Gonçalves Andrade *

Department of Chemical Engineering, State University of Maringa, Maringa 87020-900, PR, Brazil;
lprovensi@uem.br (L.L.P.); pg54842@uem.br (R.M.d.S.); gabrielgrala@gmail.com (G.H.G.);
rbergamasco@uem.br (R.B.); rkrummenauer2@uem.br (R.K.)

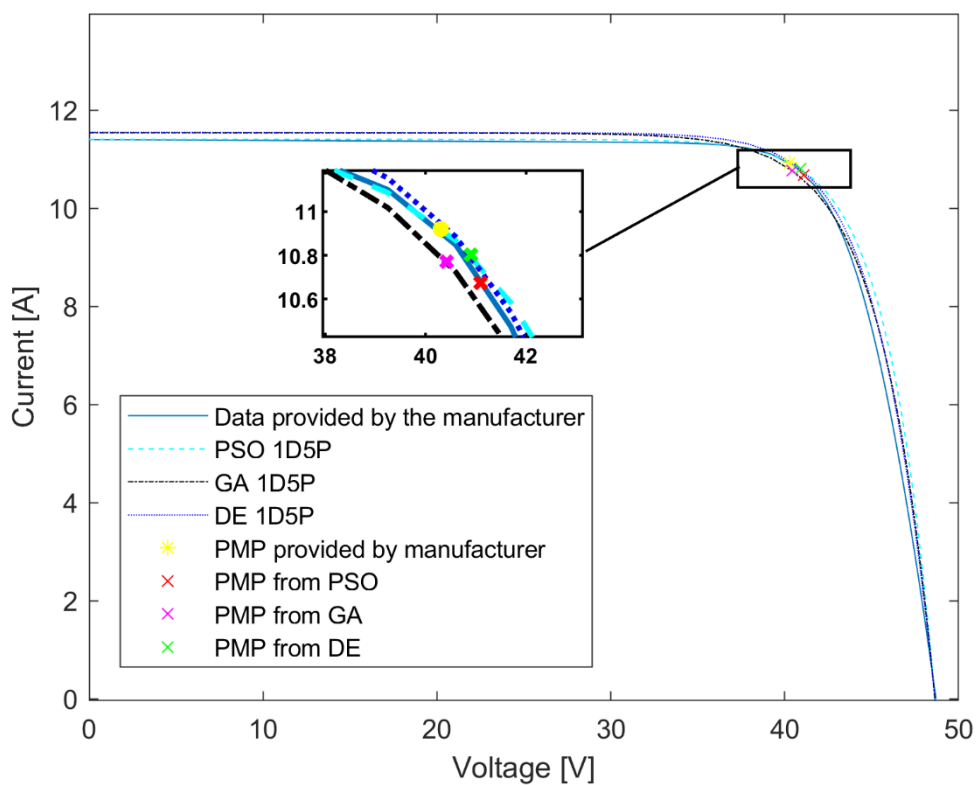
* Correspondence: cmgandrade@uem.br; Tel.: +55-44-3011-4778

Complementary research of the module Canadian CS3W-440Wp P Poly-crystalline (CANADIAN, 2020).

Table S1. Parameters extracted by each method from the CANADIAN CS-3W-440-P module.

	I_{01}	R_s	$A1$	R_{sh}	I_L	I_{02}	$A2$
PSO 1D5P	$7.3759 \cdot 10^{-8}$	$1.4539 \cdot 10^{-2}$	1.4695	3478.6876	11.405		
PSO 2D7P	$1.8627 \cdot 10^{-7}$	$4.0683 \cdot 10^{-2}$	1.5449	4658.635	11.501	$1.141 \cdot 10^{-8}$	1.9779
GA 1D5P	$1.00 \cdot 10^{-6}$	$7.656 \cdot 10^{-3}$	1.704	4999.98	11.539		
GA 2D7P	$3.6455 \cdot 10^{-7}$	$1.689 \cdot 10^{-2}$	1.690	4999.99	11.5638	$1.00 \cdot 10^{-6}$	1.7622
DE 1D5P	$4.6268 \cdot 10^{-8}$	$7.499 \cdot 10^{-2}$	1.43352	3076.919	11.5493		
DE 2D7P	$3.9558 \cdot 10^{-7}$	$2.2470 \cdot 10^{-9}$	1.8170	4199.99	11.6051	$7.788 \cdot 10^{-8}$	1.48605

(a)



(b)

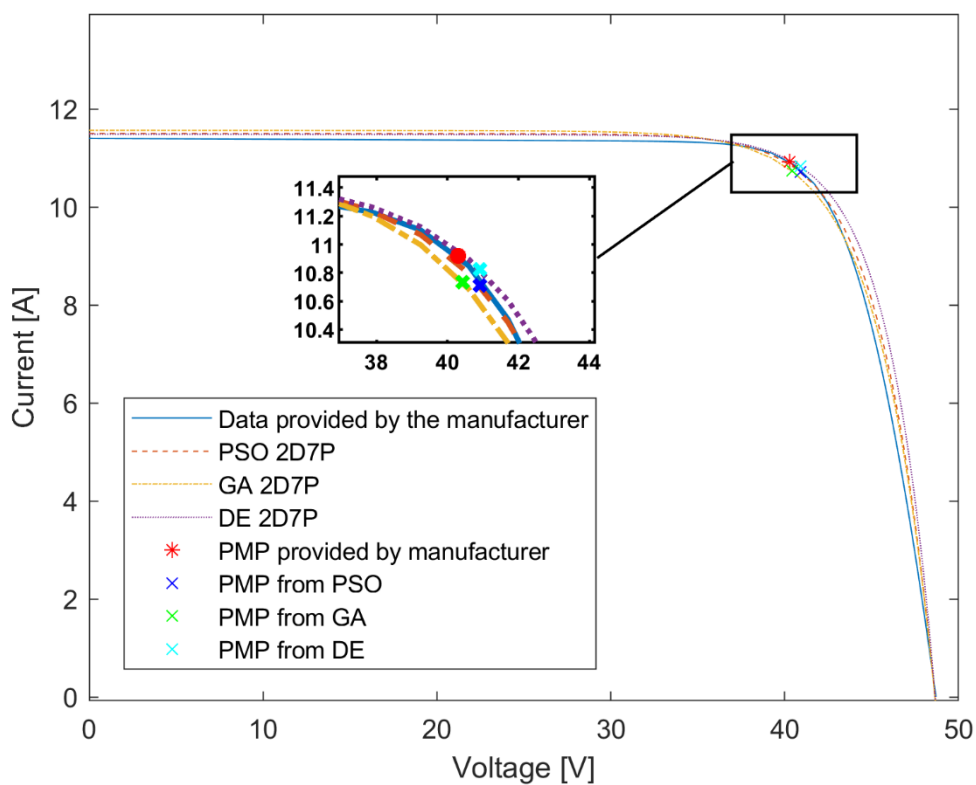
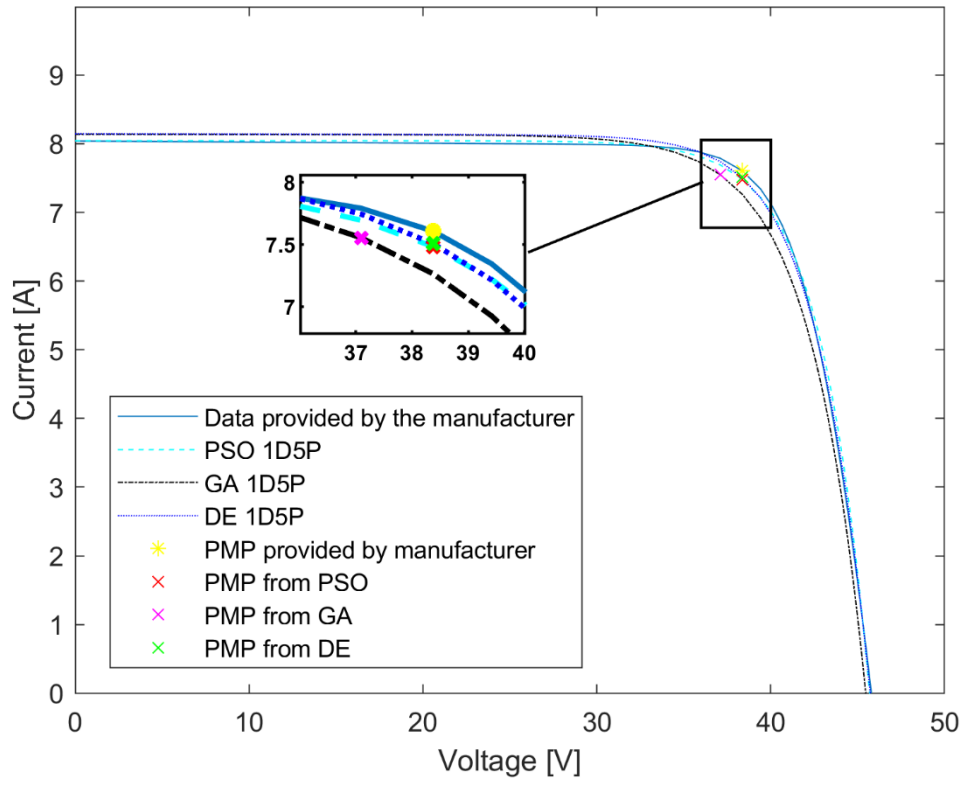


Figure S1. Superposition of $I \times V$ curves generated by PSO, GA and DE for (a) 1D5P and (b) 2D7P under conditions $G = 1000 \text{ W / m}^2$ and $T_c = 25^\circ \text{ C}$.

Table S2. Points of interest for the different methods under conditions $G = 1000 \text{ W / m}^2$ and $T_c = 25^\circ \text{ C}$.

Method	P_{MP}	I_{MP}	V_{MP}	I_{SC}	V_{OC}
Data provided by Manufacture	440.000 W	10.920 A	40.300 V	11.400 A	48.700 V
PSO 1D5P	440.8775 W	10.675 A	41.3 V	11.405 A	48.611 V
e%	0.20%	2.24%	2.48%	<0.10%	0.18%
GA 1D5P	435.3234 W	10.770 A	40.420 V	11.539 A	48.604 V
e%	1.06%	1.37%	0.30%	1.22%	0.20%
DE 1D5P	441.929 W	10.803 A	40.908 V	11.540 A	48.650 V
e%	0.44%	1.07%	1.51%	1.23%	0.10%
PSO 2D7P	438.247 W	10.713 A	40.908 V	11.500 A	48.488 V
e%	0.40%	1.90%	1.51%	0.88%	0.44%
GA 2D7P	433.879 W	10.734 A	40.421 V	11.57 A	48.486 V
e%	1.39%	1.70%	0.30%	1.49%	0.44%
DE 2D7P	442.829 W	10.825 A	40.908 V	11.480 A	48.525 V
e%	0.64%	0.87%	1.51%	0.70%	0.36%

(a)



(b)

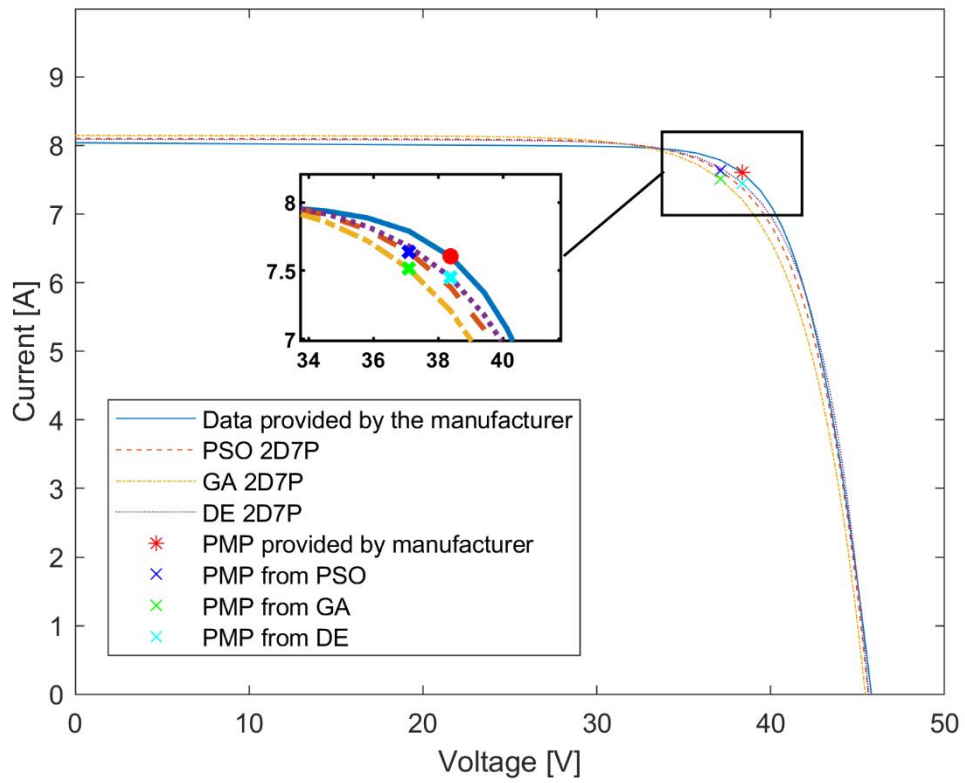
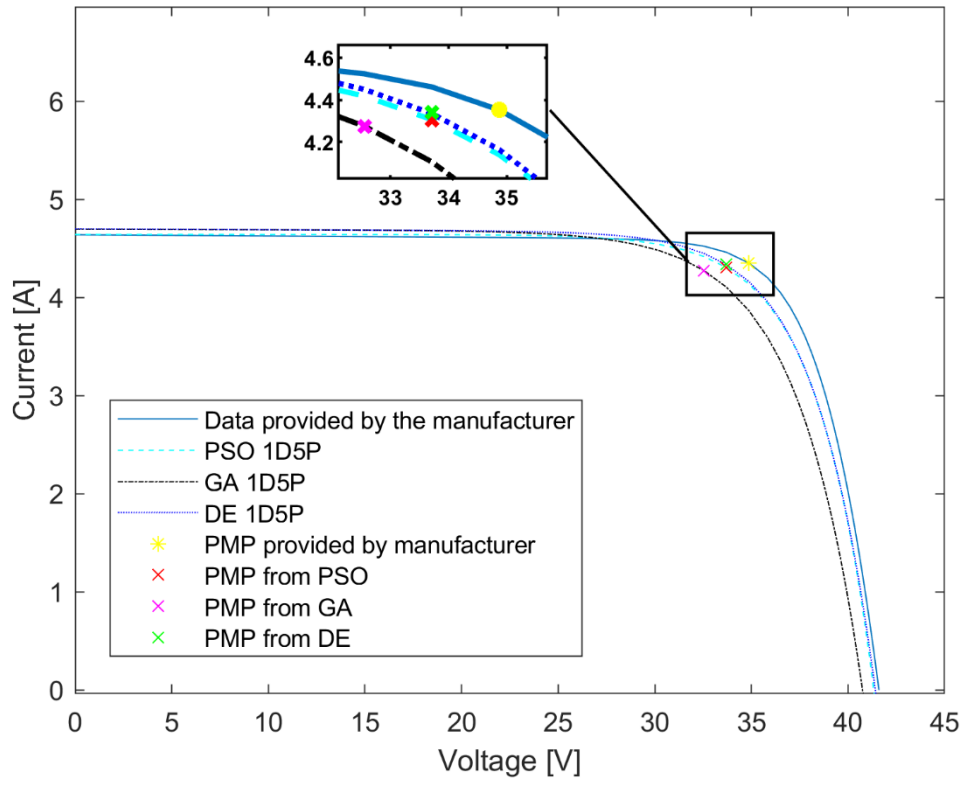


Figure S2. Superposition of $I \times V$ curves generated by PSO, GA and DE for (a) 1D5P and (b) 2D7P under conditions $G = 700 \text{ W / m}^2$ and $T_c = 40^\circ \text{ C}$.

Table S3. Points of interest for the different methods under conditions $G = 700 \text{ W / m}^2$ and $T_c = 40^\circ \text{ C}$.

Method	P_{MP}	I_{MP}	V_{MP}	I_{SC}	V_{OC}
Data provided by Manufacture	291.811 W	7.604 A	38.376 V	8.040 A	45.785 V
PSO 1D5P	287.0525 W	7.48 A	38.376 V	8.0443 A	45.688 V
e%	1.63%	1.63%	<0.10%	<0.10%	0.21%
GA 1D5P	280.105 W	7.550 A	37.100 V	8.139 A	45.588 V
e%	4.18%	0.72%	3.44%	1.22%	0.43%
DE 1D5P	288.204 W	7.510 A	38.376 V	8.145 A	45.725 V
e%	1.24%	1.24%	<0.1%	1.31%	0.13%
PSO 2D7P	283.273 W	7.636 A	37.097 V	8.101 A	45.508 V
e%	2.93%	0.42%	3.33%	0.76%	0.61%
GA 2D7P	278.747 W	7.514 A	37.097 V	8.15 A	45.255 V
e%	4.48%	1.18%	3.33%	1.37%	1.16%
DE 2D7P	285.972 W	7.453 A	38.370 V	8.145 A	45.548 V
e%	2.00%	1.99%	<0.10%	1.31%	0.52%

(a)



(b)

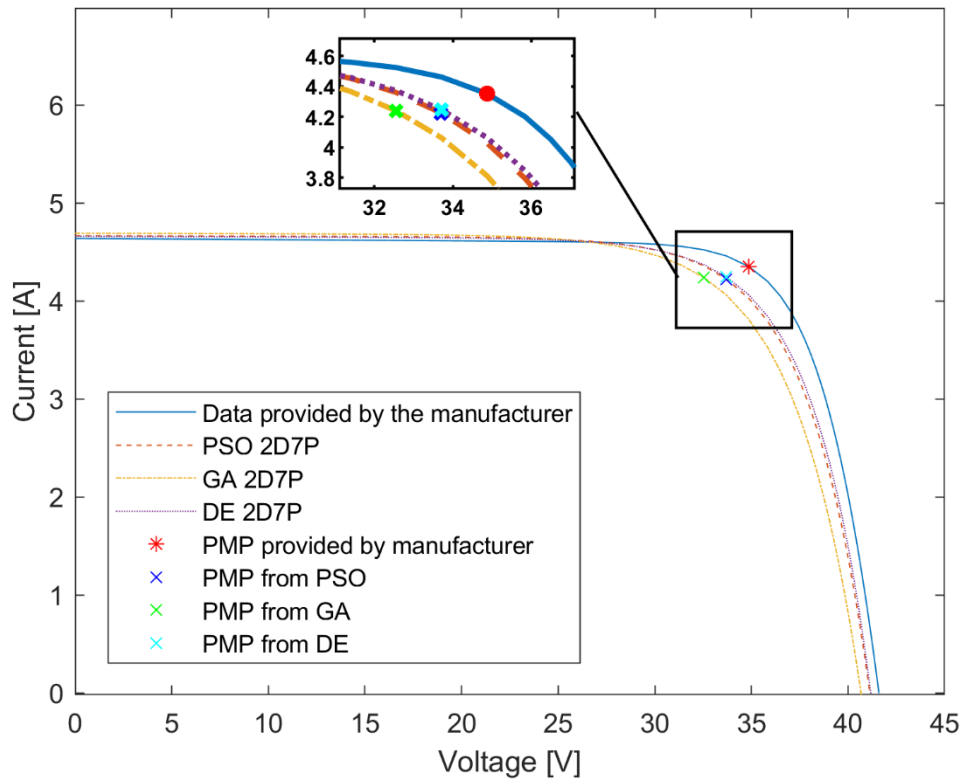


Figure S3. Superposition of $I \times V$ curves generated by PSO, GA and DE for (a) 1D5P and (b) 2D7P under conditions $G = 700 \text{ W} / \text{m}^2$ and $T_c = 40^\circ \text{ C}$.

Table S4. Points of interest for the different methods under conditions $G = 400 \text{ W / m}^2$ and $T_c = 60^\circ \text{ C}$.

Method	P_{MP}	I_{MP}	V_{MP}	I_{SC}	V_{OC}
Data provided by Manufacture	151.763 W	4.352 A	34.872 V	4.640 A	41.600 V
PSO 1D5P	145.155 W	4.306 A	33.710 V	4.643 A	41.380 V
e%	4.35%	1.06%	3.33%	<0.10%	0.53%
GA 1D5P	139.143 W	4.275 A	32.548 V	4.697 A	40.740 V
e%	8.32%	1.77%	6.67%	1.23%	2.07%
DE 1D5P	146.301 W	4.340 A	33.710 V	4.699 A	41.420 V
e%	1.63%	1.63%	<0.10%	<0.10%	<0.10%
PSO 2D7P	142.214 W	4.220 A	33.700 V	4.700 A	41.150 V
e%	6.29%	3.03%	3.36%	1.29%	1.08%
GA 2D7P	138.004 W	4.240 A	32.548 V	4.700 A	40.685 V
e%	9.07%	2.57%	6.67%	1.29%	2.20%
DE 2D7P	143.166 W	4.247 A	33.710 V	4.697 A	41.160 V
e%	5.66%	2.41%	3.33%	1.23%	1.06%

References

CANADIAN SOLAR, 2020. Canadian Solar HiKu CS3W 440Wp Poly-Crystalline Datasheet; 2 Accessed July 31 2023 at https://www.canadiansolar.com/test-au/wp-content/uploads/sites/2/2020/04/Canadian_Solar-Datasheet-HiKu_CS3W-P_v5.59_AU-2.pdf