

Supplementary materials

In the following, according to the measured and simulated I - V and P - V characteristic data (rounded to certain decimal places) obtained by combining one algorithm (as an example) with different simulation current calculation methods, we give the results of RMSE (root mean square error), AE (absolute error), MAE (mean absolute error) and RE (relative error) calculated by using Excel. Specifically, for SDM parameter extraction from the French RTC solar cell and the PWP 201 PV module as well as DDM parameter extraction from the French RTC solar cell, since all the algorithms achieve the same parameter-extraction accuracy, we use the GNDO algorithm as the representative because of its highest robustness. For DDM parameter extraction from the PWP 201 PV module, we use the AEO algorithm as the representative because of its highest parameter-extraction accuracy. The following are our calculation results (the original Excel file is available on request).

Table S1. The measured and simulated characteristic data of the French RTC solar cell with the latter determined by SDM parameters given by combining the GNDO algorithm with the three simulation current calculation methods (Table S1 gives a part of data in Figure 7 corresponding to the GNDO algorithm. In addition, RMSE is also calculated by using Excel, and the data are given in Table S1. The small difference between the RMSEs in Table S1 and Table 3 is caused by the truncation error of the current values).

Data point	V_{exp} (V)	I_{exp} (A)	P_{exp} (W)	Method	I_{cal} (A)	P_{cal} (W)	Method	I_{cal} (A)	P_{cal} (W)	Method	I_{cal} (A)	P_{cal} (W)
1	-0.2057	0.764	-0.15715	GNDO +Approx. method	0.7640877	-0.15717	GNDO+ LW method	0.7641495	-0.15719	GNDO+ NR method	0.7641495	-0.15719
2	-0.1291	0.762	-0.09837		0.7626631	-0.09846		0.7627022	-0.09846		0.7627021	-0.09846
3	-0.0588	0.7605	-0.04472		0.7613553	-0.04477		0.7613738	-0.04477		0.7613738	-0.04477
4	0.0057	0.7605	0.004335		0.760154	0.004333		0.7601545	0.004333		0.7601545	0.004333
5	0.0646	0.76	0.049096		0.7590552	0.049035		0.7590391	0.049034		0.7590391	0.049034
6	0.1185	0.759	0.089942		0.7580423	0.089828		0.7580108	0.089824		0.7580108	0.089824
7	0.1678	0.757	0.127025		0.7570917	0.12704		0.7570457	0.127032		0.7570457	0.127032
8	0.2132	0.757	0.161392		0.7561414	0.161209		0.7560848	0.161197		0.7560848	0.161197
9	0.2545	0.7555	0.192275		0.7550869	0.19217		0.7550223	0.192153		0.7550224	0.192153
10	0.2924	0.754	0.22047		0.7536639	0.220371		0.7535974	0.220352		0.7535974	0.220352
11	0.3269	0.7505	0.245338		0.751391	0.24563		0.7513273	0.245609		0.7513273	0.245609
12	0.3585	0.7465	0.26762		0.7473539	0.267926		0.7473053	0.267909		0.7473053	0.267909
13	0.3873	0.7385	0.286021		0.7401172	0.286647		0.7400846	0.286635		0.7400846	0.286635

14	0.4137	0.728	0.301174	0.7273822	0.300918	0.7274262	0.300936	0.7274262	0.300936
15	0.4373	0.7065	0.308952	0.7069727	0.309159	0.7070259	0.309182	0.7070259	0.309182
16	0.459	0.6755	0.310055	0.6752802	0.309954	0.6754003	0.310009	0.6754003	0.310009
17	0.4784	0.632	0.302349	0.6307583	0.301755	0.6309982	0.30187	0.6309981	0.30187
18	0.496	0.573	0.284208	0.5719284	0.283676	0.5721747	0.283799	0.5721747	0.283799
19	0.5119	0.499	0.255438	0.499607	0.255749	0.499539	0.255714	0.4995389	0.255714
20	0.5265	0.413	0.217445	0.4136488	0.217786	0.4134849	0.2177	0.4134848	0.2177
21	0.5398	0.3165	0.170847	0.3175101	0.171392	0.3171615	0.171204	0.3171615	0.171204
22	0.5521	0.212	0.117045	0.2121549	0.117131	0.2120167	0.117054	0.2120165	0.117054
23	0.5633	0.1035	0.058302	0.1022513	0.057598	0.1026367	0.057815	0.1026365	0.057815
24	0.5736	-0.01	-0.00574	-0.008718	-0.005	-0.009298	-0.00533	-0.009299	-0.00533
25	0.5833	-0.1233	-0.07192	-0.125507	-0.07321	-0.124361	-0.07254	-0.124362	-0.07254
26	0.59	-0.21	-0.1239	-0.208472	-0.123	-0.209102	-0.12337	-0.209102	-0.12337
RMSE				0.000958	0.000457	0.000755	0.000308	0.000755	0.000308

Table S2 The absolute errors between the measured and simulated characteristic curves of the French RTC solar cell with the latter determined by SDM parameters given by combining the GNDO algorithm with the three simulation current calculation methods (Table S2 gives a part of the data in Figure 8 corresponding to the GNDO algorithm. In addition, the MAE is also calculated by using Excel, and the data are given in Table S2).

Data point	V_{exp} (V)	I_{exp} (A)	P_{exp} (W)	Method	I_{AE} (A)	P_{AE} (W)	Method	I_{AE} (A)	P_{AE} (W)	Method	I_{AE} (A)	P_{AE} (W)
1	-0.2057	0.764	-0.15715	GNDO +Approx. method	8.77E-05	1.80E-05	GNDO+ LW method	0.0001495	3.07E-05	GNDO+ NR method	0.0001495	3.07E-05
2	-0.1291	0.762	-0.09837		0.0006631	8.56E-05		0.0007022	9.06E-05		0.0007021	9.06E-05
3	-0.0588	0.7605	-0.04472		0.0008553	5.03E-05		0.0008738	5.14E-05		0.0008738	5.14E-05
4	0.0057	0.7605	0.004335		0.000346	1.97E-06		0.0003455	1.97E-06		0.0003455	1.97E-06
5	0.0646	0.76	0.049096		0.0009448	6.10E-05		0.0009609	6.21E-05		0.0009609	6.21E-05
6	0.1185	0.759	0.089942		0.0009577	0.000113		0.0009892	0.000117		0.0009892	0.000117
7	0.1678	0.757	0.127025		9.17E-05	1.54E-05		4.57E-05	7.67E-06		4.57E-05	7.67E-06
8	0.2132	0.757	0.161392		0.0008586	0.000183		0.0009152	0.000195		0.0009152	0.000195
9	0.2545	0.7555	0.192275		0.0004131	0.000105		0.0004777	0.000122		0.0004776	0.000122

10	0.2924	0.754	0.22047		0.0003361	9.83E-05		0.0004026	0.000118		0.0004026	0.000118
11	0.3269	0.7505	0.245338		0.000891	0.000291		0.0008273	0.00027		0.0008273	0.00027
12	0.3585	0.7465	0.26762		0.0008539	0.000306		0.0008053	0.000289		0.0008053	0.000289
13	0.3873	0.7385	0.286021		0.0016172	0.000626		0.0015846	0.000614		0.0015846	0.000614
14	0.4137	0.728	0.301174		0.0006178	0.000256		0.0005738	0.000237		0.0005738	0.000237
15	0.4373	0.7065	0.308952		0.0004727	0.000207		0.0005259	0.00023		0.0005259	0.00023
16	0.459	0.6755	0.310055		0.0002198	0.000101		9.97E-05	4.57E-05		9.97E-05	4.58E-05
17	0.4784	0.632	0.302349		0.0012417	0.000594		0.0010018	0.000479		0.0010019	0.000479
18	0.496	0.573	0.284208		0.0010716	0.000532		0.0008253	0.000409		0.0008253	0.000409
19	0.5119	0.499	0.255438		0.000607	0.000311		0.000539	0.000276		0.0005389	0.000276
20	0.5265	0.413	0.217445		0.0006488	0.000342		0.0004849	0.000255		0.0004848	0.000255
21	0.5398	0.3165	0.170847		0.0010101	0.000545		0.0006615	0.000357		0.0006615	0.000357
22	0.5521	0.212	0.117045		0.0001549	8.55E-05		1.67E-05	9.24E-06		1.65E-05	9.12E-06
23	0.5633	0.1035	0.058302		0.0012487	0.000703		0.0008633	0.000486		0.0008635	0.000486
24	0.5736	-0.01	-0.00574		0.0012825	0.000736		0.0007017	0.000402		0.0007013	0.000402
25	0.5833	-0.1233	-0.07192		0.0022074	0.001288		0.0010613	0.000619		0.0010616	0.000619
26	0.59	-0.21	-0.1239		0.0015277	0.000901		0.0008983	0.00053		0.0008977	0.00053
Sum of AE					2.12E-02	8.56E-03		0.017333	0.006306		0.017332	0.006306
MAE					8.16E-04	3.29E-04		0.000667	0.000243		0.000667	0.000243

Table S3 The calculated relative current error and relative power error for each data point obtained by fitting the measured I - V characteristic curve of the French RTC solar cell with the SDM equation determined by combining the GNDO algorithm with three simulation current calculation methods.

Data point	V_{exp} (V)	I_{exp} (A)	P_{exp} (W)	Method	I_{RE}	P_{RE}	Method	I_{RE}	P_{RE}	Method	I_{RE}	P_{RE}
1	-0.2057	0.764	-0.15715	GNDO +Approx. method	1.15E-04	1.15E-04	GNDO+ LW method	1.96E-04	1.96E-04	GNDO+ NR method	1.96E-04	1.96E-04
2	-0.1291	0.762	-0.09837		8.70E-04	8.70E-04		9.21E-04	9.21E-04		9.21E-04	9.21E-04
3	-0.0588	0.7605	-0.04472		1.12E-03	1.12E-03		1.15E-03	1.15E-03		1.15E-03	1.15E-03
4	0.0057	0.7605	0.004335		4.55E-04	4.55E-04		4.54E-04	4.54E-04		4.54E-04	4.54E-04
5	0.0646	0.76	0.049096		1.24E-03	1.24E-03		1.26E-03	1.26E-03		1.26E-03	1.26E-03

6	0.1185	0.759	0.089942	1.26E-03	0.001262	1.30E-03	0.001303	1.30E-03	0.001303
7	0.1678	0.757	0.127025	1.21E-04	1.21E-04	6.04E-05	6.04E-05	6.04E-05	6.04E-05
8	0.2132	0.757	0.161392	1.13E-03	0.001134	1.21E-03	0.001209	1.21E-03	0.001209
9	0.2545	0.7555	0.192275	5.47E-04	0.000547	6.32E-04	0.000632	6.32E-04	0.000632
10	0.2924	0.754	0.22047	4.46E-04	4.46E-04	5.34E-04	0.000534	5.34E-04	0.000534
11	0.3269	0.7505	0.245338	1.19E-03	0.001187	1.10E-03	0.001102	1.10E-03	0.001102
12	0.3585	0.7465	0.26762	1.14E-03	0.001144	1.08E-03	0.001079	1.08E-03	0.001079
13	0.3873	0.7385	0.286021	2.19E-03	0.00219	2.15E-03	0.002146	2.15E-03	0.002146
14	0.4137	0.728	0.301174	8.49E-04	0.000849	7.88E-04	0.000788	7.88E-04	0.000788
15	0.4373	0.7065	0.308952	6.69E-04	0.000669	7.44E-04	0.000744	7.44E-04	0.000744
16	0.459	0.6755	0.310055	3.25E-04	0.000325	1.48E-04	1.48E-04	1.48E-04	1.48E-04
17	0.4784	0.632	0.302349	1.96E-03	0.001965	1.59E-03	0.001585	1.59E-03	0.001585
18	0.496	0.573	0.284208	1.87E-03	0.00187	1.44E-03	0.00144	1.44E-03	0.00144
19	0.5119	0.499	0.255438	1.22E-03	0.001216	1.08E-03	0.00108	1.08E-03	0.00108
20	0.5265	0.413	0.217445	1.57E-03	0.001571	1.17E-03	0.001174	1.17E-03	0.001174
21	0.5398	0.3165	0.170847	3.19E-03	0.003191	2.09E-03	0.00209	2.09E-03	0.00209
22	0.5521	0.212	0.117045	7.31E-04	7.31E-04	7.89E-05	7.89E-05	7.79E-05	7.79E-05
23	0.5633	0.1035	0.058302	1.21E-02	0.012065	8.34E-03	0.008341	8.34E-03	0.008343
24	0.5736	-0.01	-0.00574	1.28E-01	0.128246	7.02E-02	0.070169	7.01E-02	0.070131
25	0.5833	-0.1233	-0.07192	1.79E-02	0.017903	8.61E-03	0.008608	8.61E-03	0.00861
26	0.59	-0.21	-0.1239	7.27E-03	0.007275	4.28E-03	0.004278	4.27E-03	0.004275

Table S4. The measured and simulated characteristic data of the PWP 201 PV module, with the latter determined by SDM parameters given by combining the GNDO algorithm with the three simulation current calculation methods (Table S4 gives a part of data in Figure 9 corresponding to the GNDO algorithm. In addition, the RMSE is also calculated by using Excel, and the data are given in Table S4).

Data point	V_{exp} (V)	I_{exp} (A)	P_{exp} (W)	Method	I_{cal} (A)	P_{cal} (W)	Method	I_{cal} (A)	P_{cal} (W)	Method	I_{cal} (A)	P_{cal} (W)
1	0.1248	1.0315	0.128731	GNDO	1.029119162	0.128434	GNDO+	1.029728303	0.12851	GNDO+	1.02972831	0.12851
2	1.8093	1.03	1.863579		1.027381074	1.858841		1.027661016	1.859347		1.027661018	1.859347

3	3.3511	1.026	3.438229	+Approx. method	1.025741797	3.437363	LW method	1.025724513	3.437305	1.02572451	3.437305
4	4.7622	1.022	4.866968		1.024107155	4.877003		1.023833378	4.875699	1.023833369	4.875699
5	6.0538	1.018	6.162768		1.022291804	6.18875		1.021813717	6.185856	1.021813704	6.185856
6	7.2364	1.0155	7.348564		1.019930681	7.380626		1.019323084	7.37623	1.019323064	7.376229
7	8.3189	1.014	8.435365		1.016363105	8.455023		1.015733384	8.449784	1.015733334	8.449784
8	9.3097	1.01	9.402797		1.010496151	9.407416		1.009978659	9.402598	1.009978565	9.402597
9	10.2163	1.0035	10.25206		1.000628969	10.22273		1.000409496	10.22048	1.000409416	10.22048
10	11.0449	0.988	10.91236		0.984548378	10.87424		0.984742717	10.87638	0.984742629	10.87638
11	11.8018	0.963	11.36513		0.959521676	11.32408		0.960188693	11.33195	0.960188541	11.33195
12	12.4929	0.9255	11.56218		0.922838818	11.52893		0.923873767	11.54186	0.923873409	11.54186
13	13.1231	0.8725	11.4499		0.872599663	11.45121		0.873566711	11.4639	0.873566198	11.4639
14	13.6983	0.8075	11.06138		0.807274264	11.05829		0.808203153	11.07101	0.808202518	11.071
15	14.2221	0.7265	10.33236		0.728336478	10.35847		0.728550161	10.36151	0.728549844	10.36151
16	14.6995	0.6345	9.326833		0.637138	9.36561		0.636633568	9.358195	0.636633372	9.358192
17	15.1346	0.5345	8.089444		0.536213063	8.11537		0.535428206	8.103492	0.535427592	8.103482
18	15.5311	0.4275	6.639545		0.429511325	6.670783		0.428199543	6.65041	0.428198939	6.650401
19	15.8929	0.3185	5.061889		0.318774483	5.066251		0.31785011	5.05156	0.317849585	5.051552
20	16.2229	0.2085	3.382475		0.207389507	3.364459		0.207008271	3.358274	0.207008223	3.358274
21	16.5241	0.101	1.668934		0.096167172	1.589076		0.097644564	1.613489	0.097644172	1.613482
22	16.7987	-0.008	-0.13439		-0.00832539	-0.13986		-0.00858898	-0.14428	-0.00858917	-0.14429
23	17.0499	-0.111	-1.89254		-0.11093648	-1.89146		-0.11097201	-1.89206	-0.11097216	-1.89206
24	17.2793	-0.209	-3.61137		-0.20924727	-3.61565		-0.20860706	-3.60458	-0.20860705	-3.60458
25	17.4885	-0.303	-5.29902		-0.30086359	-5.26165		-0.30092697	-5.26276	-0.30092689	-5.26276
RMSE					0.002425075	0.027821		0.002052961	0.022864	0.002052966	0.022864

Table S5 The absolute errors between the measured and simulated characteristic curves of the PWP 201 PV module, with the latter determined by SDM parameters given by combining the GNDO algorithm with the three simulation current calculation methods (Table S5 gives a part of the data in Figure 10, corresponding to the GNDO algorithm. In addition, the MAE is also calculated by using Excel, and the data are given in the Table S5).

Data point	V_{exp} (V)	I_{exp} (A)	P_{exp} (W)	Method	I_{AE} (A)	P_{AE} (W)	Method	I_{AE} (A)	P_{AE} (W)	Method	I_{AE} (A)	P_{AE} (W)		
1	0.1248	1.0315	0.128731	GNDO +Approx. method	0.002380838	2.97E-04	GNDO+ LW method	0.001771697	2.21E-04	GNDO+ NR method	0.00177169	2.21E-04		
2	1.8093	1.03	1.863579		0.002618926	0.004738		0.002338984	0.004232		0.002338982	0.004232		
3	3.3511	1.026	3.438229		2.58E-04	8.65E-04		2.75E-04	9.23E-04		2.75E-04	9.23E-04		
4	4.7622	1.022	4.866968		0.002107155	0.010035		0.001833378	0.008731		0.001833369	0.008731		
5	6.0538	1.018	6.162768		0.004291804	0.025982		0.003813717	0.023087		0.003813704	0.023087		
6	7.2364	1.0155	7.348564		0.004430681	0.032062		0.003823084	0.027665		0.003823064	0.027665		
7	8.3189	1.014	8.435365		0.002363105	0.019658		0.001733384	0.01442		0.001733334	0.014419		
8	9.3097	1.01	9.402797		4.96E-04	0.004619		2.13E-05	1.99E-04		2.14E-05	2.00E-04		
9	10.2163	1.0035	10.25206		0.002871031	0.029331		0.003090504	0.031574		0.003090584	0.031574		
10	11.0449	0.988	10.91236		0.003451622	0.038123		0.003257283	0.035976		0.003257371	0.035977		
11	11.8018	0.963	11.36513		0.003478324	0.04105		0.002811307	0.033178		0.002811459	0.03318		
12	12.4929	0.9255	11.56218		0.002661182	0.033246		0.001626233	0.020316		0.001626591	0.020321		
13	13.1231	0.8725	11.4499		9.97E-05	0.001308		0.001066711	0.013999		0.001066198	0.013992		
14	13.6983	0.8075	11.06138		2.26E-04	0.003092		7.03E-04	0.009632		7.03E-04	0.009623		
15	14.2221	0.7265	10.33236		0.001836478	0.026119		0.002050161	0.029158		0.002049844	0.029153		
16	14.6995	0.6345	9.326833		0.002638	0.038777		0.002133568	0.031362		0.002133372	0.03136		
17	15.1346	0.5345	8.089444		0.001713063	0.025927		9.28E-04	0.014048		9.28E-04	0.014039		
18	15.5311	0.4275	6.639545		0.002011325	0.031238		7.00E-04	0.010865		6.99E-04	0.010855		
19	15.8929	0.3185	5.061889		2.74E-04	0.004362		6.50E-04	0.010329		6.50E-04	0.010337		
20	16.2229	0.2085	3.382475		0.001110493	0.018015		0.001491729	0.0242		0.001491777	0.024201		
21	16.5241	0.101	1.668934		0.004832828	0.079858		0.003355436	0.055446		0.003355828	0.055452		
22	16.7987	-0.008	-0.13439		3.25E-04	0.005466		5.89E-04	0.009894		5.89E-04	0.009897		
23	17.0499	-0.111	-1.89254		6.35E-05	0.001083		2.80E-05	4.77E-04		2.78E-05	4.75E-04		
24	17.2793	-0.209	-3.61137		2.47E-04	0.004273		3.93E-04	0.00679		3.93E-04	0.00679		
25	17.4885	-0.303	-5.29902		0.002136414	0.037363		0.002073028	0.036254		0.002073111	0.036256		
Sum of AE					0.048923675	0.516888	0.042557738					0.452976	0.042556627	0.452961
MAE					0.001956947	0.020676	0.00170231					0.018119	0.001702265	0.018118

Table S6 The calculated relative current error and relative power error for each data point obtained by fitting the measured I - V characteristic curve of the PWP 201 PV module with the SDM equation determined by combining the GNDO algorithm with three simulation current calculation methods.

Data point	V_{exp} (V)	I_{exp} (A)	P_{exp} (W)	Method	I_{RE}	P_{RE}	Method	I_{RE}	P_{RE}	Method	I_{RE}	P_{RE}
1	0.1248	1.0315	0.128731	GNDO +Approx. method	0.002308132	0.002308	GNDO+ LW method	0.001717593	0.001718	GNDO+ NR method	0.001717587	0.001718
2	1.8093	1.03	1.863579		0.002542647	0.002543		0.002270858	0.002271		0.002270856	0.002271
3	3.3511	1.026	3.438229		0.00025166	0.000252		0.000268506	0.000269		0.000268509	0.000269
4	4.7622	1.022	4.866968		0.002061795	0.002062		0.001793912	0.001794		0.001793903	0.001794
5	6.0538	1.018	6.162768		0.004215918	0.004216		0.003746284	0.003746		0.003746271	0.003746
6	7.2364	1.0155	7.348564		0.004363054	0.004363		0.003764731	0.003765		0.003764711	0.003765
7	8.3189	1.014	8.435365		0.002330479	0.00233		0.001709452	0.001709		0.001709402	0.001709
8	9.3097	1.01	9.402797		0.000491239	0.000491		2.11E-05	2.11E-05		2.12E-05	2.12E-05
9	10.2163	1.0035	10.25206		0.002861016	0.002861		0.003079725	0.00308		0.003079804	0.00308
10	11.0449	0.988	10.91236		0.003493545	0.003494		0.003296845	0.003297		0.003296933	0.003297
11	11.8018	0.963	11.36513		0.003611967	0.003612		0.002919322	0.002919		0.002919479	0.002919
12	12.4929	0.9255	11.56218		0.002875399	0.002875		0.00175714	0.001757		0.001757527	0.001758
13	13.1231	0.8725	11.4499		1.14E-04	0.000114		0.001222591	0.001223		0.001222005	0.001222
14	13.6983	0.8075	11.06138		0.000279549	0.00028		0.000870778	0.000871		0.000869991	0.00087
15	14.2221	0.7265	10.33236		0.002527843	0.002528		0.00282197	0.002822		0.002821535	0.002822
16	14.6995	0.6345	9.326833		0.004157604	0.004158		0.003362597	0.003363		0.003362288	0.003362
17	15.1346	0.5345	8.089444		0.003204982	0.003205		0.001736587	0.001737		0.001735439	0.001735
18	15.5311	0.4275	6.639545		0.004704851	0.004705		0.001636358	0.001636		0.001634943	0.001635
19	15.8929	0.3185	5.061889		0.000861796	0.000862		0.002040471	0.00204		0.002042122	0.002042
20	16.2229	0.2085	3.382475		0.00532611	0.005326		0.007154576	0.007155		0.007154806	0.007155
21	16.5241	0.101	1.668934		0.047849792	0.04785		0.033222139	0.033222		0.03322602	0.033226
22	16.7987	-0.008	-0.13439		0.04067325	0.040673		0.073622125	0.073622		0.07364625	0.073646
23	17.0499	-0.111	-1.89254		5.72E-04	0.000572		2.52E-04	0.000252		2.51E-04	0.000251
24	17.2793	-0.209	-3.61137		0.001183086	0.001183		0.001880105	0.00188		0.001880134	0.00188
25	17.4885	-0.303	-5.29902		0.007050871	0.007051		0.006841677	0.006842		0.006841947	0.006842

Table S7. The measured and simulated characteristic data of the French RTC solar cell, with the latter determined by the DDM parameters given by combining the GNDO algorithm with the two simulation current calculation methods (Table S7 gives a part of data in Figure 13 corresponding to the GNDO algorithm. In addition, RMSE is also calculated by using Excel, and the data are given in Table S7. The small difference between the RMSEs in Table S7 and Table 8 is caused by the truncation error of the current values).

Data point	V_{exp} (V)	I_{exp} (I)	P_{exp} (W)	Method	I_{cal} (A)	P_{cal} (W)	Method	I_{cal} (A)	P_{cal} (W)
1	-0.2057	0.764	-0.15715	GNDO+Approx. method	0.763628024	-0.15708	GNDO+NR method	0.763478377	-0.15705
2	-0.1291	0.762	-0.09837		0.762447953	-0.09843		0.762395233	-0.09843
3	-0.0588	0.7605	-0.04472		0.761347749	-0.04477		0.761374766	-0.04477
4	0.0057	0.7605	0.004335		0.760312889	0.004334		0.760400486	0.004334
5	0.0646	0.76	0.049096		0.759333509	0.049053		0.759458137	0.049061
6	0.1185	0.759	0.089942		0.7583881	0.089869		0.758523317	0.089885
7	0.1678	0.757	0.127025		0.757448452	0.1271		0.757565129	0.127119
8	0.2132	0.757	0.161392		0.75645039	0.161275		0.756521184	0.16129
9	0.2545	0.7555	0.192275		0.755293467	0.192222		0.755292989	0.192222
10	0.2924	0.754	0.22047		0.753724787	0.220389		0.753639404	0.220364
11	0.3269	0.7505	0.245338		0.751287712	0.245596		0.751119178	0.245541
12	0.3585	0.7465	0.26762		0.747100592	0.267836		0.746881547	0.267757
13	0.3873	0.7385	0.286021		0.739768698	0.286512		0.739545412	0.286426
14	0.4137	0.728	0.301174		0.727024789	0.30077		0.72692135	0.300727
15	0.4373	0.7065	0.308952		0.706702728	0.309041		0.706704634	0.309042
16	0.459	0.6755	0.310055		0.675169267	0.309903		0.675354133	0.309988
17	0.4784	0.632	0.302349		0.630818723	0.301784		0.631204066	0.301968
18	0.496	0.573	0.284208		0.572114424	0.283769		0.572513837	0.283967
19	0.5119	0.499	0.255438		0.499835391	0.255866		0.4998522	0.255874
20	0.5265	0.413	0.217445		0.413820902	0.217877		0.413643126	0.217783
21	0.5398	0.3165	0.170847		0.317562758	0.17142		0.317114028	0.171178
22	0.5521	0.212	0.117045		0.212064526	0.117081		0.211796842	0.116933

23	0.5633	0.1035	0.058302	0.102056879	0.057489	0.102349326	0.057653
24	0.5736	-0.01	-0.00574	-0.008878898	-0.00509	-0.00951176	-0.00546
25	0.5833	-0.1233	-0.07192	-0.125563183	-0.07324	-0.124338164	-0.07253
26	0.59	-0.21	-0.1239	-0.208260627	-0.12287	-0.208801408	-0.12319
RMSE				0.000928132	0.000467	0.000673656	0.000309

Table S8 The absolute errors between the measured and simulated characteristic curves of the French RTC solar cell, with the latter determined by the DDM parameters given by combining the GNDO algorithm with the two simulation current calculation methods (Table S8 gives a part of the data in Figure 14 corresponding to the GNDO algorithm. In addition, the MAE is also calculated by using Excel, and the data are given in Table S8).

Data point	V_{exp} (V)	I_{exp} (A)	P_{exp} (W)	Method	I_{AE} (A)	P_{AE} (W)	Method	I_{AE} (A)	P_{AE} (W)
1	-0.2057	0.764	-0.15715	GNDO+Approx. method	0.000371976	7.65E-05	GNDO+NR method	0.000521623	0.000107
2	-0.1291	0.762	-0.09837		0.000447953	5.78E-05		0.000395233	5.10E-05
3	-0.0588	0.7605	-0.04472		0.000847749	4.98E-05		0.000874766	5.14E-05
4	0.0057	0.7605	0.004335		0.000187111	1.07E-06		9.95E-05	5.67E-07
5	0.0646	0.76	0.049096		0.000666491	4.31E-05		0.000541863	3.50E-05
6	0.1185	0.759	0.089942		0.0006119	7.25E-05		0.000476683	5.65E-05
7	0.1678	0.757	0.127025		0.000448452	7.53E-05		0.000565129	9.48E-05
8	0.2132	0.757	0.161392		0.00054961	0.000117		0.000478816	0.000102
9	0.2545	0.7555	0.192275		0.000206533	5.26E-05		0.000207011	5.27E-05
10	0.2924	0.754	0.22047		0.000275213	8.05E-05		0.000360596	0.000105
11	0.3269	0.7505	0.245338		0.000787712	0.000258		0.000619178	0.000202
12	0.3585	0.7465	0.26762		0.000600592	0.000215		0.000381547	0.000137
13	0.3873	0.7385	0.286021		0.001268698	0.000491		0.001045412	0.000405
14	0.4137	0.728	0.301174		0.000975211	0.000403		0.00107865	0.000446
15	0.4373	0.7065	0.308952		0.000202728	8.87E-05		0.000204634	8.95E-05
16	0.459	0.6755	0.310055		0.000330733	0.000152		0.000145867	6.70E-05
17	0.4784	0.632	0.302349		0.001181277	0.000565		0.000795934	0.000381
18	0.496	0.573	0.284208		0.000885576	0.000439		0.000486163	0.000241
19	0.5119	0.499	0.255438		0.000835391	0.000428		0.0008522	0.000436

20	0.5265	0.413	0.217445	0.000820902	0.000432	0.000643126	0.000339
21	0.5398	0.3165	0.170847	0.001062758	0.000574	0.000614028	0.000331
22	0.5521	0.212	0.117045	6.45E-05	3.56E-05	0.000203158	0.000112
23	0.5633	0.1035	0.058302	0.001443121	0.000813	0.001150674	0.000648
24	0.5736	-0.01	-0.00574	0.001121102	0.000643	0.00048824	0.00028
25	0.5833	-0.1233	-0.07192	0.002263183	0.00132	0.001038164	0.000606
26	0.59	-0.21	-0.1239	0.001739373	0.001026	0.001198592	0.000707
Sum of AE				0.020195871	0.00851	0.015466801	0.006085
MAE				0.000776764	0.000327	0.000594877	0.000234

Table S9. The calculated relative current error and relative power error for each data point obtained by fitting the measured I - V characteristic curve of the French RTC solar cell, with the DDM equation determined by combining the GNDO algorithm with two simulation current calculation methods.

Data point	V_{exp} (V)	I_{exp} (A)	P_{exp} (W)	Method	I_{RE}	P_{RE}	Method	I_{RE}	P_{RE}
1	-0.2057	0.764	-0.15715	GNDO+Approx. method	0.00048688	4.87E-04	GNDO+NR method	0.000682753	0.000683
2	-0.1291	0.762	-0.09837		0.000587865	5.88E-04		0.000518678	5.19E-04
3	-0.0588	0.7605	-0.04472		0.001114726	1.11E-03		0.001150251	1.15E-03
4	0.0057	0.7605	0.004335		0.000246037	2.46E-04		1.31E-04	1.31E-04
5	0.0646	0.76	0.049096		0.000876962	8.77E-04		0.000712978	7.13E-04
6	0.1185	0.759	0.089942		0.000806192	8.06E-04		0.000628041	6.28E-04
7	0.1678	0.757	0.127025		0.000592407	5.92E-04		0.000746538	7.47E-04
8	0.2132	0.757	0.161392		0.000726037	0.000726		0.000632518	0.000633
9	0.2545	0.7555	0.192275		0.000273373	2.73E-04		0.000274005	2.74E-04
10	0.2924	0.754	0.22047		0.000365004	3.65E-04		0.000478244	0.000478
11	0.3269	0.7505	0.245338		0.001049583	0.00105		0.000825021	0.000825
12	0.3585	0.7465	0.26762		0.000804544	0.000805		0.000511115	0.000511
13	0.3873	0.7385	0.286021		0.001717939	0.001718		0.001415588	0.001416
14	0.4137	0.728	0.301174		0.001339576	0.00134		0.001481662	0.001482
15	0.4373	0.7065	0.308952		0.000286947	2.87E-04		0.000289645	2.90E-04
16	0.459	0.6755	0.310055		0.000489612	0.00049		0.000215939	2.16E-04

17	0.4784	0.632	0.302349		0.001869109	0.001869		0.001259389	0.001259
18	0.496	0.573	0.284208		0.001545508	0.001546		0.000848452	0.000848
19	0.5119	0.499	0.255438		0.00167413	0.001674		0.001707816	0.001708
20	0.5265	0.413	0.217445		0.001987656	0.001988		0.001557206	0.001557
21	0.5398	0.3165	0.170847		0.003357845	0.003358		0.001940057	0.00194
22	0.5521	0.212	0.117045		3.04E-04	3.04E-04		0.000958292	0.000958
23	0.5633	0.1035	0.058302		0.013943198	0.013943		0.011117623	0.011118
24	0.5736	-0.01	-0.00574		0.1121102	0.11211		0.048824	0.048824
25	0.5833	-0.1233	-0.07192		0.018355093	0.018355		0.008419822	0.00842
26	0.59	-0.21	-0.1239		0.008282729	0.008283		0.005707581	0.005708

Table S10. The measured and simulated characteristic data of the PWP 201 PV module with the latter determined by the DDM parameters given by combining the AEO algorithm with the two simulation current calculation methods (Table S10 gives a part of data in Figure 15 corresponding to the AEO algorithm. In addition, the RMSE is also calculated by using Excel, and the data are given in the Table S10).

Data point	V_{exp} (V)	I_{exp} (A)	P_{exp} (W)	Method	I_{cal} (A)	P_{cal} (W)	Method	I_{cal} (A)	P_{cal} (W)
1	0.1248	1.0315	0.128731	AEO+Approx. method	1.029131103	0.128436	AEO+NR method	1.02974885	0.128513
2	1.8093	1.03	1.863579		1.027372659	1.858825		1.027658353	1.859342
3	3.3511	1.026	3.438229		1.025717202	3.437281		1.025702658	3.437232
4	4.7622	1.022	4.866968		1.024072374	4.876837		1.023798346	4.875532
5	6.0538	1.018	6.162768		1.02225616	6.188534		1.021774792	6.18562
6	7.2364	1.0155	7.348564		1.019907398	7.380458		1.019293653	7.376017
7	8.3189	1.014	8.435365		1.016368204	8.455065		1.015729908	8.449756
8	9.3097	1.01	9.402797		1.01054434	9.407865		1.010016054	9.402946
9	10.2163	1.0035	10.25206		1.000722642	10.22368		1.000492181	10.22133
10	11.0449	0.988	10.91236		0.984672823	10.87561		0.984854105	10.87762
11	11.8018	0.963	11.36513		0.959636402	11.32544		0.960288359	11.33313
12	12.4929	0.9255	11.56218		0.922890893	11.52958		0.923911335	11.54233
13	13.1231	0.8725	11.4499		0.872561756	11.45072		0.873511062	11.46317

14	13.6983	0.8075	11.06138	0.807114515	11.0561	0.808065789	11.06913
15	14.2221	0.7265	10.33236	0.728133089	10.35558	0.728383143	10.35914
16	14.6995	0.6345	9.326833	0.636959228	9.362982	0.636500208	9.356235
17	15.1346	0.5345	8.089444	0.536100475	8.113666	0.535372632	8.102651
18	15.5311	0.4275	6.639545	0.429555188	6.671465	0.428233448	6.650937
19	15.8929	0.3185	5.061889	0.318906027	5.068342	0.317954534	5.05322
20	16.2229	0.2085	3.382475	0.207570899	3.367402	0.207147021	3.360525
21	16.5241	0.101	1.668934	0.096172959	1.589172	0.09777559	1.615654
22	16.7987	-0.008	-0.13439	-0.008092335	-0.13594	-0.008501268	-0.14281
23	17.0499	-0.111	-1.89254	-0.110809954	-1.8893	-0.110954576	-1.89176
24	17.2793	-0.209	-3.61137	-0.209373235	-3.61782	-0.208675866	-3.60577
25	17.4885	-0.303	-5.29902	-0.301090837	-5.26563	-0.301088368	-5.26558
RMSE				0.00237528	0.027048	0.001990507	0.021802

Table S11. The absolute errors between the measured and simulated characteristic curves of the PWP 201 PV module with the latter determined by the DDM parameters given by combining the AEO algorithm with the two simulation current calculation methods (Table S11 gives a part of the data in Figure 16 corresponding to the AEO algorithm. In addition, the MAE is also calculated by using Excel, and the data are given in Table S11).

Data point	V_{exp} (V)	I_{exp} (A)	P_{exp} (W)	Method	I_{AE} (A)	P_{AE} (W)	Method	I_{AE} (A)	P_{AE} (W)
1	0.1248	1.0315	0.128731	AEO+Approx. method	0.002368897	0.000296	AEO+NR method	0.00175115	0.000219
2	1.8093	1.03	1.863579		0.002627341	0.004754		0.002341647	0.004237
3	3.3511	1.026	3.438229		0.000282798	0.000948		0.000297342	0.000996
4	4.7622	1.022	4.866968		0.002072374	0.009869		0.001798346	0.008564
5	6.0538	1.018	6.162768		0.00425616	0.025766		0.003774792	0.022852
6	7.2364	1.0155	7.348564		0.004407398	0.031894		0.003793653	0.027452
7	8.3189	1.014	8.435365		0.002368204	0.019701		0.001729908	0.014391
8	9.3097	1.01	9.402797		0.00054434	0.005068		1.61E-05	0.000149
9	10.2163	1.0035	10.25206		0.002777358	0.028374		0.003007819	0.030729
10	11.0449	0.988	10.91236		0.003327177	0.036748		0.003145895	0.034746

11	11.8018	0.963	11.36513		0.003363598	0.039697		0.002711641	0.032002
12	12.4929	0.9255	11.56218		0.002609107	0.032595		0.001588665	0.019847
13	13.1231	0.8725	11.4499		6.18E-05	0.00081		0.001011062	0.013268
14	13.6983	0.8075	11.06138		0.000385485	0.00528		0.000565789	0.00775
15	14.2221	0.7265	10.33236		0.001633089	0.023226		0.001883143	0.026782
16	14.6995	0.6345	9.326833		0.002459228	0.036149		0.002000208	0.029402
17	15.1346	0.5345	8.089444		0.001600475	0.024223		0.000872632	0.013207
18	15.5311	0.4275	6.639545		0.002055188	0.031919		0.000733448	0.011391
19	15.8929	0.3185	5.061889		0.000406027	0.006453		0.000545466	0.008669
20	16.2229	0.2085	3.382475		0.000929101	0.015073		0.001352979	0.021949
21	16.5241	0.101	1.668934		0.004827041	0.079763		0.00322441	0.05328
22	16.7987	-0.008	-0.13439		9.23E-05	0.001551		0.000501268	0.008421
23	17.0499	-0.111	-1.89254		0.000190046	0.00324		4.54E-05	0.000774
24	17.2793	-0.209	-3.61137		0.000373235	0.006449		0.000324134	0.005601
25	17.4885	-0.303	-5.29902		0.001909163	0.033388		0.001911632	0.033432
Sum of AE					0.047926922	0.503234		0.040928507	0.430112
MAE					0.001917077	0.020129		0.00163714	0.017204

Table S12. The calculated relative current error and relative power error for each data point obtained by fitting the measured I - V characteristic curve of the PWP 201 PV module, with the DDM equation determined by combining the AEO algorithm with two simulation current calculation methods.

Data point	V_{exp} (V)	I_{exp} (A)	P_{exp} (W)	Method	I_{RE}	P_{RE}	Method	I_{RE}	P_{RE}
1	0.1248	1.0315	0.128731	AEO+Approx. method	0.002296556	0.002297	AEO+NR method	0.001697673	0.001698
2	1.8093	1.03	1.863579		0.002550817	0.002551		0.002273444	0.002273
3	3.3511	1.026	3.438229		0.000275632	0.000276		0.000289807	0.00029
4	4.7622	1.022	4.866968		0.002027763	0.002028		0.001759634	0.00176
5	6.0538	1.018	6.162768		0.004180904	0.004181		0.003708047	0.003708
6	7.2364	1.0155	7.348564		0.004340126	0.00434		0.003735749	0.003736
7	8.3189	1.014	8.435365		0.002335507	0.002336		0.001706024	0.001706
8	9.3097	1.01	9.402797		0.00053895	0.000539		1.59E-05	1.59E-05

9	10.2163	1.0035	10.25206	0.002767671	0.002768	0.002997328	0.002997
10	11.0449	0.988	10.91236	0.003367588	0.003368	0.003184104	0.003184
11	11.8018	0.963	11.36513	0.003492833	0.003493	0.002815827	0.002816
12	12.4929	0.9255	11.56218	0.002819132	0.002819	0.001716548	0.001717
13	13.1231	0.8725	11.4499	7.08E-05	7.08E-05	0.00115881	0.001159
14	13.6983	0.8075	11.06138	0.000477381	0.000477	0.000700667	0.000701
15	14.2221	0.7265	10.33236	0.002247886	0.002248	0.002592076	0.002592
16	14.6995	0.6345	9.326833	0.003875852	0.003876	0.003152416	0.003152
17	15.1346	0.5345	8.089444	0.002994341	0.002994	0.001632614	0.001633
18	15.5311	0.4275	6.639545	0.004807457	0.004807	0.001715668	0.001716
19	15.8929	0.3185	5.061889	0.00127481	0.001275	0.001712609	0.001713
20	16.2229	0.2085	3.382475	0.00445612	0.004456	0.006489108	0.006489
21	16.5241	0.101	1.668934	0.047792485	0.047792	0.031924851	0.031925
22	16.7987	-0.008	-0.13439	1.15E-02	0.011542	0.0626585	0.062658
23	17.0499	-0.111	-1.89254	0.001712126	0.001712	4.09E-04	0.000409
24	17.2793	-0.209	-3.61137	0.001785813	0.001786	0.00155088	0.001551
25	17.4885	-0.303	-5.29902	0.006300868	0.006301	0.006309017	0.006309

It should be noted that the following equation is used:

$$AE = |I_{meas} - I_{cal}| \quad (S1)$$

$$RE = \left| \frac{I_{meas} - I_{cal}}{I_{meas}} \right| \quad (S2)$$

$$MAE = \frac{1}{N} \sum_{i=1}^N |I_{meas,i} - I_{cal,i}| \quad (S3)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^N (I_{meas,i} - I_{cal,i})^2}{n}} \quad (S4)$$

where N is the number of measured I - V data points.

It should be mentioned that the robustness of a parameter-extraction method is generally characterized by the standard deviation (STD or SD) of the RMSEs. The lower the STD of the RMSEs, the higher the robustness of the parameter-extraction method. In order to evaluate the robustness of the

different methods, each parameter-extraction method was executed 30 times independently. According to the statistical results of the RMSEs obtained from 30 times of parameter extraction by a method (an algorithm + a simulation current calculation method), we calculate the standard deviation (STD or SD) of the RMSEs by using the following equation

$$\text{STD} = \sqrt{\frac{\sum_{i=1}^n (\text{RMSE}_i - \overline{\text{RMSE}})^2}{n-1}} \quad (\text{S5})$$

where $n=30$, and $\overline{\text{RMSE}}$ denotes the average value of RMSEs.

In the following, taking the GNDO as an example for the SDM parameter extraction from the solar cell and the PV module, as well as DDM parameter extraction from the solar cell, and taking the AEO as an example for DDM parameter extraction from the PV module, we give Figures S1, S2, S3, S4, S5, S6, S7, and S8, which correspond to the 3D Figures 7, 8, 9, 10, 13, 14, 15, and 16 in the paper, respectively.

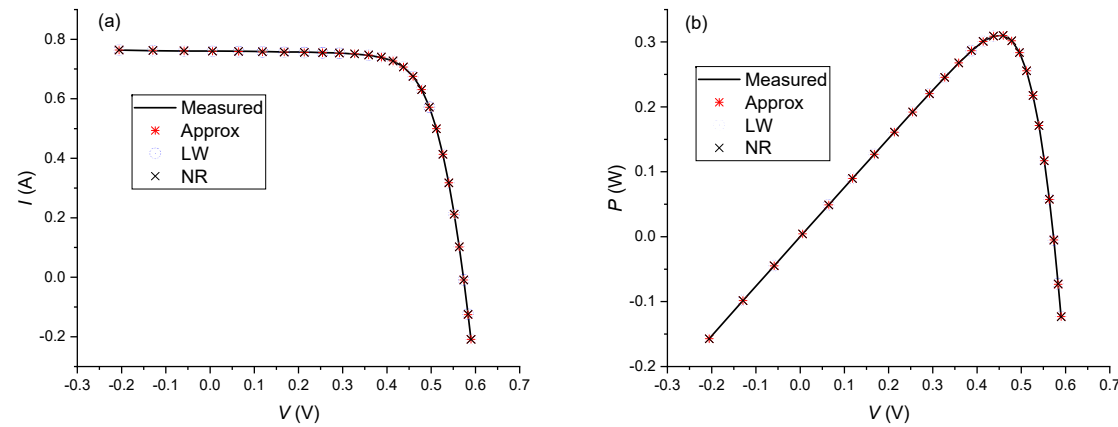


Figure S1. Comparison between the measured and simulated characteristic curves of the French RTC solar cell, with the latter determined by the SDM parameters given by combining the GNDO algorithms with the three simulation current calculation methods. (a) I - V characteristic curves; (b) P - V characteristic curves.

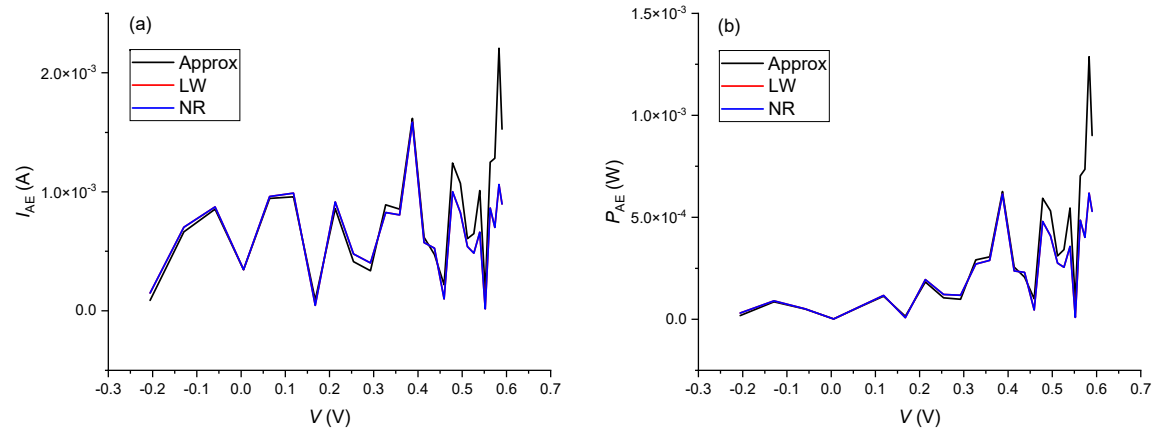


Figure S2. The absolute errors between the measured and simulated characteristic curves of the French RTC solar cell, with the latter determined by the SDM parameters given by combining the GNDO algorithm with the three simulation current calculation methods. (a) The absolute errors between the measured and simulated I - V characteristic curves; (b) the absolute errors between the measured and simulated P - V characteristic curves.

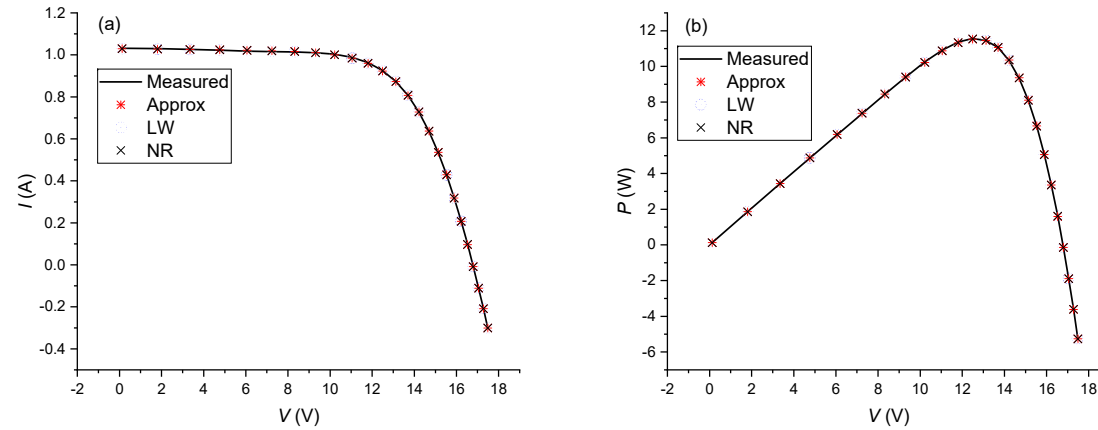


Figure S3. Comparison between the measured and simulated characteristic curves of the PWP 201 PV module, with the latter determined by the SDM parameters given by

combining the GNDO algorithm with the three simulation current calculation methods. (a) I - V characteristic curves; (b) P - V characteristic curves.

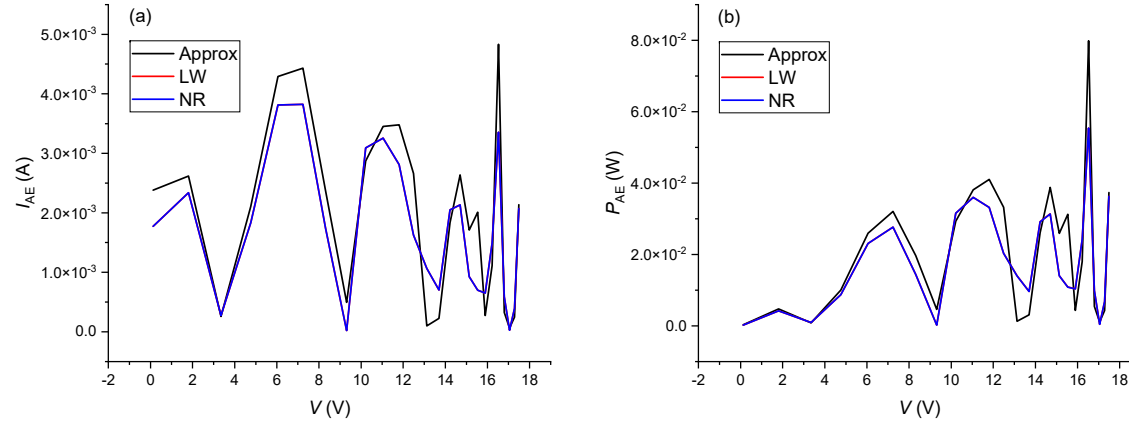


Figure S4. The absolute errors between the measured and simulated characteristic curves of the PWP 201 PV module, with the latter determined by the SDM parameters given by combining the GNDO algorithm with the three simulation current calculation methods. (a) The absolute errors between the measured and simulated I - V characteristic curves; (b) the absolute errors between the measured and simulated P - V characteristic curves.

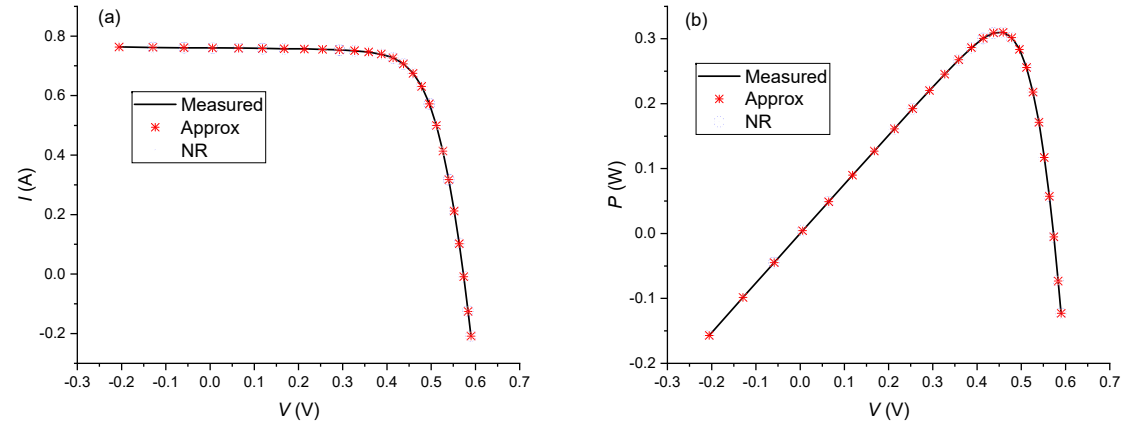


Figure S5. The measured and simulated characteristic curves of the French RTC solar cell, with the latter determined by the DDM parameters given by combining the GNDO algorithm with the two simulation current calculation methods. (a) I - V characteristic curves; (b) P - V characteristic curves.

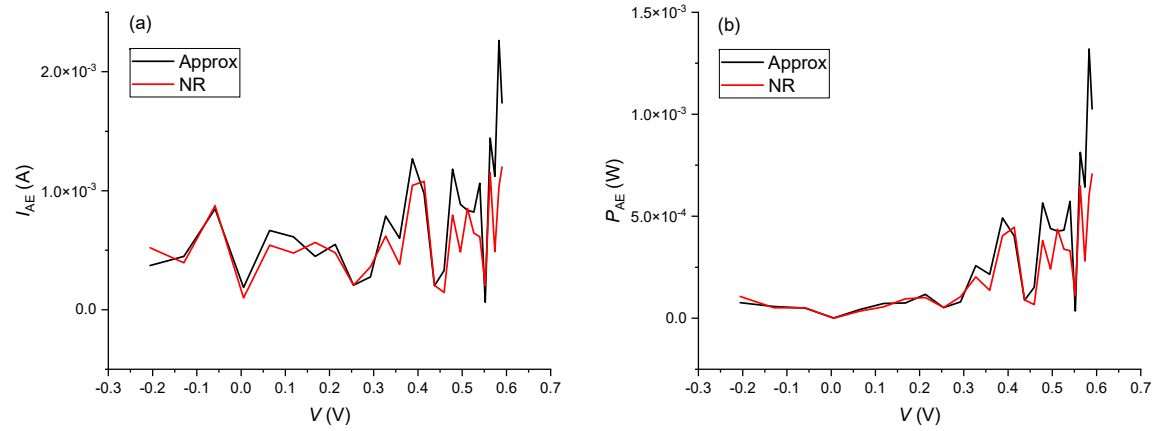


Figure S6. The absolute errors between the measured and simulated characteristic curves of the French RTC solar cell, with the latter determined by the DDM parameters given by combining the GNDO algorithm with the two simulation current calculation methods. (a) The absolute errors between the measured and simulated I - V

characteristic curves; (b) the absolute errors between the measured and simulated P - V characteristic curves.

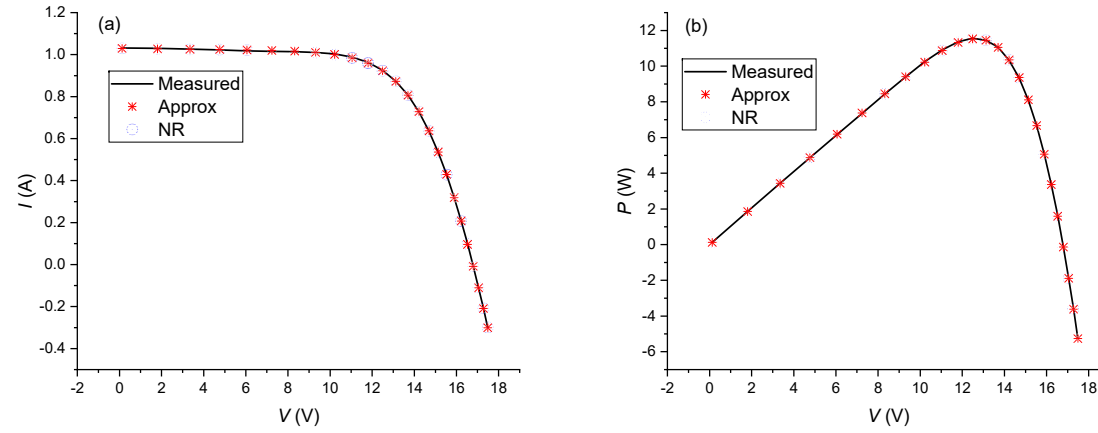


Figure S7. Comparison between the measured and simulated characteristic curves of the PWP 201 PV module, with the latter determined by the DDM parameters given by combining the AEO algorithm with the two simulation current calculation methods. (a) I - V characteristic curves; (b) P - V characteristic curves.

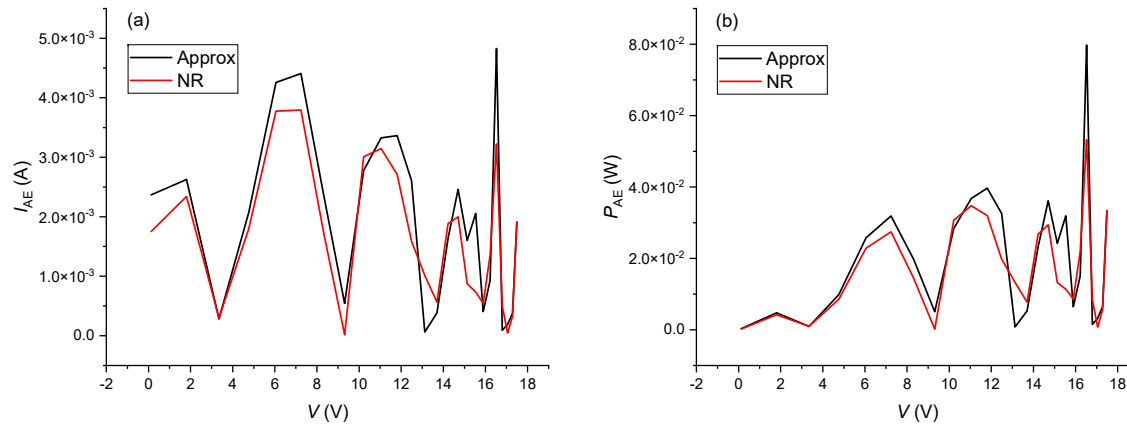


Figure S8. The absolute errors between the measured and simulated characteristic curves of the PWP 201 PV module, with the latter determined by the DDM parameters given by combining the AEO algorithm with the two simulation current calculation methods. (a) The absolute errors between the measured and simulated I - V characteristic curves; (b) the absolute errors between the measured and simulated P - V characteristic curves.