PV Modules technical specifications

This technical sheet provides:
• Details on the appearance of different PV modules
• Sample PV module datasheet and highlight of important parameters
• Details on how PV cells are connected to form a PV module
• An understanding of the effect of different cell connection configurations on electrical parameters
• How PV modules can be connected together to form a PV system
• An understanding of the scalability/modularity of PV systems
• An explanation of how PV module efficiency relates to surface area required for a certain output

1. PV Modules

Photovoltaic modules are composed of PV cells connected in series and/or parallel to obtain the desired power output of the module. This section provides some examples of PV modules currently on the market. Currently, thousands of different module models with different technologies are available. Selecting the correct module for a system is a major decision and it is important to get it right. Mistakes can be expensive! The choice should not only be a function of the cost, but also of quality, performance, efficiency, electric parameters (e.g. I-V curve) and the environment in which the modules will be installed.

2. PV modules datasheet

Before selecting a PV module, the module datasheet should be carefully consulted. This will contain all relevant specifications, both electrical and mechanical. The international standard EN 50380:
Datasheets and Nameplate Information for Photovoltaic Modules specify what information a module datasheet should provide.

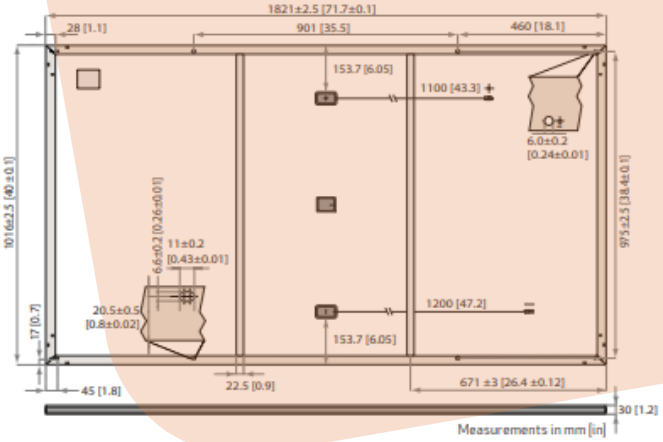
This includes:
•The electrical parameters (VOC, VMPP, ISC, IMPP, maximum system voltage and temperature coefficients) at STC
• The peak power, measured in Watt-peak (Wp), at STC
• The module I-V curve at STC
• Tolerances
• Reverse current values (for series fusing requirements)
• Cell type and number of cells
• Module efficiency at STC
• The module dimensions and weight

CIRCUIT ENERGY

- Information on junction boxes, diodes and cable connectors
- Module frame details
- Earthing/grounding requirements if any
- Standards and certification information

GENERAL DATA

Cell type:	132 half-cut REC heterojunction cells with lead-free, gapless technology, 6 strings of 22 cells in series
Glass:	3.2 mm solar glass with anti-reflective surface treatment in accordance with EN 12150
Backsheet:	Highly resistant polymer (black)
Frame:	Anodized aluminum (black)
Junction box:	3-part, 3 bypass diodes, lead-free IP68 rated, in accordance with IEC 62790
Connectors:	Stäubli MC4 PV-KBT4/KST4 (4 mm²) in accordance with IEC 62852, IP68 only when connected
Cable:	4 mm² solar cable, 1.1 m + 1.2 m in accordance with EN 50618
Dimensions:	1821 x 1016 x 30 mm (1.85 m²)
Weight:	20.5 kg
Origin:	Made in Singapore



ELECTRICAL DATA — Product Code*: RECxxxAA Pure

STC						
Power Output - P_{MAX} (Wp)	385	390	395	400	405	410
Watt Class Sorting - (W)	0/+5	0/+5	0/+5	0/+5	0/+5	0/+5
Nominal Power Voltage - V_{MPP} (V)	41.2	41.5	41.8	42.1	42.4	42.7
Nominal Power Current - I_{MPP} (A)	9.35	9.40	9.45	9.51	9.56	9.61
Open Circuit Voltage - V_{OC} (V)	48.5	48.6	48.7	48.8	48.9	49.0
Short Circuit Current - I_{SC} (A)	10.18	10.22	10.25	10.28	10.30	10.35
Power Density (W/m²)	208	211	214	216	219	222
Panel Efficiency (%)	20.8	21.1	21.4	21.6	21.9	22.2
NMOT						
Power Output - P_{MAX} (Wp)	293	297	301	305	309	312
Nominal Power Voltage - V_{MPP} (V)	38.8	39.1	39.4	39.7	40.0	40.2
Nominal Power Current - I_{MPP} (A)	7.55	7.59	7.63	7.68	7.72	7.76
Open Circuit Voltage - V_{OC} (V)	45.7	45.8	45.9	46.0	46.1	46.2
Short Circuit Current - I_{SC} (A)	8.16	8.20	8.24	8.28	8.32	8.36

Values at standard test conditions (STC: air mass AM 1.5, irradiance 1000 W/m², temperature 25°C), based on a production spread with a tolerance of P_{MAX}, V_{OC} & I_{SC} ±3% within one watt class. Nominal module operating temperature (NMOT: air mass AM 1.5, irradiance 800 W/m², temperature 20°C, windspeed 1 m/s). * Where xxx indicates the nominal power class (P_{MAX}) at STC above.

CERTIFICATIONS

IEC 61215:2016, IEC 61730:2016, UL 61730	
IEC 62804	PID
IEC 61701	Salt Mist
IEC 62716	Ammonia Resistance
ISO 11925-2	Ignitability (Class E)
IEC 62782	Dynamic Mechanical Load
IEC 61215-2:2016	Hailstone (35mm)
IEC 62321	Lead-free acc. to RoHS EU 863/2015
ISO 14001, ISO 9001, IEC 45001, IEC 62941	

TEMPERATURE RATINGS*

Nominal Module Operating Temperature:	44°C (±2°C)
Temperature coefficient of P_{MAX}:	-0.26 %/°C
Temperature coefficient of V_{OC}:	-0.24 %/°C
Temperature coefficient of I_{SC}:	0.04 %/°C

*The temperature coefficients stated are linear values

MAXIMUM RATINGS

Operational temperature:	-40 ... +85°C
Maximum system voltage:	1000 V
Maximum test load (front):	+7000 Pa (713 kg/m²)*
Maximum test load (rear):	-4000 Pa (407 kg/m²)*
Max series fuse rating:	25 A
Max reverse current:	25 A

*See installation manual for mounting instructions. Design load = Test load / 1.5 (safety factor)

WARRANTY

	Standard	REC ProTrust	
Installed by an REC Certified Solar Professional	No	Yes	Yes
System Size	All	≤25 kW	25-500 kW
Product Warranty (yrs)	20	25	25
Power Warranty (yrs)	25	25	25
Labor Warranty (yrs)	0	25	10
Power in Year 1	98%	98%	98%
Annual Degradation	0.25%	0.25%	0.25%
Power in Year 25	92%	92%	92%

See warranty documents for details. Conditions apply

DELIVERY INFORMATION

Panels per pallet:	33
Panels per 40 ft GP/high cube container:	792 (24 pallets)
Panels per 13.6 m truck:	924 (28 pallets)
Panels per 53 ft truck:	891 (27 pallets)

LOW LIGHT BEHAVIOUR

Typical low irradiance performance of module at STC:

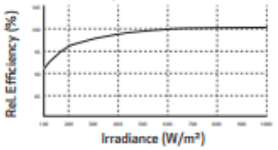


Figure 1: Sample PV module datasheet

3. PV modules configuration

PV cells can be connected in series, in parallel or in series-parallel, depending on the system voltage requirements.
If PV cells are connected in series, the total voltage is equal to the sum of all cell voltages. The total current remains that of one single cell. The I-V curves of each cell 'stack up' on the voltage axis.
If PV cells are connected in parallel, the total voltage remains that of a single cell, but the total current is equal to the sum of all cell currents. The I-V curves of each cell 'stack up' on the current axis.
The electrical parameters VOC, VMPP, ISC and IMPP can be calculated based on the combination of parallel and series connections of cells. They are also provided in the datasheet and on the PV module nameplate.

Example:

Assume that the V_{OC} of a PV cell is 0.6 V and the I_{SC} is 9 A.

- What is the total V_{OC} and the total I_{SC} of 8 cells connected in series?

Total V_{OC}: $0.6\ V \times 8 = 4.8\ V$

Total I_{SC}: 9 A

- What is the total V_{OC} and the total I_{SC} of 5 cells connected in parallel?

Total V_{OC}: 0.6 V

Total I_{SC}: $9\ A \times 5 = 45\ A$

- What is the total V_{OC} and the total I_{SC} of 8 cells connected in series with 5 strings in parallel?

Total V_{OC}: $0.6\ V \times 8 = 4.8\ V$

Total I_{SC}: $9\ A \times 5 = 45\ A$

- A module is built from these PV cells. It has a total $V_{OC,Module}$ of 12 V and a total $I_{SC,Module}$ of 27 A. How many cells are connected in series and how many strings in parallel?

Series: $\frac{12\ V}{0.6\ V} = 20\ cells$

Parallel: $\frac{27\ A}{9\ A} = 3\ strings$

So, it will be 3 $strings\ with$ 20 $cells\ per\ string$. (Totally 60 cells)

4. PV array configuration

Similar to the PV cells, PV modules can also be connected in series, in parallel or in series-parallel, depending on the system voltage requirements as determined, for example, by the inverter.
When PV modules are connected in series-parallel, the total voltage is equal to the sum of all modules voltages in one series string, and the total current is equal to the sum of all string currents in parallel connection. If different modules with different electrical characteristics are connected in a system, the current will be set by the module with the lowest current in that particular string.
Likewise, the voltage will be set by the module with the lowest voltage in the parallel strings.
Therefore, only modules with similar I-V curves should be connected together in a PV array to avoid unnecessary power losses.
The electrical parameters of the PV array must match the requirements of the inverter. The PV array's voltage, current and power must not surpass the inverter limitations under any operating conditions.
A PV system can be made up of several arrays connected either to several inverters or to only one central inverter. Since the configuration is modular, more PV modules and inverters can be added to the system at a later date provided that there is sufficient capacity and that grid connection conditions allow higher power injection to the grid.

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