PAN FILE DEVELOPMENT REPORT

ZNSHINE PV-TECH CO. LTD.

SOLAR MODULE: ZXP6-72-325/P, ZXP6-72-320/P, ZXP6-72-315/P

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EVALUATION OF

ZXP6-72-325/P, ZXP6-72-320/P, ZXP6-72-315/P

RENDERED by

Znshine PV-Tech Co. Ltd.

Date of receipt of the test item: 2018-05-07
Date of performance of the test item: 2018-05-10 ~ 2018-06-22

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CONTENT

Executive Summary

Znshine PV-Tech Co. Ltd. contracted Intertek Testing Services NA (Intertek) to create a photo-voltaic (PV) module characterization file (known as a “PAN” File) for use in PVsyst modeling software for the ZXP6-72-325/P, ZXP6-72-320/P, ZXP6-72-315/P crystalline silicon module.

Intertek used its test measurements for three samples of the ZXP6-72-325/P module, which quantified the performance metrics of the sample after Light- Induced Degradation (i.e. Pre- LID) at multiple irradiance and temperature conditions, according to the testing standard IEC61853-1. ZXP6-72-320/P, ZXP6-72-315/P is identical to ZXP6-72-325/P except the output power. And it can be considered that there is an excellent uniformity of these two models’ electrical characteristic. Intertek created a Base Case PAN file for the module using the module datasheet and PVsyst defaults. After evaluating the fit of the Base Case PAN file efficiency curves to the measured efficiency curves, Intertek adjusted the PAN file input parameters to obtain the closest fit of PVsyst modeled efficiency curves to the Intertek measured curves, resulting in the final Optimized PAN file.

Intertek fitting metric to assess the improvement achieved – Root- Sum- Square (RSS), which assesses the absolute deviation between efficiencies. This metrics is presented in Table 1 for the Optimized PAN file of each model.

Table 1 Goodness of Fit Metrics ZXP6-72-325/P, ZXP6-72-320/P, ZXP6-72-315/P PAN File

Model	Optimized RSS	Relative Efficiency
ZXP6-72-325/P	1.88 %	16.78 %
ZXP6-72-320/P	1.93 %	16.51 %
ZXP6-72-315/P	1.10 %	16.23 %

The Optimized PAN file is designed to be used in PVsyst software version 6.5.2 for modeling the expected performance of the given module. This PAN file is provided separately as “.PAN” file.

Note to PAN file users: This PAN file is derived from Pre-LID laboratory measurements.

1.0 Apporach

The purpose of this effort was to create a PVsyst-compatible PAN file that more accurately represents the ZXP6-72-325/P, ZXP6-72-320/P, ZXP6-72-315/P in tested conditions.

In order to accomplish this, Intertek took the following approach:

1. Measured Data: Process raw measured data from test lab and develop “Measured” efficiency curves for the ZXP6-72-325/P under certain irradiance and module temperatures. Since the measured data represented a module at nominal power, the efficiency curves were scaled to represent module nominal rating (referred to as “Scaled Measured”).
2. Base Case PAN File: Create a Base Case PAN file using parameters from the module datasheet and default values in PVsyst. Compare the resulting Base Case “Modeled" efficiency curves to the measured efficiency curves from step 1 to determine the extent of deviation.
3. Optimization: Adjust PAN file parameters until the Modeled efficiency curves generated by PVsyst match the measured curves as closely as possible.

1.1 Measured Data

Intertek measured three samples ZXP6-72-325/P module, which quantified the performance metrics of the sample module after Light-Induced Degradation (i.e. Pre-LID) at multiple irradiance and temperature test conditions, according to the testing standard IEC61853-1.

Test conditions:

The testing standard IEC 61853-1 required test conditions at four module temperatures:

15°C, 25°C, 50°C, 75°C

And seven irradiances:

100W/m^2, 200W/m^2, 400W/m^2, 600W/m^2, 800W/m^2, 1000W/m^2, 1100W/m^2

The test results for the Pre-LID ZXP6-72-325/P module resulted in maximum power (Pmp) at standard test conditions (STC = 25 °C and 1000W/m^2). These were a little different with the datasheet nominal power of rating, but were within the tolerance of sample ratings.

Table 2 shows the test data (average) for the Pre-LID ZXP6-72-325/P module, which serves as the basis for creating efficiency curves for the PAN file in this report.

Table 2 Measured Pre-LID (average) Maximum Powers at Test Conditions for the ZXP6-72-325/P

ZXP6-72-325/P

IRRADIANCE (W/m^2)	Spectrum	Pmp at 15°C (W)	Pmp at 25°C (W)	Pmp at 50°C (W)	Pmp at 75°C (W)
100	AM1.5	31.390	30.019	-	-
200	AM1.5	65.613	62.965	-	-
400	AM1.5	136.061	128.815	114.546	-
600	AM1.5	203.284	194.783	173.305	153.991
800	AM1.5	271.344	260.166	231.867	205.681
1000	AM1.5	341.236	327.826	293.103	259.172
1100	AM1.5	-	359.635	320.856	283.480

Since the Pre-LID test data measured were different with module nominal ratings, Intertek scaled the Pmp measurement to standard test condition (STC) to create scaled measured efficiency curves. Efficiency curves describe module efficiency as a function of module temperature and irradiance at various conditions determined by the IEC 61853 testing standard. Efficiency is calculated as:

$$\text{Efficiency} = \frac{\text{Module Rating[Wp]}}{\text{Module Area } [\text{m}^2] * \text{Irradiance } [\frac{\text{W}}{\text{m}^2}]}$$

Previous parametric data has shown that for a given manufacturer, the shape of the efficiency curves is within the tolerance range of declaring of manufacturer. Therefore, Intertek scaled the test data to module rating by applying a linear scaling factor. These measured efficiency curves were then used to verify the accuracy of the PAN file in the next steps.

1.2 BASE CASE PAN FILE

In order to create a Base Case PAN file in PVsyst, Intertek used the Znshine PV-Tech Co. Ltd. module datasheet (see Appendix A) for the following PVsyst inputs: module area, short-circuit current (Isc), open-circuit voltage (Voc), maximum power current (Imp), maximum power voltage (Vmp) and the temperature coefficients of Isc and Pmp. The other necessary module parameters were left at PVsyst defaults.

The Modeled efficiency curves generated by PVsyst from these Base Case PAN file parameters were then compared to the Measured curves based on the test data.

The comparison of Measured curves with those Modeled was performed using following metrics to quantify deviation:

Root Sum Square (RSS) Deviation : The agreement between the Modeled and Measured efficiency curves was evaluated by analyzing the sum of the square of differences between the two, called the root sum square (RSS) Deviation.

1.3 OPTIMIZATION

After determining the discrepancy between the Measured and Modeled efficiency curves for the Base Case, Intertek adjusted PAN file parameters in order to force the Modeled efficiency curves generated by PVsyst to better match the Measured efficiency curves seen in the lab.

Using an algorithm for optimization, the PAN file was iteratively refined to minimize the deviation between these efficiency curves, with the goal of minimizing the RSS primarily and other secondarily. The adjusted parameters are documented in the Results section.

Since Interteck’s optimized PAN file uses high-accuracy laboratory measurements of irradiance and temperature dependent PV module performance as the references for optimization of the PAN file, the accuracies of the resulting PVsyst simulations are improved.

2.0 RESULTS

The results and parameters for the ZXP6-72-325/P, ZXP6-72-320/P and ZXP6-72-315/P module are presented in the following sections.

2.1 ZXP6-72-325/P, ZXP6-72-320/P, ZXP6-72-315/P

2.1.1 Measured Data

Table 3 documents the measured Pre-LID module powers at Test Conditions, after scaling to the rated nominal power of the module.

Table 3 Scaled Pre-LID Maximum Powers at Test Conditions for ZXP6-72-325/P, ZXP6-72-320/P, and ZXP6-72-315/P module

ZXP6-72-325/P

IRRADIANCE (W/m^2)	Spectrum	Pmp at 15°C (W)	Pmp at 25°C (W)	Pmp at 50°C (W)	Pmp at 75°C (W)
100	AM1.5	31.119	29.760	-	-
200	AM1.5	65.047	62.422	-	-
400	AM1.5	134.888	127.705	113.559	-
600	AM1.5	201.532	193.104	171.811	152.664
800	AM1.5	269.005	257.923	229.868	203.908
1000	AM1.5	338.294	325.000	290.576	256.938
1100	AM1.5		356.535	318.090	281.037

ZXP6-72-320/P

IRRADIANCE (W/m^2)	Spectrum	Pmp at 15°C (W)	Pmp at 25°C (W)	Pmp at 50°C (W)	Pmp at 75°C (W)
100	AM1.5	30.640	29.302	-	-
200	AM1.5	64.047	61.462	-	-
400	AM1.5	132.813	125.740	111.812	-
600	AM1.5	198.432	190.133	169.168	150.315
800	AM1.5	264.866	253.955	226.332	200.771
1000	AM1.5	333.090	320.000	286.106	252.985
1100	AM1.5		351.050	313.196	276.713

ZXP6-72-315/P

IRRADIANCE (W/m^2)	Spectrum	Pmp at 15°C (W)	Pmp at 25°C (W)	Pmp at 50°C (W)	Pmp at 75°C (W)
100	AM1.5	30.162	28.845	-	-
200	AM1.5	63.046	60.502	-	-
400	AM1.5	130.738	123.775	110.065	-
600	AM1.5	195.331	187.162	166.524	147.966
800	AM1.5	260.728	249.987	222.795	197.634
1000	AM1.5	327.885	315.000	281.636	249.032
1100	AM1.5	-	345.564	308.302	272.389

2.1.2 Base Case PAN File

Table 4 summarizes the PVsyst inputs for the Base Case PAN file. Figure 1 shows the efficiency curves of the Base Case PAN file generated by PVsyst.

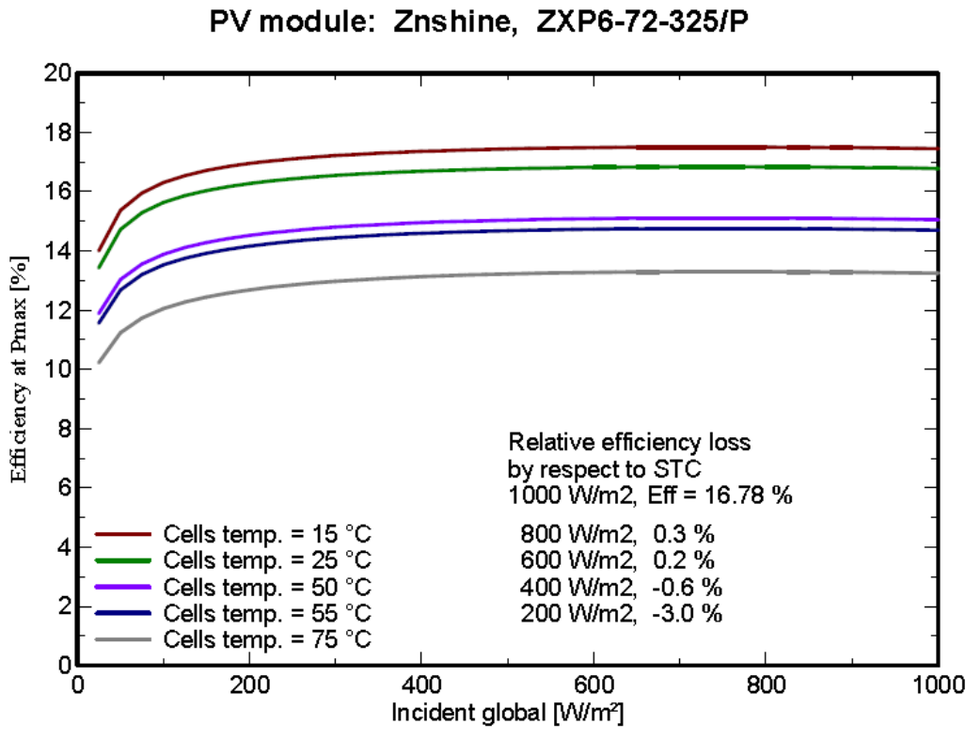
Table 4 Summary of inputs and Sources for Base Case Model

ZXP6-72-325/P	VALUE	SOURCE
Isc (A)	9.26	Datasheet
Voc (V)	46.34	Datasheet
Imp (A)	8.72	Datasheet
Vmp (V)	37.34	Datasheet
Temp. Coeff. Isc (%/℃)	0.06	Datasheet
Temp. Coeff Pmp (%/℃)	-0.41	Datasheet
Shunt Resistance Rsh (Ohm)	350	PVsyst Default
Series Resistance Rs (Ohm)	0.369	PVsyst Default
Rshunt at Ginc=0 (Ohm)	1600	PVsyst Default
Rshunt Expinential Parameter	5.5	PVsyst Default

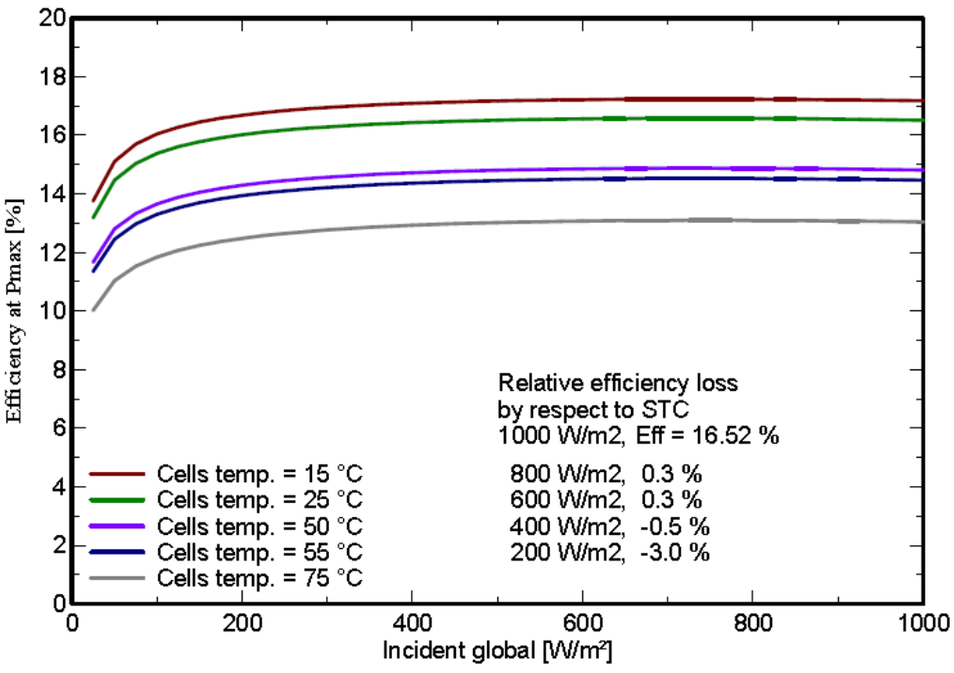
ZXP6-72-320/P	VALUE	SOURCE
Isc (A)	9.26	Datasheet
Voc (V)	46.22	Datasheet
Imp (A)	8.61	Datasheet
Vmp (V)	37.22	Datasheet
Temp. Coeff. Isc (mA/℃)	0.06	Datasheet
Temp. Coeff Pmp (%/℃)	-0.41	Datasheet
Shunt Resistance Rsh (Ohm)	350	PVsyst Default
Series Resistance Rs (Ohm)	0.381	PVsyst Default
Rshunt at Ginc=0 (Ohm)	1600	PVsyst Default
Rshunt Expinential Parameter	5.5	PVsyst Default

ZXP6-72-315/P	VALUE	SOURCE
Isc (A)	8.96	Datasheet
Voc (V)	45.6	Datasheet
Imp (A)	8.45	Datasheet
Vmp (V)	37.28	Datasheet
Temp. Coeff. Isc (%/℃)	0.06	Datasheet
Temp. Coeff Pmp (%/℃)	-0.41	Datasheet
Shunt Resistance Rsh (Ohm)	350	PVsyst Default
Series Resistance Rs (Ohm)	0.347	PVsyst Default
Rshunt at Ginc=0 (Ohm)	1600	PVsyst Default
Rshunt Expinential Parameter	5.5	PVsyst Default

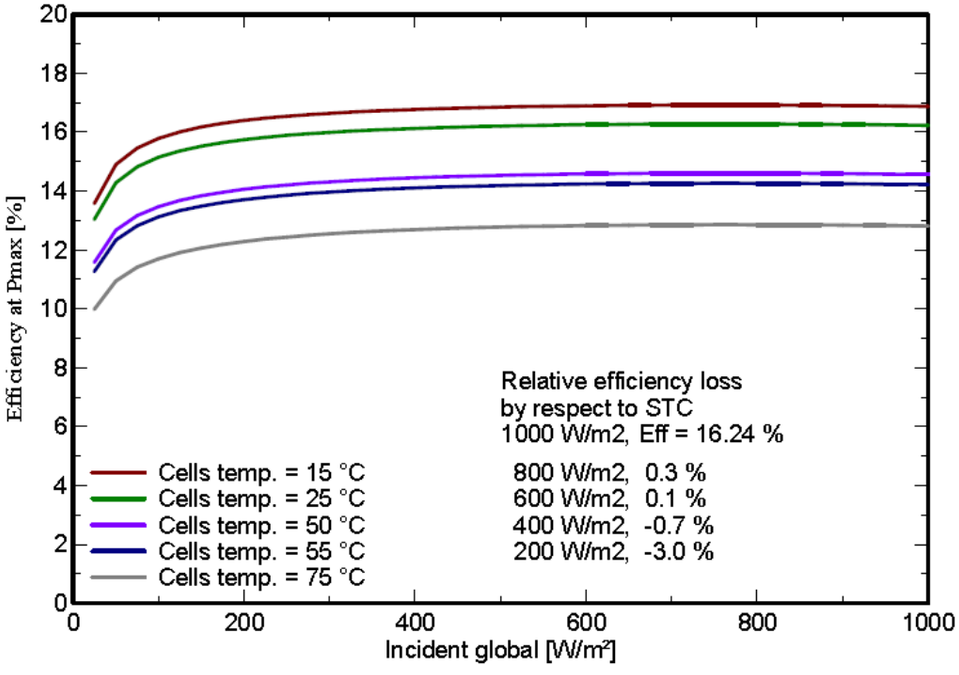
Figure 1 PVsyst Efficiency Curves for the Base Case ZXP6-72-325/P, ZXP6-72-320/P and ZXP6-72-315/P



PV module: Znshine, ZXP6-72-320/P



PV module: Znshine, ZXP6-72-315/P



2.1.3 Optimized PAN File

Table 5 summarizes the adjusted PVsyst inputs for the Optimized PAN file. Figure 2 shows the corresponding efficiency curves generated by PVsyst.

Table 5 Summary of Adjusted Inputs for Optimized ZXP6-72-325/P, ZXP6-72-320/P and ZXP6-72-315/P PAN File

ZXP6-72-325/P	VALUE
Temp. Coeff Pmp (%/℃)	-0.408
Series Resistance Rs (Ohm)	0.446
Shunt Resistance Rsh (Ohm)	350
Rshunt at Ginc=0 (Ohm)	1600

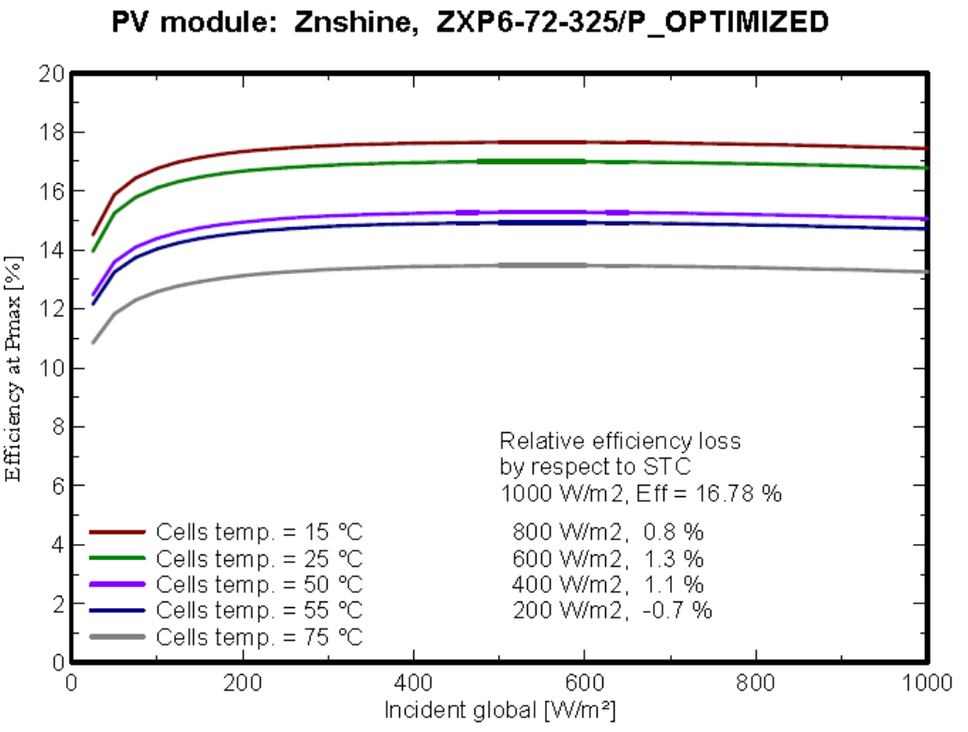
ZXP6-72-320/P	VALUE
Temp. Coeff Pmp (%/℃)	-0.408
Series Resistance Rs (Ohm)	0.468
Shunt Resistance Rsh (Ohm)	350
Rshunt at Ginc=0 (Ohm)	1600

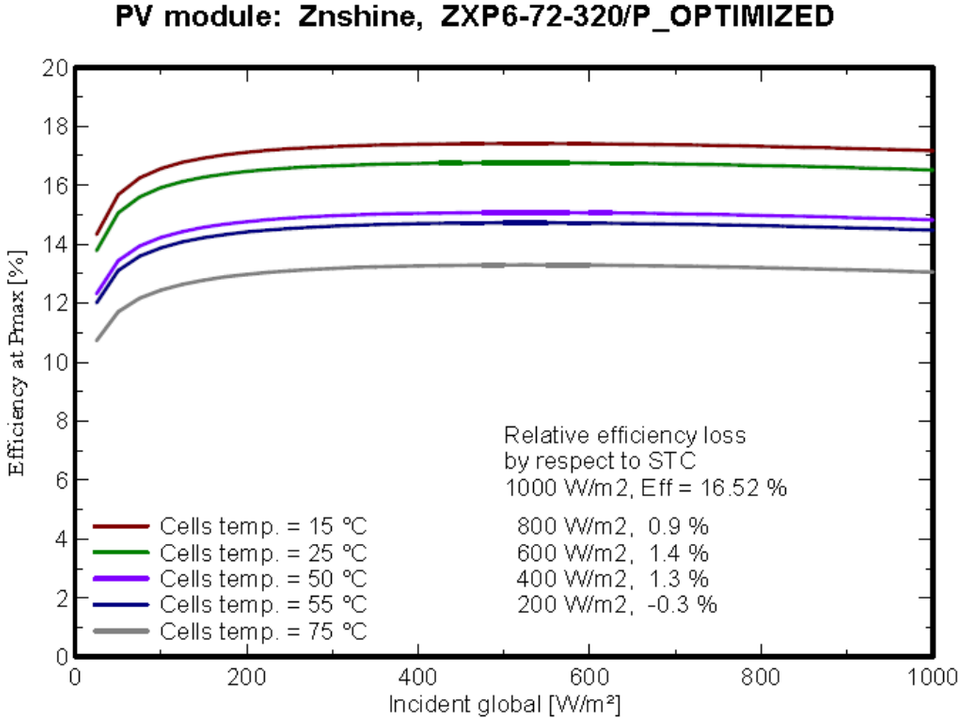
ZXP6-72-315/P	VALUE
Temp. Coeff Pmp (%/℃)	-0.408
Series Resistance Rs (Ohm)	0.382
Shunt Resistance Rsh (Ohm)	350
Rshunt at Ginc=0 (Ohm)	1600

IAM defined:

θ /°	0	20	40	60	70	75	80	85
IAM	1	1	0.99	0.98	0.85	0.77	0.62	0.37

Figure 2 PVsyst Efficiency Curves for the Optimized ZXP6-72-325/P, ZXP6-72-320/P and ZXP6-72-315/P PAN File





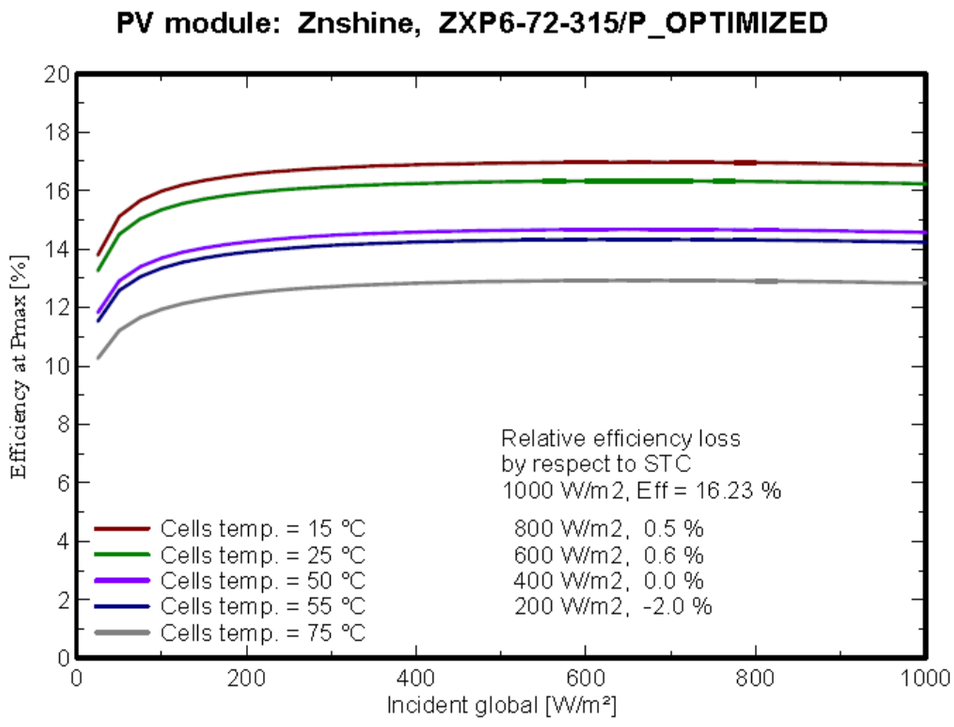

PV module: Znshine, ZXP6-72-315/P_OPTIMIZED
Efficiency at Pmax [%]
Incident global [W/m²]
Relative efficiency loss
by respect to STC
1000 W/m2, Eff = 16.23 %
800 W/m2, 0.5 %
600 W/m2, 0.6 %
400 W/m2, 0.0 %
200 W/m2, -2.0 %
Cells temp. = 15 °C
Cells temp. = 25 °C
Cells temp. = 50 °C
Cells temp. = 55 °C
Cells temp. = 75 °C

Table 6 shows the metrics of deviation from the optimized PAN file.

Table 6 Goodness of Fit Metrics for ZXP6-72-325/P, ZXP6-72-320/P, ZXP6-72-315/P PAN File

Model	Optimized RSS	Relative Efficiency
ZXP6-72-325/P	0.02 %	16.78 %
ZXP6-72-320/P	0.02 %	16.51 %
ZXP6-72-315/P	0.01 %	16.23 %

Note to PAN file users: This PAN file was derived from Pre-LID laboratory measurements.

PVSYST V6.52		22/06/18 20h21

Characteristics of a PV module

Manufacturer, model : **Znshine, ZXP6-72-325/P_OPTIMIZED**

Data source : Manufacturer

STC power (manufacturer)	Pnom	325	Wp	Technology		Si-poly	
Module size (W x L)	0.992 x 1.956		m²	Rough module area	Amodule	1.94	m²
Number of cells	1 x 72			Sensitive area (cells)	Acells	1.77	m²

Specifications for the model (manufacturer or measurement data)

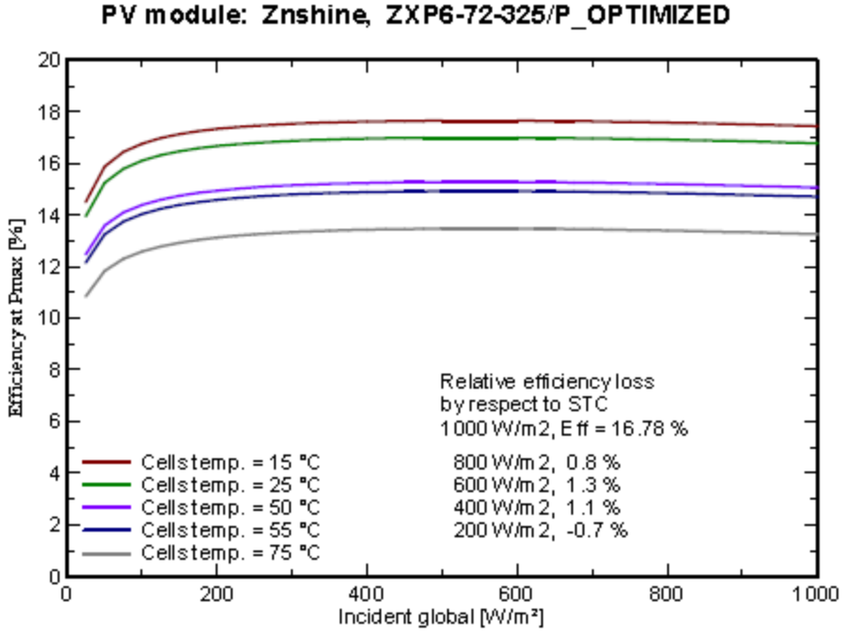
Reference temperature	TRef	25	°C	Reference irradiance	GRef	1000	W/m²
Open circuit voltage	Voc	46.3	V	Short-circuit current	Isc	9.26	A
Max. power point voltage	Vmpp	37.3	V	Max. power point current	Impp	8.72	A
=> maximum power	Pmpp	325.6	W	Isc temperature coefficient	muIsc	5.6	mA/°C

One-diode model parameters

Shunt resistance	Rshunt	350	ohm	Diode saturation current	IoRef	0.009	nA
Serie resistance	Rserie	0.45	ohm	Voc temp. coefficient	MuVoc	-157	mV/°C
				Diode quality factor	Gamma	0.91	
Specified Pmax temper. coeff.	muPMaxR	-0.41	%/°C	Diode factor temper. coeff.	muGamma	-0.001	1/°C

Model results for standard conditions (STC: T=25°C, G=1000 W/m², AM=1.5)

Max. power point voltage	Vmpp	37.3	V	Max. power point current	Impp	8.74	A
Maximum power	Pmpp	325.6	Wc	Power temper. coefficient	muPmpp	-0.40	%/°C
Efficiency(/ Module area)	Eff_mod	16.8	%	Fill factor	FF	0.759	
Efficiency(/ Cells area)	Eff_cells	18.4	%				



PVSYST V6.52		22/06/18 20h42

Characteristics of a PV module

Manufacturer, model : **Znshine, ZXP6-72-320/P_OPTIMIZED**

Data source : Manufacturer

STC power (manufacturer)	Pnom	320	Wp	Technology		Si-poly	
Module size (W x L)	0.992 x 1.956		m²	Rough module area	Amodule	1.94	m²
Number of cells	1 x 72			Sensitive area (cells)	Acells	1.75	m²

Specifications for the model (manufacturer or measurement data)

Reference temperature	TRef	25	°C	Reference irradiance	GRef	1000	W/m²
Open circuit voltage	Voc	46.2	V	Short-circuit current	Isc	9.18	A
Max. power point voltage	Vmpp	37.2	V	Max. power point current	Impp	8.61	A
=> maximum power	Pmpp	320.5	W	Isc temperature coefficient	muIsc	5.5	mA/°C

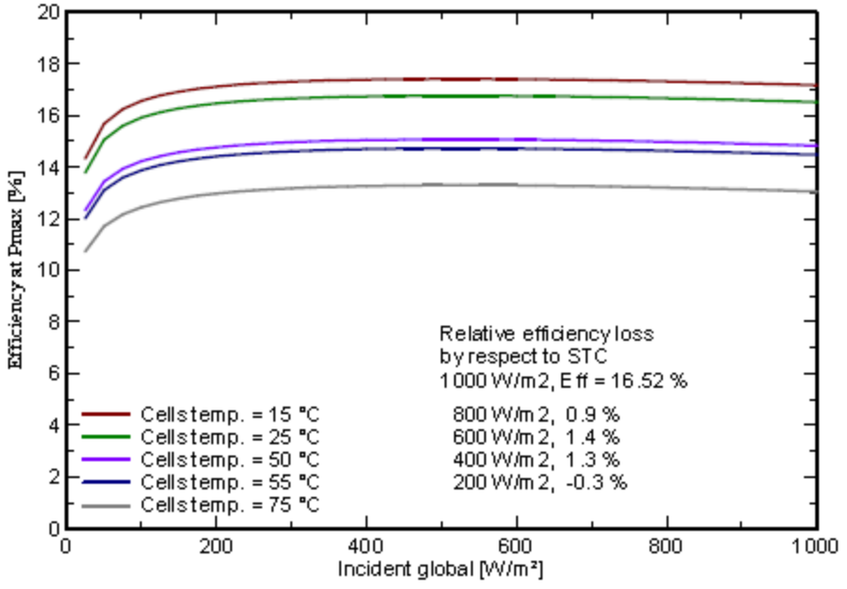
One-diode model parameters

Shunt resistance	Rshunt	350	ohm	Diode saturation current	IoRef	0.009	nA
Serie resistance	Rserie	0.47	ohm	Voc temp. coefficient	MuVoc	-156	mV/°C
				Diode quality factor	Gamma	0.90	
Specified Pmax temper. coeff.	muPMaxR	-0.41	%/°C	Diode factor temper. coeff.	muGamma	0.000	1/°C

Model results for standard conditions (STC: T=25°C, G=1000 W/m², AM=1.5)

Max. power point voltage	Vmpp	37.0	V	Max. power point current	Impp	8.66	A
Maximum power	Pmpp	320.5	Wc	Power temper. coefficient	muPmpp	-0.40	%/°C
Efficiency(/ Module area)	Eff_mod	16.5	%	Fill factor	FF	0.755	
Efficiency(/ Cells area)	Eff_cells	18.3	%				

PV module: Znshine, ZXP6-72-320/P_OPTIMIZED



PVSYST V6.52		22/06/18 20h37

Characteristics of a PV module

Manufacturer, model : **Znshine, ZXP6-72-315/P_OPTIMIZED**

Data source : Manufacturer

STC power (manufacturer)	Pnom	315	Wp	Technology		Si-poly	
Module size (W x L)		0.992 x 1.956	m²	Rough module area	Amodule	1.94	m²
Number of cells		1 x 72		Sensitive area (cells)	Acells	1.75	m²

Specifications for the model (manufacturer or measurement data)

Reference temperature	TRef	25	°C	Reference irradiance	GRef	1000	W/m²
Open circuit voltage	Voc	45.6	V	Short-circuit current	Isc	8.96	A
Max. power point voltage	Vmpp	37.3	V	Max. power point current	Impp	8.45	A
=> maximum power	Pmpp	315.0	W	Isc temperature coefficient	muIsc	5.4	mA/°C

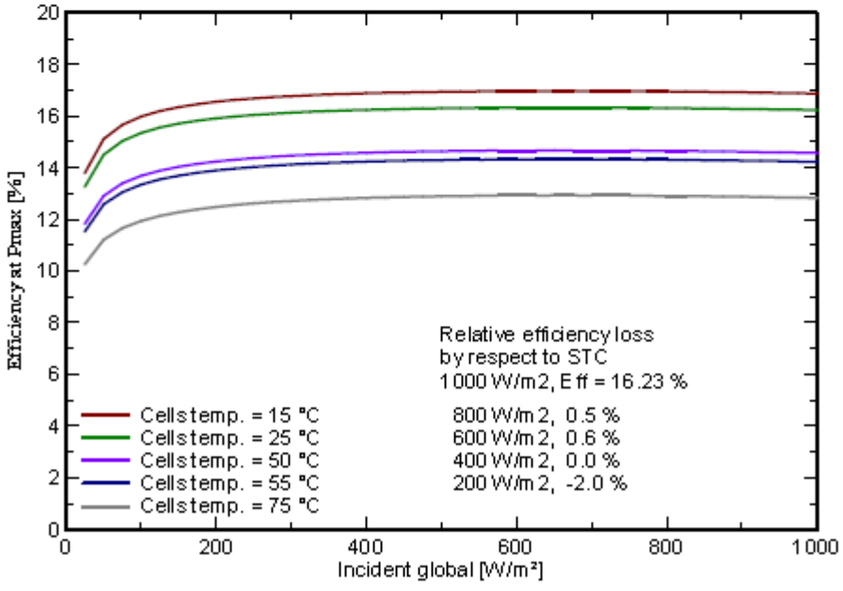
One-diode model parameters

Shunt resistance	Rshunt	350	ohm	Diode saturation current	IoRef	0.009	nA
Serie resistance	Rserie	0.38	ohm	Voc temp. coefficient	MuVoc	-157	mV/°C
				Diode quality factor	Gamma	0.89	
Specified Pmax temper. coeff.	muPMaxR	-0.41	%/°C	Diode factor temper. coeff.	muGamma	0.000	1/°C

Model results for standard conditions (STC: T=25°C, G=1000 W/m², AM=1.5)

Max. power point voltage	Vmpp	37.2	V	Max. power point current	Impp	8.46	A
Maximum power	Pmpp	315.0	W/c	Power temper. coefficient	muPmpp	-0.40	%/°C
Efficiency(/ Module area)	Eff_mod	16.2	%	Fill factor	FF	0.771	
Efficiency(/ Cells area)	Eff_cells	18.0	%				

PV module: Znshine, ZXP6-72-315/P_OPTIMIZED



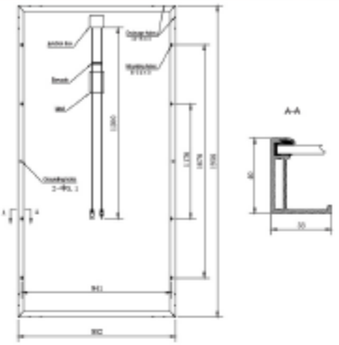
3.0 APPENDIX

Appendix A: ZXP6-72-325/P, ZXP6-72-320/P and ZXP6-72-315/P datasheet

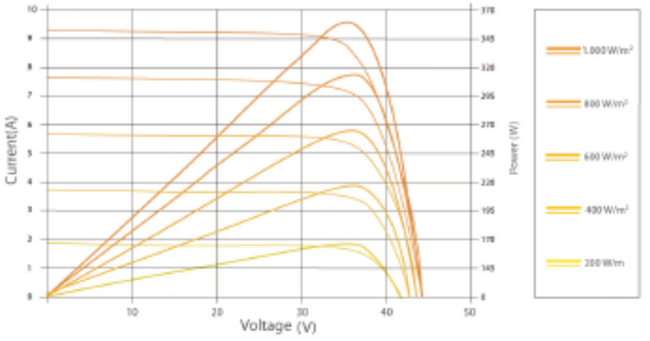
ZXP6 72/310-345

ZNSHINESOLAR

Dimension of the PV module



I-V Curves of the PV module



Electrical data

Model	ZXP6 72-310/P	ZXP6 72-315/P	ZXP6 72-320/P	ZXP6 72-325/P	ZXP6 72-330/P	ZXP6 72-335/P	ZXP6 72-340/P	ZXP6 72-345/P
Nominal Power Watt $P_{max}(W_p)$	310	315	320	325	330	335	340	345
Power Output Tolerance $P_{max}(\%)$	0~+3	0~+3	0~+3	0~+3	0~+3	0~+3	0~+3	0~+3
Maximum Power Voltage $V_{mp}(V)$	36.98	37.28	37.22	37.34	37.45	37.64	37.74	37.83
Maximum Power Current $I_{mp}(A)$	8.39	8.45	8.61	8.72	8.83	8.91	9.01	9.12
Open Circuit Voltage $V_{oc}(V)$	45.98	45.60	46.22	46.34	46.46	46.58	46.70	46.82
Short Circuit Current $I_{sc}(A)$	9.02	8.96	9.18	9.26	9.34	9.42	9.50	9.58
Module Efficiency $\eta_m(\%)$	15.98	16.23	16.49	16.75	17.01	17.26	17.52	17.78

Mechanical data

Solar cells	Poly 156×156 / 156.75×156.75 mm
Cells orientation	72 (6×12)
Module dimension	1956 ×992×40 mm
Weight	22.5 kg
Glass	High transparency,low iron,tempered glass 3.2mm (AR-coating)
Junction box	IP 68, 3 diodes
Cables	4 mm² ,1200 mm
Connectors	MC4-compatible

Temperature ratings

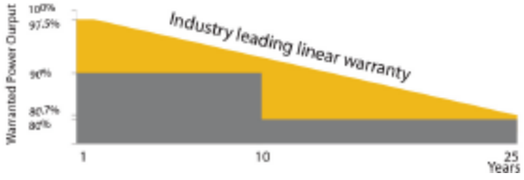
Nominal Operating Cell Temperature	45℃ ±2℃
Temperature coefficient of P_{max}	-0.41%/K
Temperature coefficient of V_{oc}	-0.33%/K
Temperature coefficient of I_{sc}	0.06%/K

Working conditions

Maximum system voltage	1000 / 1500 V DC
Operating temperature	-40℃~+85℃
Maximum series fuse	15 A
Maximum load (snow/wind)	5400 Pa / 2400 Pa

Warranty information

10 years workmanship warranty
25 years output warranty(polycrystalline):2.5% in the 1st year, thereafter 0.7% per year ending with 80.7% in the 25th year



Packaging information

Modules per box	27 pcs.(40 mm)
Modules per 40' HQ container	648 pcs.(40mm)

Measurement Tolerance STC: ±3% (P_{max}) ; ±10%(V_{oc}, I_{sc}, V_{mp}, I_{mp}). Values at Standard Test Conditions STC(Air Mass AM1.5, Irradiance 1000W/m², Cell Temperature 25℃) | Remark: please read safety and installation instructions before using the product | Subject to change without prior notice © ZNSHINE SOLAR 2018 | Version: ZXP6-72-1805.E