PAN FILE DEVELOPMENT REPORT

Greenbrilliance Renewable Energy LLP

SOLAR MODULE:
GBPLF-72-330-24

INTERTEK TESTING SERVICES SHANGHAI
Address: 1-2F, No.2, Alley 1218, Wan Rong Road,
Shanghai, China

EVALUATION OF

GBPLF-72-330-24

RENDERED by

Greenbrilliance Renewable Energy LLP

Related Standard

IEC61853-1:2016

Date of receipt of the test item: May 20, 2019
Date of performance of the test item: May 28, 2019 ~ May 30, 2019

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Date of issue : June 11, 2019

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Executive Summary

Greenbrilliance Renewable Energy LLP contracted Intertek Testing Services Shanghai (Intertek) to create a photo-voltaic (PV) module characterization file (known as a “PAN” File) for use in PVsyst modeling software for the GBPLF-72-320-24 crystalline silicon module.

Intertek used its test measurements for three samples of the GBPLF-72-320-24 module, which quantified the performance metrics of the sample Pre Light-Induced Degradation (i.e. Pre-LID) at multiple irradiance and temperature conditions, according to the testing standard IEC61853-1, then used the average data of the three samples to design the PAN file. IAM data is the default value of AR coating front surface in PVsyst software, version 6.7.7. GBPLF-72-320-24 is identical to GBPLF-72-330-24 except the output power, and it can be considered that there is an excellent uniformity of these 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 for GBPLF-72-330-24

Model	Optimized RSS	Relative Efficiency
GBPLF-72-330-24	1.82%	17.04%

The Optimized PAN file is designed to be used in PVsyst software version 6.7.7 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 GBPLF-72-320-24 module 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 GBPLF-72-320-24 module 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 of GBPLF-72-320-24 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 GBPLF-72-320-24 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 average test data for three GBPLF-72-320-24 modules, which serves as the basis for creating efficiency curves for the PAN file in this report.

Table 2 Measured Pre-LID Maximum Powers at Test Conditions for the GBPLF-72-320-24

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	30.374	29.019	-	-
200	AM1.5	62.972	60.874	-	-
400	AM1.5	128.401	124.925	110.002	-
600	AM1.5	193.363	189.022	166.680	147.554
800	AM1.5	258.905	252.797	222.214	196.900
1000	AM1.5	324.232	318.054	281.949	250.440
1100	AM1.5	-	348.250	309.415	274.236

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 Greenbrilliance Renewable Energy LLP 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 Intertek'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 GBPLF-72-320-24 module are presented in the following sections.

2.1 GBPLF-72-330-24

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 GBPLF-72-330-24 module

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	31.515	30.109	-	-
200	AM1.5	65.337	63.160	-	-
400	AM1.5	133.223	129.617	114.133	-
600	AM1.5	200.626	196.122	172.941	153.096
800	AM1.5	268.629	262.291	230.561	204.295
1000	AM1.5	336.410	330.000	292.539	259.846
1100	AM1.5		361.330	321.036	284.536

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

GBPLF-72-330-24	VALUE	SOURCE
Isc (A)	9.24	Datasheet
Voc (V)	46.30	Datasheet
Imp (A)	8.70	Datasheet
Vmp (V)	38.00	Datasheet
Temp. Coeff. Isc (mA/°C)	5.5	Datasheet
Temp. Coeff Pmp (%/°C)	-0.424	Datasheet
Shunt Resistance Rsh (Ohm)	350	PVsyst Default
Series Resistance Rs (Ohm)	0.337	PVsyst Default
Rshunt at Ginc=0 (Ohm)	1400	PVsyst Default
Rshunt Expinential Parameter	5.5	PVsyst Default

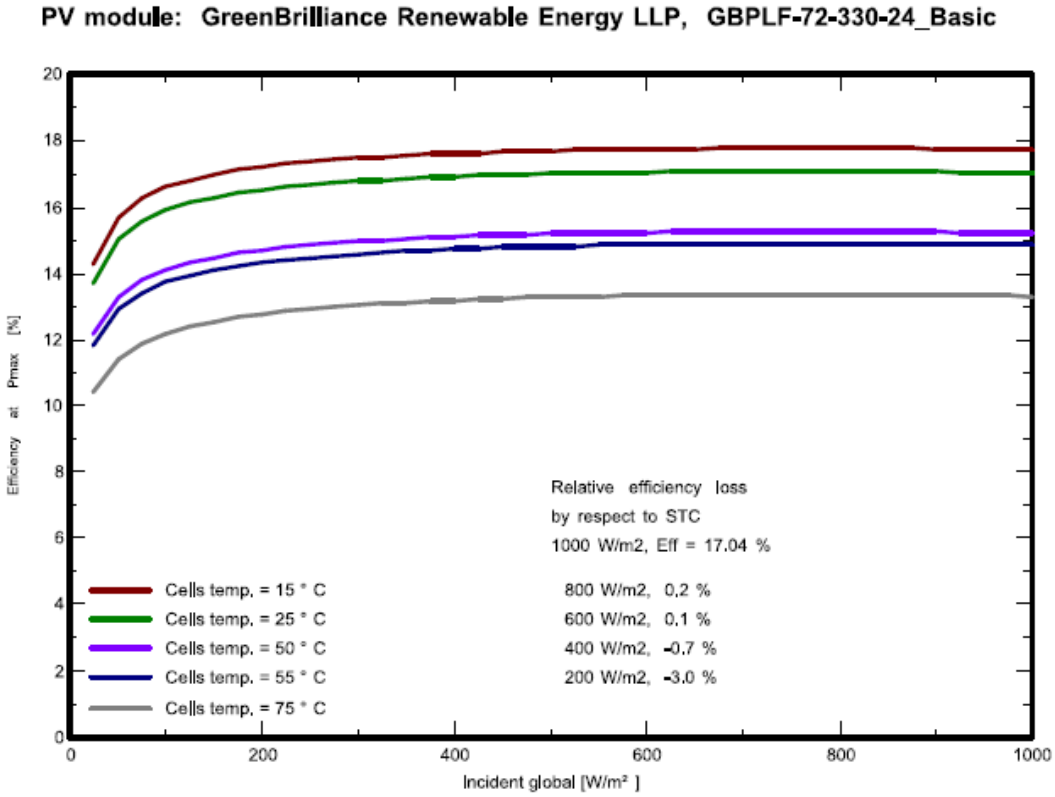

Figure 1 PVsyst Efficiency Curves for the Base Case

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 GBPLF-72-330-24 PAN File

GBPLF-72-330-24	VALUE
Series Resistance Rs (Ohm)	0.367
Shunt Resistance Rsh (Ohm)	350
Rshunt at Ginc=0 (Ohm)	1400
Temp. Coeff Pmp (%/°C)	-0.414

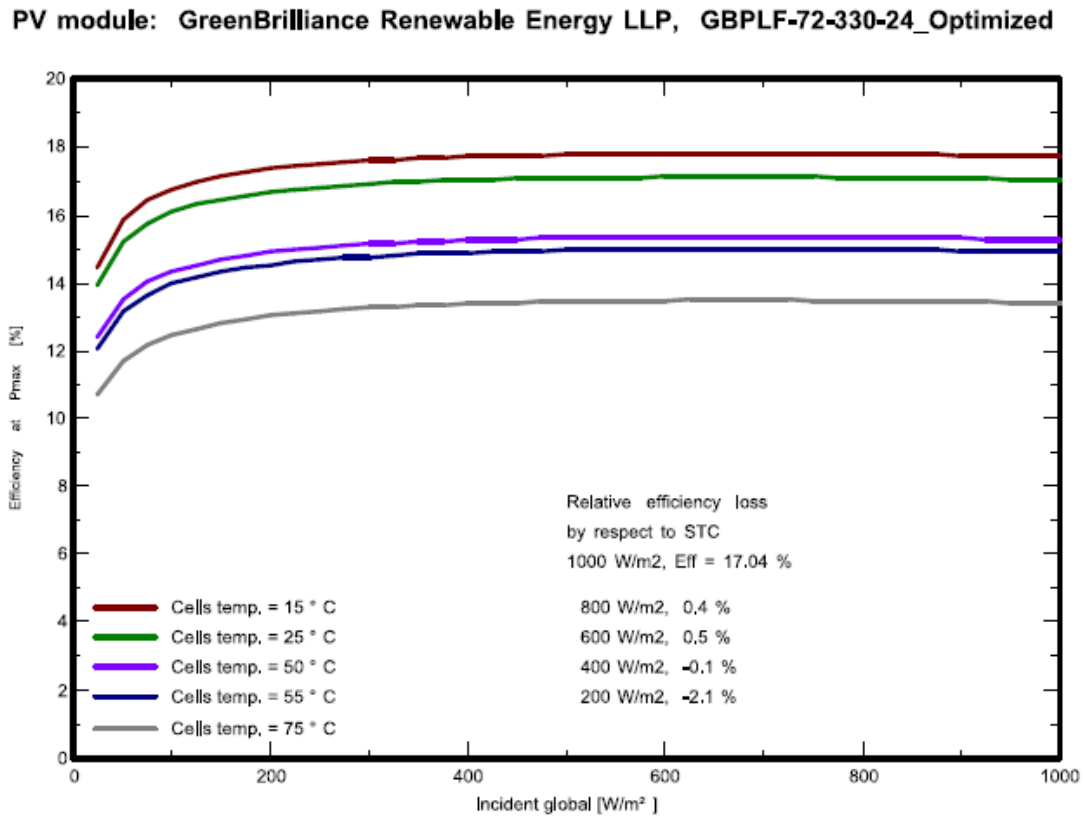

Figure 2 PVsyst Efficiency Curves for the Optimized PAN File.

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

Table 6 Goodness of Fit Metrics for GBPLF-72-320-24

Model	Optimized RSS	Relative Efficiency
GBPLF-72-330-24	1.82%	17.04%

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

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Characteristics of a PV module

Manufacturer, model : **GreenBrilliance Renewable Energy LLP, GBPLF-72-330-24_Optimized**

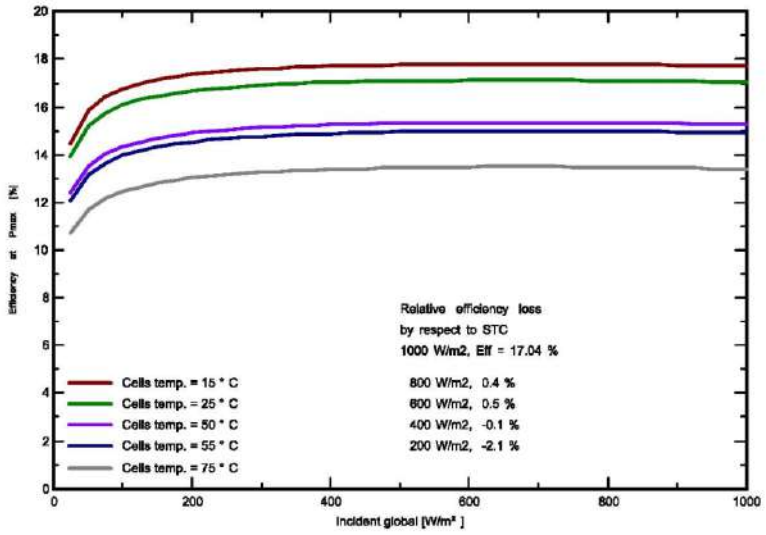
Data source : Manufacturer

STC power (manufacturer)	**Pnom**	**330**	**Wp**	**Technology**		**Si-poly**	
Module size (W x L)		0.990 x 1.960	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	9.24	A
Max. power point voltage	Vmpp	38.0	V	Max. power point current	Impp	8.70	A
=> maximum power	Pmpp	330.6	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	0.37	ohm	Voc temp. coefficient	MuVoc	-163	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	37.9	V	Max. power point current	Impp	8.73	A
Maximum power	Pmpp	330.6	Wc	Power temper. coefficient	muPmpp	-0.40	%/° C
Efficiency(/ Module area)	Eff_mod	17.0	%	Fill factor	FF	0.773	
Efficiency(/ Cells area)	Eff_cells	18.7	%				

PV module: GreenBrilliance Renewable Energy LLP, GBPLF-72-330-24_Optimized



PVsyst Licensed to Shanghai Intertek Testing Services Co Ltd., (China)

3.0 APPENDIX

Appendix A: GBPLF-72-330-24 datasheet

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GreenBrilliance is committed to providing high quality solar products and solar system solutions to customers worldwide.

Electrical Parameters at STC (AM 1.5, 1000 W/m², 25°C)

Peak Power - Pmax (Wp)	315	320	325	330	335	340
Maximum Voltage - Vmpp (V)	37.50	37.70	37.80	38.00	38.10	38.2
Maximum Current - Impp (A)	8.40	8.50	8.60	8.70	8.80	8.91
Open Circuit Voltage - Voc (V)	45.80	46.00	46.20	46.30	46.50	46.80
Short Circuit Voltage - Isc (A)	8.92	9.03	9.13	9.24	9.35	9.43
Module Efficiency - η (%)	16.23	16.49	16.75	17.01	17.26	17.52

Electrical Parameters at NOCT (800 W/m², 20°C, wind speed 1 m/sec)

Power (Wp)	231.2	234.60	238.30	242.0	245.60	253.0
V at Pmax (V)	34.40	34.50	34.60	34.80	34.90	35.9
I at Pmax (A)	6.73	6.80	6.84	6.95	7.03	7.05
V_{oc} (V)	42.50	42.60	42.65	42.70	42.80	44.00
I_{sc} (A)	7.22	7.30	7.34	7.46	7.54	7.98

Temperature Co-efficient (T_c) & Permissible Operating Conditions

T_c of Open Circuit Voltage (β)	- 0.341 %/°C
T_c of Short Circuit Current (α)	0.050 %/°C
T_c of Power (Ɣ)	- 0.424 %/°C
Maximum System Voltage	1000 V
NOCT	45 +/- 2°C
Temperature Range	- 40°C to +85°C

Mechanical Data

Length x Width x Height	1960 mm x 990 mm x 35 mm
Weight	21.5 Kgs
Junction Box	IP67, 3 bypass diodes
Cable & Connectors	1000 / 1200 mm length cables, MC4 connectors
Application Class	Class A (Safety Class II)
Superstrate	High transmission low iron tempered AR glass
Cells	72 poly crystalline solar cell
Cell Encapsulant	EVA (Ethylene Vinyl Acetate)
Back Sheet	Composite film
Frame	Anodized AL Frame with twin wall profile
Mechanical Load Test	Snow load upto 5400Pa/ Wind load upto 2400Pa
Maximum Series Fuse Rating	15A

Packaging Information

Container	20' GP	40'GP	40'HC
Pallet (26 in 1) / Container	10	24	24 + 20 (2in1 Box)
Pieces / Container	260	624	664

Warranty and Certifications

Product Warranty**	10 years
Performance Warranty**	Linear power warranty for 25 years with 2.5% for 1st
	1st year degradation and 0.75% from year 2 to year 25.
Approvals and Certifications	IEC 61215-2016*, IEC 61730-1&2*, IEC 61701*,
	IEC 62804*, IEC 62716*, UL-1703*, CE*

** Refer to GreenBrilliance warranty document for terms and conditions. *All(*) certification under progress.
Caution: Read Safety and Installation Manual before using the product.
Specification included in this datasheet are subject to change without notice. Electrical data without guarantee.
Please confirm your exact requirements with company representative while placing your order.