



# Application Note

## Recommended Parametric Descriptions of First Solar Series 4 (V3) PV Modules for Use with PVSYST

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### Purpose:

The purpose of this document is to provide users of the PV system simulation software PVSYST<sup>1</sup> with accurate parametric descriptions of First Solar Series 4 (V3) products. Results obtained with PVSYST are strongly dependent upon the various input parameters used to describe PV module operation. First Solar has developed these parametric descriptions to ensure that performance estimation obtained with PVSYST will accurately reflect the measured performance of actual PV systems constructed with First Solar Series 4 (V3) products.

### Scope:

The recommended parametric descriptions included in this document are intended for use with the PV system simulation software PVSYST, versions 4.35 and higher. The values in the following tables may be entered into a new PV module record and saved into the application's database of PV module descriptions for later use. This is done using the "Tools" option of PVSYST releases through version 5.73. In PVSyst releases 6.xx, this is done via the "Databases" button on the intro screen of the software.

### Discussion:

To simulate the performance of PV modules, at the time of this writing PVSYST utilizes a standard "single diode" model, which typically simulates the measured characteristics of mono- and polycrystalline silicon PV devices well. However, this model makes certain assumptions which do not necessarily hold for thin film devices. The most significant of these are the assumptions that the shunt resistance is constant and that the photocurrent is purely a function of the effective irradiance on the surface of the device. As a result, the standard "single diode" PV device model is not fully optimized for theoretical simulation of thin film PV technologies.

In order to extend this simple "single diode" model and enable better simulation of thin film device operation, several enhancements to the standard single diode model are incorporated in PVSYST. First Solar has collaborated with PVSYST developer André Mermoud in an effort to improve the accuracy of PVSYST simulations of our thin film CdTe PV modules. This work has shown that the performance of First Solar PV modules can be more accurately simulated by defining recombination losses in PVSYST. As a result, in version 4.35 and later of PVSYST, the user can now specify a value for the recombination loss parameter  $di^2/\mu\tau$  when "CdTe" is selected as the PV technology in the PV module definition dialog. In addition, definition of an exponential dependence of  $R_{SH}$  on irradiance has enabled more accurate simulation of First Solar PV module products.

While these enhancements to the standard PV device model improve the accuracy of simulations of First Solar products performed with PVSYST, it should be noted that this enhanced model is still limited in its ability to precisely simulate the performance of thin film CdTe PV modules in all conditions. However, when assessing validity of simulation results by means of aggregate functions (such as performance ratio or specific energy yield over a finite time period) significant

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<sup>1</sup> PVSYST is a commercial software product for the simulation of PV systems. For more information, visit [www.pvsyst.com](http://www.pvsyst.com).



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improvement in agreement of simulated results with real-world data has been obtained.

By applying the parameters and factors outlined in this document, more accurate modeling of First Solar's thin film CdTe modules can be achieved. Validation of PVSYST simulations for First Solar's thin film CdS/CdTe PV technology using these settings has shown more accurate simulation of the measured I(V) characteristic over a range of operating conditions, and enables improvement in overall simulation results.

In order to achieve this more accurate module response within the PVSYST module simulation, some PVSYST module input parameters may require adjustment to ensure that the "single diode" model returns the correct result. For instance, electrical module specifications at reference conditions may not match the values specified by the First Solar datasheet or module label. Although the simulation input parameters may deviate from datasheet values, the module response and simulated energy output will achieve a more accurate result when compared to actual device and system performance.

### Results:

The parameteric descriptions included here have been used with PVSYST to simulate actual PV systems in various European and North American climates. The results of these simulations have been compared with actual, measured performance of these systems, and good agreement has been obtained. While this validation has been performed for European and North American climates, the parameteric descriptions provided in this document are applicable for simulation of PV systems worldwide.

These First Solar Series 4 (V3) PV module parameters should be included in the PV module database distributed with PVSYST software updates. Please thoroughly check that the module parameters in your software installation match the settings in this document. If they do not match, update your PVSYST software, or manually modify and save these parameters.

Section	Parameter	Unit	FS-4107-3 / FS-4107A-3
<b>Basic Data</b>			
	Model	[none]	FS-4107[A]-3 Feb 2016
	Manufacturer	[none]	First Solar
	File name	[none]	FS-4107[A]-3 CdTe Feb2016.PAN
	Data source	[none]	Manufacturer February 2016
	Nominal Power	[W]	107.5*
	Tolerance	[%]	-0.0%, +4.7%
	Technology		CdTe
<b>Manufacturer's Specifications or Other Measurements</b>	$G_{REF}$	[W/m <sup>2</sup> ]	1000
	$T_{REF}$	[°C]	25
	$I_{SC}$	[A]	1.820
	$V_{OC}$	[V]	85.80
	$I_{MPP}$	[A]	1.602
	$V_{MPP}$	[V]	67.00
	$\mu I_{SC}$	[mA/°C] [%/°C]	0.7 0.040
<b>Model Parameters</b>			
<b>Rshunt - Rserie</b>	$R_{SH}$	[Ω]	3300
	$R_S$	[Ω]	4.625
<b>Rshunt exponential</b>	$R_{SH}$ at $G_{INC}=0$	[Ω]	15000
	Exponential parameter	[none]	6.0
<b>Recombination Loss</b>	$di^2/(\mu*\tau)$	V <sup>-1</sup>	0.95
<b>Temperature Coefficient</b>	Apply the correction	[none]	checked
	Coefficient value	[%/°C]	-0.28
<b>Sizes and Technology</b>			
<b>Module</b>	Length	[mm]	1200
	Width	[mm]	600
	Thickness	[mm]	6.8
	Weight	[kg]	12.0
<b>Cells</b>	In series	[none]	108
	In parallel	[none]	2
	Cell area	[cm <sup>2</sup> ]	31.3
<b>Reverse characteristics</b>	Quadratic factor $B_{REV}$	[mA/V <sup>2</sup> ]	3.2
	Number of bypass diodes	[none]	0
	Diode reverse voltage	[V]	-0.7
<b>Module technology</b>	Line #1	[none]	Frameless module
	Line #2	[none]	Glass-polyolefin-glass laminate
	Line #3	[none]	Multicontact MC4
<b>Maximum system voltage</b>	Insulation voltage	[V]	1500
<b>Absorption coefficient for T</b>	Absorption coefficient	[none]	0.90
<b>Commercial Data</b>			
	Manufacturer		First Solar
	Remarks		www.firstsolar.com
	Available on market from		2016

Table 1a. Parametric description of First Solar's FS-4107-3 and FS-4107A-3 PV module products.

7Section	Parameter	Unit	FS-4110-3/ FS-4110A-3
<b>Basic Data</b>			
	Model	[none]	FS-4110[A]-3 Feb 2016
	Manufacturer	[none]	First Solar
	File name	[none]	FS-4110[A]-3 CdTe Feb2016.PAN
	Data source	[none]	Manufacturer February 2016
	Nominal Power	[W]	110.0
	Tolerance	[%]	-0.0%, +4.5%
	Technology		CdTe
<b>Manufacturer's Specifications or Other Measurements</b>	$G_{REF}$	[W/m <sup>2</sup> ]	1000
	$T_{REF}$	[°C]	25
	$I_{SC}$	[A]	1.820
	$V_{OC}$	[V]	86.40
	$I_{MPP}$	[A]	1.620
	$V_{MPP}$	[V]	67.85
	$\mu I_{SC}$	[mA/°C] [%/°C]	0.7 0.040
<b>Model Parameters</b>			
<b>Rshunt - Rserie</b>	$R_{SH}$	[Ω]	3500
	$R_S$	[Ω]	4.448
<b>Rshunt exponential</b>	$R_{SH}$ at $G_{INC}=0$	[Ω]	12000
	Exponential parameter	[none]	6.0
<b>Recombination Loss</b>	$di^2/(\mu\tau)$	V <sup>-1</sup>	0.95
<b>Temperature Coefficient</b>	Apply the correction	[none]	checked
	Coefficient value	[%/°C]	-0.28
<b>Sizes and Technology</b>			
<b>Module</b>	Length	[mm]	1200
	Width	[mm]	600
	Thickness	[mm]	6.8
	Weight	[kg]	12.0
<b>Cells</b>	In series	[none]	108
	In parallel	[none]	2
	Cell area	[cm <sup>2</sup> ]	31.3
<b>Reverse characteristics</b>	Quadratic factor $B_{REV}$	[mA/V <sup>2</sup> ]	3.2
	Number of bypass diodes	[none]	0
	Diode reverse voltage	[V]	-0.7
<b>Module technology</b>	Line #1	[none]	Frameless module
	Line #2	[none]	Glass-polyolefin-glass laminate
	Line #3	[none]	Multicontact MC4
<b>Maximum system voltage</b>	Insulation voltage	[V]	1500
<b>Absorption coefficient for T</b>	Absorption coefficient	[none]	0.90
<b>Commercial Data</b>			
	Manufacturer		First Solar
	Remarks		www.firstsolar.com
	Available on market from		2016

Table 1b. Parametric description of First Solar's FS-4110-3 and FS-4110A-3 PV module products.

Section	Parameter	Unit	FS-4112-3 / FS-4112A-3
<b>Basic Data</b>			
	Model	[none]	FS-4112[A]-3 Feb 2016
	Manufacturer	[none]	First Solar
	File name	[none]	FS-4112[A]-3 CdTe Feb2016.PAN
	Data source	[none]	Manufacturer February 2016
	Nominal Power	[W]	112.5*
	Tolerance	[%]	-0.0%, +4.4%
	Technology		CdTe
<b>Manufacturer's Specifications or Other Measurements</b>	$G_{REF}$	[W/m <sup>2</sup> ]	1000
	$T_{REF}$	[°C]	25
	$I_{SC}$	[A]	1.830
	$V_{OC}$	[V]	87.00
	$I_{MPP}$	[A]	1.640
	$V_{MPP}$	[V]	68.55
	$\mu I_{SC}$	[mA/°C] [%/°C]	0.7 0.040
<b>Model Parameters</b>			
<b>Rshunt - Rserie</b>	$R_{SH}$	[Ω]	3500
	$R_S$	[Ω]	4.355
<b>Rshunt exponential</b>	$R_{SH}$ at $G_{INC}=0$	[Ω]	12000
	Exponential parameter	[none]	6.0
<b>Recombination Loss</b>	$di^2/(\mu\tau)$	V <sup>-1</sup>	0.95
<b>Temperature Coefficient</b>	Apply the correction	[none]	checked
	Coefficient value	[%/°C]	-0.28
<b>Sizes and Technology</b>			
<b>Module</b>	Length	[mm]	1200
	Width	[mm]	600
	Thickness	[mm]	6.8
	Weight	[kg]	12.0
<b>Cells</b>	In series	[none]	108
	In parallel	[none]	2
	Cell area	[cm <sup>2</sup> ]	31.3
<b>Reverse characteristics</b>	Quadratic factor $B_{REV}$	[mA/V <sup>2</sup> ]	3.2
	Number of bypass diodes	[none]	0
	Diode reverse voltage	[V]	-0.7
<b>Module technology</b>	Line #1	[none]	Frameless module
	Line #2	[none]	Glass-polyolefin-glass laminate
	Line #3	[none]	Multicontact MC4
<b>Maximum system voltage</b>	Insulation voltage	[V]	1500
<b>Absorption coefficient for T</b>	Absorption coefficient	[none]	0.90
<b>Commercial Data</b>			
	Manufacturer		First Solar
	Remarks		www.firstsolar.com
	Available on market		2016

Table 1c. Parametric description of First Solar's FS-4112-3 and FS-4112A-3 PV module products.

Section	Parameter	Unit	FS-4115-3 / FS-4115A-3
<b>Basic Data</b>			
	Model	[none]	FS-4115[A]-3 Feb 2016
	Manufacturer	[none]	First Solar
	File name	[none]	FS-4115[A]-3 CdTe Feb2016.PAN
	Data source	[none]	Manufacturer February 2016
	Nominal Power	[W]	115.0
	Tolerance	[%]	-0.0%, +4.3%
	Technology		CdTe
<b>Manufacturer's Specifications or Other Measurements</b>	$G_{REF}$	[W/m <sup>2</sup> ]	1000
	$T_{REF}$	[°C]	25
	$I_{SC}$	[A]	1.830
	$V_{OC}$	[V]	87.60
	$I_{MPP}$	[A]	1.660
	$V_{MPP}$	[V]	69.30
	$\mu I_{SC}$	[mA/°C] [%/°C]	0.7 0.040
<b>Model Parameters</b>			
<b>Rshunt - Rserie</b>	$R_{SH}$	[Ω]	3500
	$R_S$	[Ω]	4.004
<b>Rshunt exponential</b>	$R_{SH}$ at $G_{INC}=0$	[Ω]	12000
	Exponential parameter	[none]	6.0
<b>Recombination Loss</b>	$di^2/(\mu \cdot \tau)$	V <sup>-1</sup>	0.95
<b>Temperature Coefficient</b>	Apply the correction	[none]	checked
	Coefficient value	[%/°C]	-0.28
<b>Sizes and Technology</b>			
<b>Module</b>	Length	[mm]	1200
	Width	[mm]	600
	Thickness	[mm]	6.8
	Weight	[kg]	12.0
<b>Cells</b>	In series	[none]	108
	In parallel	[none]	2
	Cell area	[cm <sup>2</sup> ]	31.3
<b>Reverse characteristics</b>	Quadratic factor $B_{REV}$	[mA/V <sup>2</sup> ]	3.2
	Number of bypass	[none]	0
	Diode reverse voltage	[V]	-0.7
<b>Module technology</b>	Line #1	[none]	Frameless module
	Line #2	[none]	Glass-polyolefin-glass laminate
	Line #3	[none]	Multicontact MC4
<b>Maximum system voltage</b>	Insulation voltage	[V]	1500
<b>Absorption coefficient for T</b>	Absorption coefficient	[none]	0.90
<b>Commercial Data</b>			
	Manufacturer		First Solar
	Remarks		www.firstsolar.com
	Available on market		2016

Table 1d. Parametric description of First Solar's FS-4115-3 and FS-4115A-3 PV module products.

Section	Parameter	Unit	FS-4117-3 / FS-4117A-3
<b>Basic Data</b>			
	Model	[none]	FS-4117[A]-3 Feb 2016
	Manufacturer	[none]	First Solar
	File name	[none]	FS-4117[A]-3 CdTe Feb2016.PAN
	Data source	[none]	Manufacturer February 2016
	Nominal Power	[W]	117.5*
	Tolerance	[%]	-0.0%, +4.3%
	Technology		CdTe
<b>Manufacturer's Specifications or Other Measurements</b>	$G_{REF}$	[W/m <sup>2</sup> ]	1000
	$T_{REF}$	[°C]	25
	$I_{SC}$	[A]	1.830
	$V_{OC}$	[V]	88.10
	$I_{MPP}$	[A]	1.679
	$V_{MPP}$	[V]	69.95
	$\mu I_{SC}$	[mA/°C]	0.7
[%/°C]		0.040	
<b>Model Parameters</b>			
<b>Rshunt - Rserie</b>	$R_{SH}$	[Ω]	3500
	$R_S$	[Ω]	3.801
<b>Rshunt exponential</b>	$R_{SH}$ at $G_{INC}=0$	[Ω]	12000
	Exponential parameter	[none]	7.0
<b>Recombination Loss</b>	$di^2/(\mu*\tau)$	V <sup>-1</sup>	0.95
<b>Temperature Coefficient</b>	Apply the correction	[none]	checked
	Coefficient value	[%/°C]	-0.28
<b>Sizes and Technology</b>			
<b>Module</b>	Length	[mm]	1200
	Width	[mm]	600
	Thickness	[mm]	6.8
	Weight	[kg]	12.0
<b>Cells</b>	In series	[none]	108
	In parallel	[none]	2
	Cell area	[cm <sup>2</sup> ]	31.3
<b>Reverse characteristics</b>	Quadratic factor $B_{REV}$	[mA/V <sup>2</sup> ]	3.2
	Number of bypass	[none]	0
	Diode reverse voltage	[V]	-0.7
<b>Module technology</b>	Line #1	[none]	Frameless module
	Line #2	[none]	Glass-polyolefin-glass laminate
	Line #3	[none]	Multicontact MC4
<b>Maximum system voltage</b>	Insulation voltage	[V]	1500
<b>Absorption coefficient for T</b>	Absorption coefficient	[none]	0.90
<b>Commercial Data</b>			
	Manufacturer		First Solar
	Remarks		www.firstsolar.com
	Available on market		2016

Table 1e. Parametric description of First Solar's FS-4117-3 and FS-4117A-3 PV module products.

Section	Parameter	Unit	FS-4120-3 / FS-4120A-3
<b>Basic Data</b>			
	Model	[none]	FS-4120[A]-3 Feb 2016
	Manufacturer	[none]	First Solar
	File name	[none]	FS-4120[A]-3 CdTe Feb2016.PAN
	Data source	[none]	Manufacturer February 2016
	Nominal Power	[W]	120.0
	Tolerance	[%]	-0.0, +4.2%
	Technology		CdTe
<b>Manufacturer's Specifications or Other Measurements</b>	$G_{REF}$	[W/m <sup>2</sup> ]	1000
	$T_{REF}$	[°C]	25
	$I_{SC}$	[A]	1.840
	$V_{OC}$	[V]	88.70
	$I_{MPP}$	[A]	1.695
	$V_{MPP}$	[V]	70.70
	$\mu I_{SC}$	[mA/°C]	0.7
[%/°C]		0.040	
<b>Model Parameters</b>			
<b>Rshunt - Rserie</b>	$R_{SH}$	[Ω]	3500
	$R_S$	[Ω]	3.708
<b>Rshunt exponential</b>	$R_{SH}$ at $G_{INC}=0$	[Ω]	12000
	Exponential parameter	[none]	8.0
<b>Recombination Loss</b>	$di^2/(\mu \cdot \tau)$	V <sup>-1</sup>	0.95
<b>Temperature Coefficient</b>	Apply the correction	[none]	checked
	Coefficient value	[%/°C]	-0.28
<b>Sizes and Technology</b>			
<b>Module</b>	Length	[mm]	1200
	Width	[mm]	600
	Thickness	[mm]	6.8
	Weight	[kg]	12.0
<b>Cells</b>	In series	[none]	108
	In parallel	[none]	2
	Cell area	[cm <sup>2</sup> ]	31.3
<b>Reverse characteristics</b>	Quadratic factor $B_{REV}$	[mA/V <sup>2</sup> ]	3.2
	Number of bypass	[none]	0
	Diode reverse voltage	[V]	-0.7
<b>Module technology</b>	Line #1	[none]	Frameless module
	Line #2	[none]	Glass-polyolefin-glass laminate
	Line #3	[none]	Multicontact MC4
<b>Maximum system voltage</b>	Insulation voltage	[V]	1500
<b>Absorption coefficient for T</b>	Absorption coefficient	[none]	0.90
<b>Commercial Data</b>			
	Manufacturer		First Solar
	Remarks		www.firstsolar.com
	Available on market		2016

Table 1f. Parametric description of First Solar's FS-4120-3 and FS-4120A-3 PV module products.



Section	Parameter	Unit	FS-4122-3 / FS-4122A-3
<b>Basic Data</b>			
	Model	[none]	FS-4122[A]-3 Nov 2016
	Manufacturer	[none]	First Solar
	File name	[none]	FS-4122[A]-3 CdTe Nov2016.PAN
	Data source	[none]	Manufacturer November 2016
	Nominal Power	[W]	122.5*
	Tolerance	[%]	-0.0, +4.1%
	Technology		CdTe
<b>Manufacturer's Specifications or Other Measurements</b>	$G_{REF}$	[W/m <sup>2</sup> ]	1000
	$T_{REF}$	[°C]	25
	$I_{SC}$	[A]	1.850
	$V_{OC}$	[V]	88.70
	$I_{MPP}$	[A]	1.710
	$V_{MPP}$	[V]	71.50
	$\mu I_{SC}$	[mA/°C]	0.7
[%/°C]		0.040	
<b>Model Parameters</b>			
<b>Rshunt - Rserie</b>	$R_{SH}$	[Ω]	3900
	$R_S$	[Ω]	3.526
<b>Rshunt exponential</b>	$R_{SH}$ at $G_{INC}=0$	[Ω]	12000
	Exponential parameter	[none]	9.0
<b>Recombination Loss</b>	$di^2/(\mu*\tau)$	$V^{-1}$	0.95
<b>Temperature Coefficient</b>	Apply the correction	[none]	checked
	Coefficient value	[%/°C]	-0.28
<b>Sizes and Technology</b>			
<b>Module</b>	Length	[mm]	1200
	Width	[mm]	600
	Thickness	[mm]	6.8
	Weight	[kg]	12.0
<b>Cells</b>	In series	[none]	108
	In parallel	[none]	2
	Cell area	[cm <sup>2</sup> ]	31.3
<b>Reverse characteristics</b>	Quadratic factor $B_{REV}$	[mA/V <sup>2</sup> ]	3.2
	Number of bypass diodes	[none]	0
	Diode reverse voltage	[V]	-0.7
<b>Module technology</b>	Line #1	[none]	Frameless module
	Line #2	[none]	Glass-polyolefin-glass laminate
	Line #3	[none]	Multicontact MC4 connectors
<b>Maximum system voltage</b>	Insulation voltage	[V]	1500
<b>Absorption coefficient for T</b>	Absorption coefficient	[none]	0.90
<b>Commercial Data</b>			
	Manufacturer		First Solar
	Remarks		www.firstsolar.com
	Available on market		2016

Table 1g. Parametric description of First Solar's FS-4122-3 and FS-4122A-3 PV module products.

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**\*NOTE:**

**Notice for models having nominal power rating >100W with fractional portion.**

Prior to V6.xx, PVSYST truncates nominal power at STC to to an integer value when  $P_{MAX} > 100W$ . ***This truncation affects the nominal array power, specific energy yield and performance ratio reported by PVsyst.*** Separate calculations using the total energy yield reported by PVsyst and the correct value for nominal array power will ensure accurate results for specific energy yield and performance ratio.

This limitation has been eliminated in PVSYST versions V6.xx and later.