
PV Module Power Rating: Tolerance

Alex Mikonowicz, PowerMark
Mani G. TamizhMani, Arizona State University
Gobind Atmaram, Florida Solar Energy Center

Solar ABCs
PV Stakeholder Meeting

October 15, 2010



PAST

Allowed nameplate tolerance in the Past

Measured power = Nameplate rated power **+/- 10%**

Past practice by manufacturers (example)

Nameplate rated power: 100W

Measured power: > 90W ~ < 110W

Reason for the past allowed tolerance

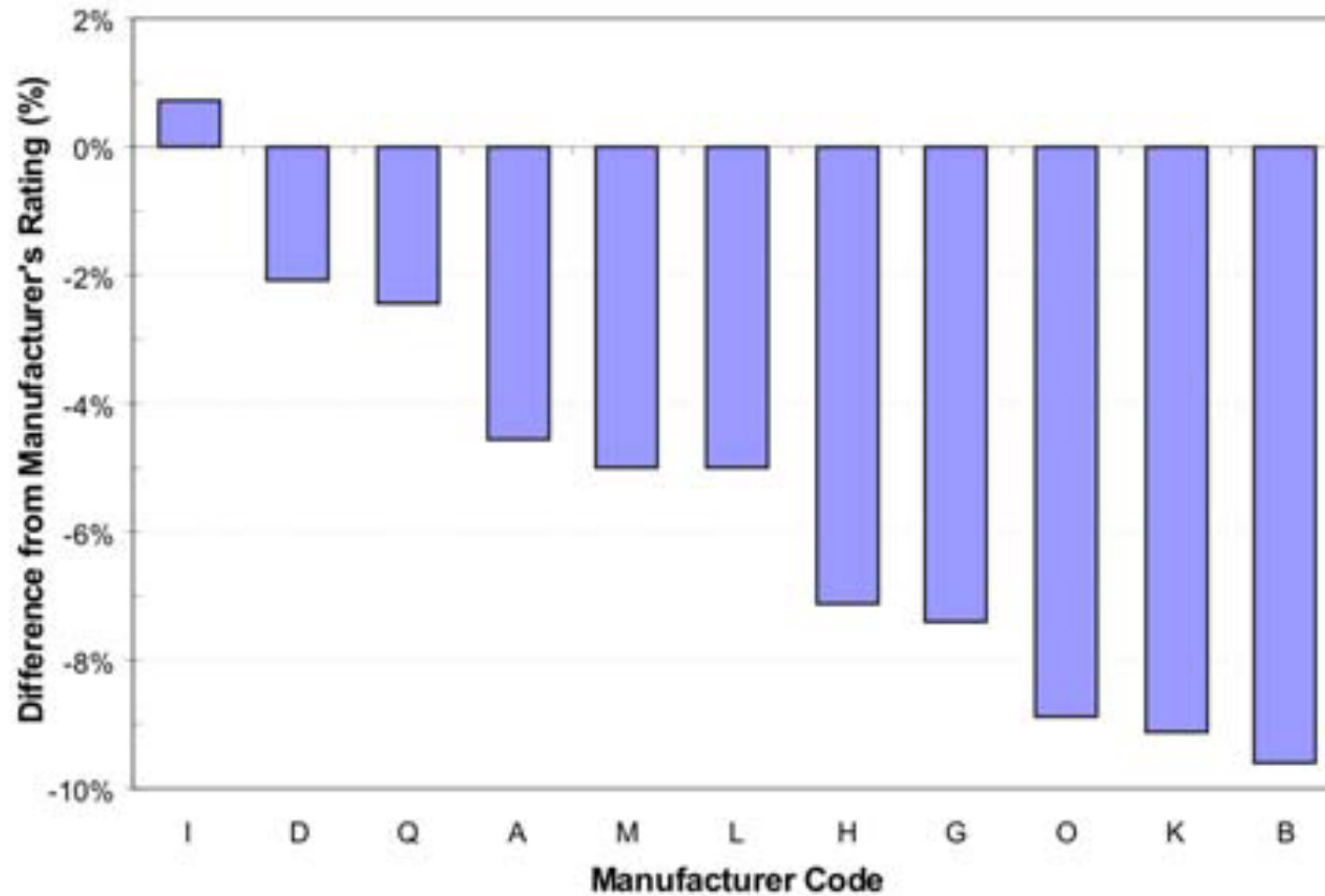
- Measurement uncertainty was high in the past!
- Reproducibility error between test labs was high in the past!

Past market issue

- Measured power: Tended to be towards 90W but priced at 100 W
(see FSEC's data next page)



Past market issue



Comparison of PV Module Measured Peak Power at STC with the Module Nameplate Ratings (Source: FSEC Data 2002-2006)



Solar ABCs' *Previous Policy* (November 2008)

“The permissible deviation from module nameplate output for current, power, and voltage for modules installed in the U.S. shall be **±5%**. A more detailed *Solar ABCs* policy shall be developed to address related issues such as stabilization, measurement uncertainty, warranties and other issues.”



PRESENT

Current Measurement Tolerance

- Measurement uncertainty is now smaller (for example, **+/- 3%** for c-Si)
- Reproducibility error between test labs is now smaller (for example, **+/- 3%** for c-Si; see NREL's and Shell Solar's round robin data)
- Nameplate tolerance is, typically, low (**+/- 3%** for c-Si) (see manufacturers' nameplate tolerance data)



Reproducibility Error

NREL Round Robin Testing – 2006 (WCPEC4-2006)

	<u><Pmax>, W</u>	<u>NREL</u> pre	<u>SNL</u>	<u>ASU</u>	<u>FSEC</u>	<u>ESTI</u>	<u>LEEE</u>	<u>TUV</u>	<u>ISE</u>	<u>JET</u>	<u>NREL</u> post
Mono-Si											
SIE0577	66.84	-2.9	3.2	1.6	-4.2	0.4	-0.2	-0.2	0.8	1.3	-2.6
SIE0586	67.22	-3.2	2.9	1.3	-4.2	0.4	0.6	-0.6	0.7	1.7	-2.8
Thin Film Si											
AsP0123	51.54	-3.5	1.7	0.7		0.9	-1.4	0.3	0.8	-0.6	-2.4
AsP0247	52.87	-3.1	1.8	0.6		1.4	-1.5	0.1	0.6	-0.9	-2.1
a-Si/a-Si:Ge											
BPS4213	41.04	4.8	-0.3	2.3		-7.2*		3.3			1.8
BPS4223	36.82	3.7	1.8	3.7		-3.3*		-3.9			1.6
a-Si/a-Si/a-Si											
USSC234	19.24	3.2	-0.6	-0.2		-7.8*		9.1			-0.5
USSC382	19.41	2.7	-0.5	-0.6		-7.2*		8.7			-0.5
CdTe											
BP4405	84.13	0.1	-0.7	4.7		-2.9		-1.0			-0.1
BP4505	87.96	-1.3	-0.5	4.1		-3.4		-1.0			0.7
CIS											
Sie9257	40.54	-3.3	5.0	3.1		-3.1		-1.3			-3.7
Sie9260	40.10	-3.5	7.6	4.2		-4.7		-3.0			-4.1
Concentrator											
PTEL#1	3.015	3.3	0.8			-3.8					3.0
PTEL#2	2.913	-0.3	3.0			-7.3					4.3

* No spectral mismatch correction applied.



Shell Solar Round Robin Testing - 2003

Tester	Pmax(W)	I _{max} (A)	V _{max} (V)	I _{sc} (A)	V _{oc} (V)	% FF	Pmax-Delta(%)
Ref.Lab Grand Average	48.6	2.88	16.9	3.14	21.3	72.8	
NREL-(LACSS, NOV '02)	47.5	2.82	16.8	3.07	21.2	72.9	-2.4%
NREL-OUTDOORS (NOV '02)	48.7	2.96	16.7	3.18	21.2	72.2	0.2%
NREL-(SPIRE240A, NOV '02)	48.5	2.80	17.3	3.11	21.4	73.0	-0.3%
TUV, (FEB'03)	48.3	2.91	16.6	3.14	21.2	72.7	-0.8%
ESTI (MARCH '03)	49.2	2.93	16.8	3.17	21.4	72.8	1.1%
RS/T-MD, (APRIL '03)	49.3	2.86	17.2	3.14	21.7	72.4	1.4%
SSI-USA(LAPSS, DEC '02)	49.3	2.90	17.0	3.15	21.4	73.1	1.3%
SSI-USA(LAPSS, APR '03)	49.1	2.91	17.0	3.16	21.49	72.9	1.0%



Nameplate tolerance of various major manufacturers (Feb 2010)

Manufacturer # 1

- Nameplate tolerance = $\pm 3\%$

Manufacturer # 2

- Nameplate tolerance = $\pm 3\%$

Manufacturer # 3

- Nameplate tolerance = $\pm 3\%$

Manufacturer # 4

- Nameplate tolerance = -5% and $+10\%$

Manufacturer # 5

- Nameplate tolerance = -0% and $+5\%$



Options for Module Power Rating Tolerance

1) EN 50380 / IEC 61853-1 (draft):

$$(P_{\text{measured}} + \underline{m}) > (P_{\text{rated}} - \underline{t})$$

Assumes that the buyer is aware of implication of negative tolerance!

(Not true for homeowners, who pay for P_{rated} , not $P_{\text{rated}} - \underline{t}$)

2) California Energy Commission:

$$P_{\text{measured}} > (P_{\text{rated}} - 5\%)$$

Assumes less than 5% measurement uncertainty!

(Not true for thin-film technologies, which have uncertainty more than 5%)

3) EN / IEC - Modified:

$$P_{\text{measured}} + \underline{m} > P_{\text{rated}}$$

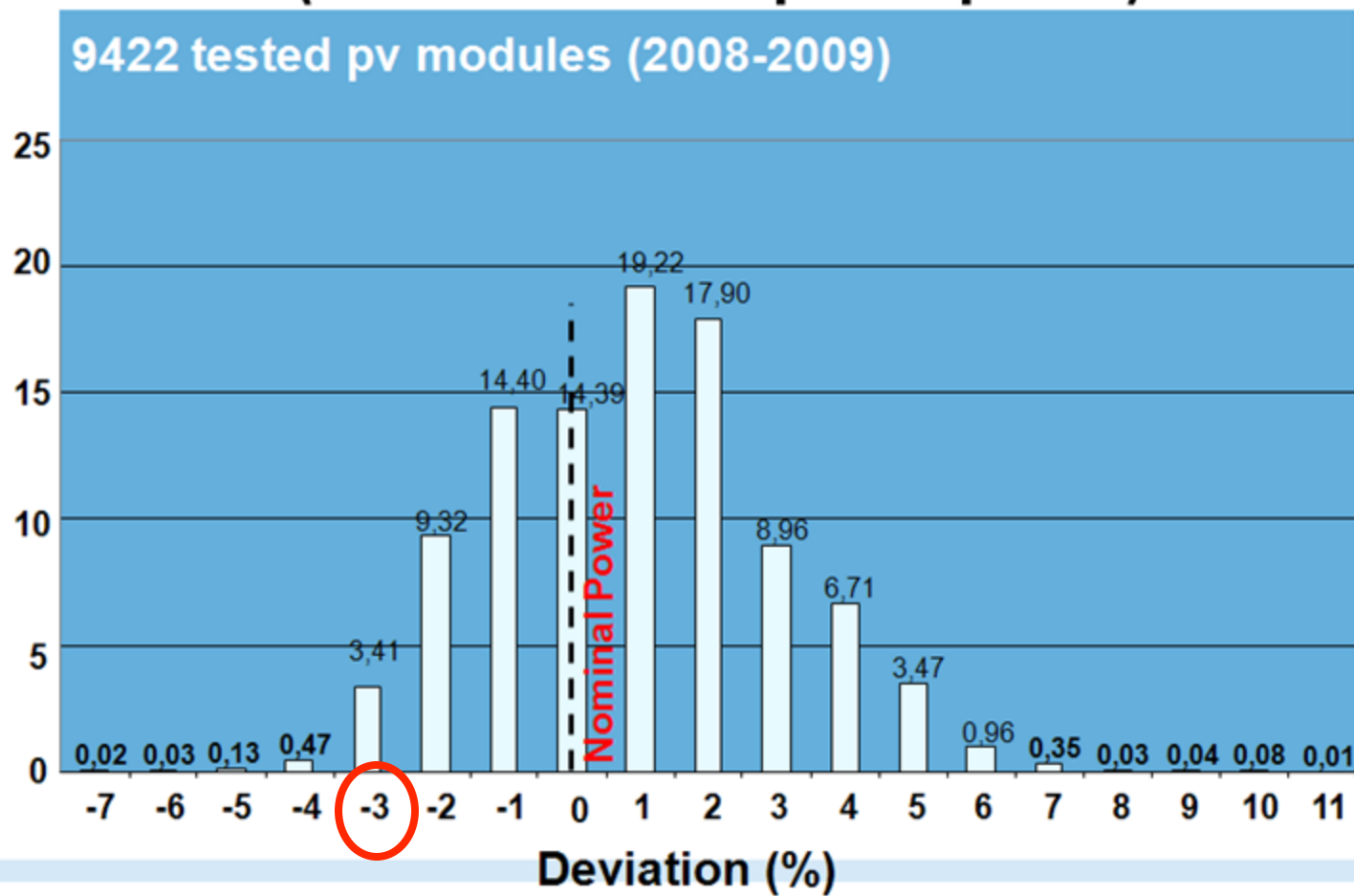
Reasonable approach & practically achievable! (see the next slide)

\underline{m} = Measurement tolerance

\underline{t} = Production tolerance



Deviation of different module types (modules for PV- power plants)



3) EN / IEC Modified:

$$P_{\text{measured}} + \underline{m} > P_{\text{rated}}$$

**Practically Possible Because
Typical Lab Uncertainty is +/- 3.4%**



Recommendation:

We recommend the following for a Solar ABCs' module power rating tolerance policy.

3) EN / IEC - Modified:

$$P_{\text{measured}} + \underline{m} > P_{\text{rated}}$$



Information Slides



Scope and Limitations of the Proposed Power Rating Policy:

- Power rating policy is a living document and its scope is dictated by the market requirements and the availability of existing standards.
- In this presentation, the power rating requirements of two major markets (California and Europe) and the availability of existing and upcoming standards (EN 50380, CEC's Equipment Eligibility & IEC 61853-1) are considered.
- Both EN and CEC call for the power ratings at only three test conditions: STC (standard test conditions), NOCT (nominal operating cell temperature) and Low Irradiance (200 W/m² at 25°C).
- The power rating policy of Solar ABCs intends to include requirements of new power rating standard of IEC (IEC 61853-1 draft). This new IEC standard covers almost all the field conditions in the US and world (see the slides to follow).



IEC 61853-1:
PHOTOVOLTAIC (PV) MODULE PERFORMANCE TESTING AND ENERGY RATING –
Part 1: Irradiance and temperature performance measurements and power rating

P_{max}, I_{sc}, V_{oc}, and V_{max} versus Irradiance and Temperature

Irradiance (W/m ²)	Spectrum	Module Temperature			
		15°C	25°C	50°C	75°C
1100	AM1.5	NA			
1000	AM1.5				
800	AM1.5				
600	AM1.5				
400	AM1.5				NA
200	AM1.5				NA
100	AM1.5			NA	NA

EN 50380 / IEC 61853-1:

Datasheet and nameplate information for photovoltaic modules

- No specific production tolerance is imposed (for example, +/- 5%) by the EN and IEC standards but manufacturer shall provide production tolerance to comply with the following:

$$(P_{\text{measured}} + \underline{m}) > (P_{\text{rated}} - \underline{t})$$

- These standards take the measurement tolerance into account
- These standards take the light stabilization into account
- Most importantly, EN / IEC approach is applicable to all the technologies as it uses “ $P_{\text{measured}} + \underline{m}$ ” rather than “ P_{measured} ” as in CEC (measurement tolerance for c-Si is less than 4% whereas it is as high as 8% for thin-film and CPV technologies – see NREL’s round robin test data – WCPEC4-2006)



EXAMPLE EN 50380:

A PV module is rated with a nominal power of " P_{\max} " of 50 watts at STC (with consideration of pre-ageing at start of operation) and production tolerances " $\pm t$ " of $\pm 10\%$. This module is measured in an external test laboratory with measurement tolerances " $\pm m$ " of $\pm 4\%$.

In the unfavourable case (lower tolerance limit), the photovoltaic module from production has an electrical power " P " of

$$P = P_{\max} \left(1 - \frac{t[\%]}{100} \right)$$

P_{\max} = Nominal rated power = 50 W

Production tolerance = -10%

P = Minimum rated power = $50 \times 0.9 = 45$ W

(1)

In this example, $P = 45$ watts.

In the unfavourable case (lower measurement tolerance), the external test laboratory measures the electrical power " $P_{\text{measurement}}$ " of

$$P_{\text{measurement}} = P \cdot \left(1 - \frac{m[\%]}{100} \right)$$

Measurement tolerance = -4%

$P_{\text{measurement}} = 45 \times 0.96 = 43.2$ W

(2)

In this example, $P_{\text{measurement}} = 43,2$ watts.

**If the measured power is higher than 43.2 W,
the datasheet complies with the requirements
of EN 50380**

This means in this example that a photovoltaic module, measured with 43,2 watts, agrees with the statement "Nominal power of 50 watts with production tolerances of $\pm 10\%$ ".



CEC Module Eligibility Requirement:

- “The lower bound of the manufacturer’s stated tolerance must be no less than 95% of the maximum power reported to the Energy Commission.” Thus, the requirement is:

$$P_{\text{measured}} > (P_{\text{rated}} - 5\%)$$

- This requirement does not take the measurement tolerance into account
- This standard takes light stabilization into account (IEC 61215/61646 light stabilization methods used)
- Most importantly, CEC approach is NOT applicable to all the technologies as it uses “measured” rather than “measured maximum” as in EN (measurement tolerance for c-Si is less than 4% whereas it is as high as 8% for thin-film and CPV technologies – see NREL round robin test data – WCPEC4-2006)

