Solar ABCs Policy Recommendation:

Module Power Rating Requirements

POLICY STATEMENT

Objective:
Develop a Solar ABCs Power Rating policy statement, establishing requirements for the procurement of PV modules for consumers, states and organizations providing incentives for photovoltaic systems in the United States.

Goals:
The goals of this policy statement are to:

1. Increase customer awareness of the potential for discrepancy between the nameplate rating and performance of delivered PV modules. Define a reasonable expectation for the consistency of these numbers;

2. Increase customer awareness of the power ratings that are made available to them as a result of the IEC 61853-1 standard. Empower customers to better compare the performance of modules under a range of conditions;

3. Improve the bankability and reduce the risk of investments in PV systems by tightening the tolerance on module ratings.

Audience for policy:
Stakeholders involved in manufacturing, purchasing, financing, or providing incentives for PV modules and systems.

Scope and limitation of policy:
Solar ABCs will continue to recommend policies that address consumer and industry concerns related to the use of various performance, reliability / qualification and safety standards. The Power Rating Policy is a living document and its scope is influenced by the market requirements and the availability of existing standards. This recommended policy is written in conformity with the performance conditions in IEC 61853-1 standard titled "*Photovoltaic (PV) module performance testing and energy rating – Part 1: Irradiance and temperature performance measurements and power rating.*"

Motivation for policy:
Without requiring a power rating tolerance policy, photovoltaic modules will continue to enter the domestic marketplace that may have a significantly lower power output than the module's rating indicates. This results in reduced performance of installed PV systems that will not meet consumers' expectations. If over-rating of modules continues to be an acceptable practice, the overall acceptance by the general population will be diminished and the overall movement towards solar energy jeopardized. In addition, without power rating data at various low/high irradiance and temperature conditions, the energy collection predictions for installed PV modules and systems will not be accurate.

Solar ABCs Policy Recommendation:

"It is recommended that photovoltaic modules types sold or installed in the United States be independently measured and certified to the following power rating tolerance: after accounting for the light induced degradation[1] as per IEC 61215 (crystalline silicon) or IEC 61646 (thin film), the measured average[2] power shall be equal to or higher than the nominal nameplate power rating at STC (standard test conditions) and no individual module power shall be more than 3% below nominal. In addition, the modules shall be rated at minimum four other reference conditions as per IEC 61853-1 standard: 200 W/m^2 & 25^{o}C cell temperature; 500 W/m^2 & 15^{o}C cell temperature; 1000 W/m^2 & 75^{o}C cell temperature; 800 W/m^2 & 20^{o}C ambient temperature."

Notes:

1) Values shall be measured after preconditioning according to IEC Standard 61215, Section 5, or after light-soaking according to IEC Standard 61646, Section 10.19.
2) The required number of samples (n) for the average is dictated by the standard deviation (σ) of the measured values. A baseline value for σ is calculated from a minimum number of 30 samples. Then this baseline value of σ is used to determine the required number of samples (n) to meet the Policy recommendation. The required number of samples "n" shall be determined using the following method:
   - Note down the nameplate rated power (P_0 in watts)
   - Measure the individual power of 30 modules
   - Calculate the standard deviation (σ in watts) of these 30 modules
   - Determine the sample size "n" using the following equation and table

$$n = (z_{\alpha/2} * \sigma/0.03P_0)^2$$

Confidence level	$z_{\alpha/2}$
90%	1.645
95%	1.96
99%	2.58
99.9%	3.3

If the "n" value is determined to be higher than 30, then the measured average power shall be based on "n" samples. If the "n' value is determined to be less than 30, then the measured average power shall be based on 30 samples. The "n" value shall be rounded upward. The details on the sample size determination are presented in the appendix.

The measurement uncertainty of each test sample at STC along with calibration traceability chain for the measuring equipment and calibrated modules shall be reported.

POLICY JUSTIFICATION

Past Issues:

Most consumers, system integrators and agencies providing incentives have relied on the module nameplate ratings to estimate the power and/or energy delivered by the installed PV systems. Unfortunately, those estimations often have not met their expectations. A possible outcome of this common trend of overstating module power ratings may be a loss of consumer and government confidence in the ability of PV modules and systems to perform as expected. It is important to recognize that the credibility of PV technology depends not only on the quality of the PV products, but also on industry practices. The nominal power ratings listed on the nameplates of PV modules were often found by independent test laboratories to be much higher than the actual measured power. As shown in Figure 1, the module testing by the Florida Solar Energy Center (FSEC) had indicated that the measured peak power of PV modules in the United States marketplace was typically less than the nameplate value [1]. In some cases, the measured power of the modules sourced from the open market was found to be nearly ten percent below the nameplate rating. Similar data was reported by BEW Engineering on installed PV arrays, as illustrated in Figure 2 [2].

There was one major reason often attributed to this overrating issue of the past: "the +/-10% tolerance allowed by the UL 1703 standard." The ANSI/UL 1703 standard [3] states that "the short-circuit current (Isc), rated current (Ir) maximum power (Pmax), and open-circuit voltage(Voc) shall be within ± 10 percent of the rated value." To be clear, the ANSI/UL 1703 standard is a safety standard for PV modules and it specifies requirements for electrical and mechanical safety of the product, and it is not a performance or power rating standard. Therefore, the use of a safety standard to justify the overrating practice could not be justified. A major reason for accepting this wide tolerance in the beginning was the high measurement reproducibility error among the test labs. Probably, the biggest reason was the fact that most modules were used in standalone systems which almost never operated at peak power. The standalone systems were designed to provide power for the worst months of the year, not the best.

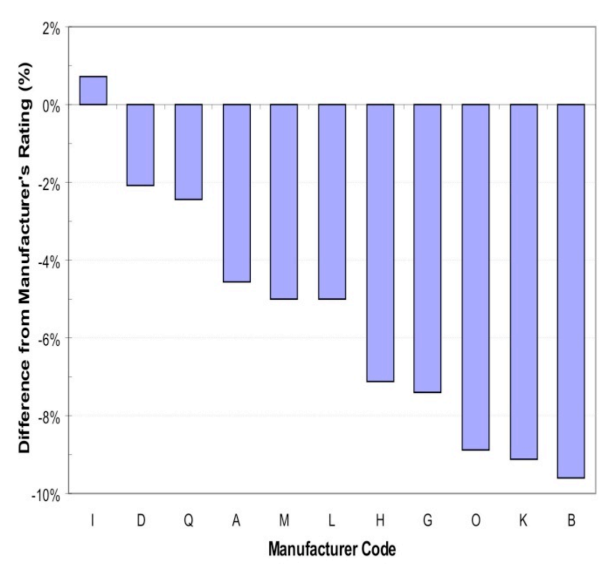

Figure 1: Comparison of measured power with nameplate ratings of modules sourced from open market (Source: FSEC [1])

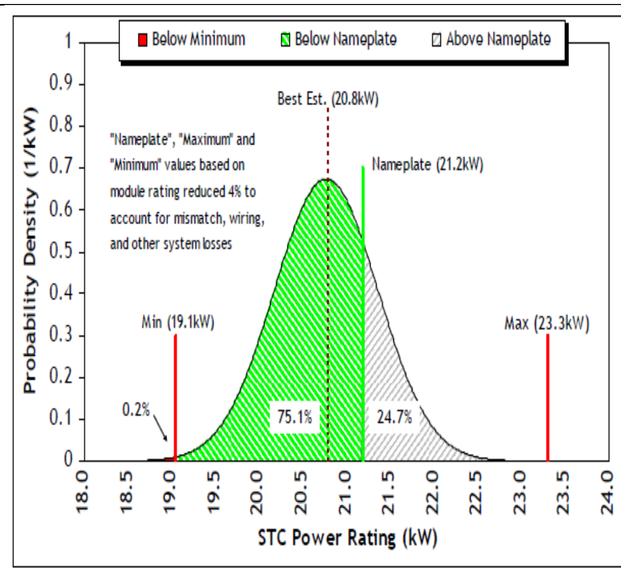

Figure 2: Comparison of the measured power with nameplate ratings of fielded modules (Source: BEW Engineering [2])

Present Evidence:

Tightening of the nameplate power rating tolerance should accommodate two inherent practical issues: (i) the measurement issue related to the reproducibility among test laboratories; and (ii) the binning/tolerance issue in the production lines. Three pieces of objective evidence are presented: one example to address the first issue and two examples to address the second issue.

Measurement Reproducibility: Every test laboratory has its own inherent uncertainty issues related to measuring the performance of PV modules. These are due to the uncertainties related to the measuring equipment (e.g. I-V curve tracer) and calibration (e.g. reference cell). The measurement uncertainties vary from one lab to the other but they are typically less than 4% for crystalline silicon technologies and as high as 6.5% for thin-film technologies. A major contributor to this module measurement uncertainty is the uncertainty related to reference cell calibration. These uncertainties in turn influence the reproducibility of the results between the test labs. Table 1 presented below indicates that the measurements between a large number of test laboratories can be typically reproduced within about 5% for all the module technologies [4]. This is a great progress made by the test/measurement laboratories to tighten the measurement uncertainties and improve the reproducibility.

Table 1: Pmax reproducibility between the test/measurement laboratories (% deviation from average)

Reproducibility Tolerance

NREL Round Robin Testing – 2006 (WCPEC4-2006)

	<Pmax>, W	NREL pre	SNL	ASU	FSEC	ESTI	LEEE	TUV	ISE	JET	NREL 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.

Production Tolerance: When the industry was producing at just a few MW of scale, a wide production tolerance of +/-10% was accepted by the consumers because of the measurement reproducibility issues and inherent variations in production lines, and due to the fact most modules went to standalone systems where it was not as apparent. Since the industry is approaching an amazing 10 GW scale for the grid-tied market by 2010, consumers, especially in Europe, have tightened their procurement specifications including the power rating tolerance requirement. Because of these increased consumer expectations, all the major manufacturers serving the European market, have tightened their nameplate specifications to meet the requirement of EN 50380 standard [5]. The EN standard requirement can be presented as:

$$(P_{measured} + m) \geq (P_{rated} - t)$$

Where:
m is the measurement uncertainty
t is the production tolerance

The EN standard allows benefit of doubt leniency on both sides of the equation: the production tolerance leniency on the right hand side of the equation and the measurement uncertainty leniency on the left side of the equation. Unfortunately, the measurement uncertainty varies from one lab to the other, and one technology to the other. Also, the EN standard does not impose any specific lower/upper limit for the production tolerance. Many manufacturers offer data sheets meeting the requirements of EN standard as shown below. The sampling of major manufactures data sheets from the Web during 2010 clearly indicates that the manufacturers have evolved and have better quality assurance practices (improved sorting and better measurement accuracy) to be able to tighten the production tolerances to +/- 3%.

Manufacturer # 1
- Production tolerance = +/- 3%
- The datasheet complies with the requirements of EN 50380 [5]

Manufacturer # 2
- Production tolerance = +/- 3%
- The datasheet complies with the requirements of EN 50380

Manufacturer # 3
- Production tolerance = +/- 3%
- No indication of the datasheet complying with the requirements of EN 50380

Manufacturer # 4
- Production tolerance = -5% and +10%
- No indication of the datasheet complying with the requirements of EN 50380

Manufacturer # 5
- Production tolerance = -0% and +5%
- No indication of the datasheet complying with the requirements of EN 50380 but it indirectly complies with EN 50380 as the negative tolerance is 0%

Figure 3 compares the nameplate ratings with the independently measured values of 9,422 modules sold for some power plant applications in Europe [6]. This figure clearly indicates that only less than 0.7% of these 9,422 modules have the measured values less than -3% of the nameplate rated values. Again, this confirms that the manufacturers now have a better quality assurance practices that allow them to maintain nearly 100% of the production modules above the -3% tolerance limit. Therefore, the Solar ABCs policy has been designed based on the following two equations:

$$\mathbf{P_{measured\text{-}average} \geq P_{rated}}$$

&

$$\mathbf{P_{measured\text{-}individual} \geq (P_{rated} - 3\%\ tolerance)}$$

Where $P_{measured\text{-}average}$ is the measured average power of "n" samples and $P_{measured\text{-}individual}$ is the measured power of individual samples.

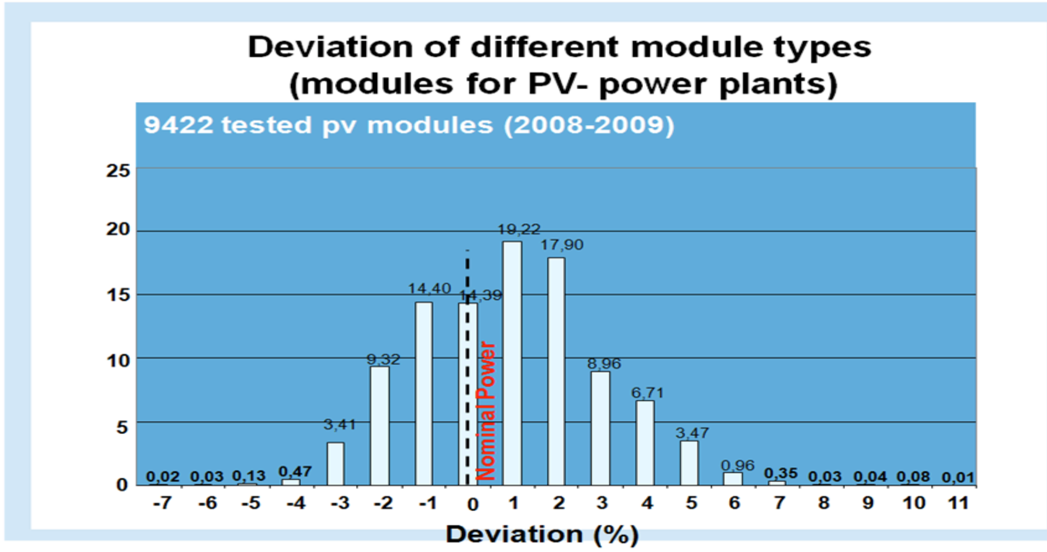

Figure 3: Comparison of the measured power with nameplate ratings of power plant modules (Source: TUV Rheinland [6])

REFERENCES

1. G. Atmaram, G. TamizhMani and G. Ventre: Need for Uniform Photovoltaic Module Performance Testing and Ratings, IEEE Photovoltaic Specialists Conference, San Diego, May 2008.

2. P. Lilly, M. Carpenter, W. Kitto, F. Soroushian, C. Whitaker and H. Zaininger: PIER Renewables Multi-Programmatic Workshop, Sacramento, March 2006.

3. ANSI/UL 1703: Flat-Plate Photovoltaic Modules and Panels, 2008, 2004 and prior versions.

4. S. Rummel, A. Anderberg, K. Emery, D. King, G. TamizhMani, T. Arends, G. Atmaram, L. Demetrius, W. Zaaiman, N. Cereghetti, W. Herrmann, W. Warta, F. Neuberger and K. Morita: Results from the Second International Module Intercomparison, World Conference on Photovoltaic Energy Converson, Hawaii, 2006.

5. EN 50380: Datasheet and nameplate information for photovoltaic modules, 2003.

6. W. Vaassen, Quality Assurance for PV Power Plants, TUV Rheinland, Cologne, August 2010.

7. J. Kuitche, Private communication, Arizona State University, January 2011.

Appendix

Sample size (n) determination [7]

Let's assume we want the measured average power of "n" samples (say, P_r) to be within +/-3% of the rated value (say, P_0). That is, if we draw a random sample (for example 30 modules) from a production line and compute the average or mean of 30 samples (say, P), then that value (average) shall fall between $0.97P_0$ and $1.03P_0$; with a certain degree of confidence.

We can set our sight on a 95% (2-sigma) or 99% (3-sigma) confidence level for example. So a 95% confidence interval can be computed as $P_r \pm 2\sigma_P$

Where

$\sigma_P = \sigma/\sqrt{n}$ = standard error of the mean

σ = standard deviation of the sample drawn (30 samples)

n = sample size

Thus, the half-width confidence interval is given by

$$w = 2 * \sigma/\sqrt{n}$$

More accurately, 95% confidence level <--> $z_{\alpha/2}$-sigma; so

$$w = z_{\alpha/2} * \sigma/\sqrt{n}$$

where $z_{\alpha/2}$ can be obtained from statistical tables for any confidence level.

The commonly used values of $z_{\alpha/2}$ are shown in the following table.

Confidence level	$z_{\alpha/2}$
90%	1.645
95%	1.96
99%	2.58
99.9%	3.3

If the target half-width is 3% P_0 as stated, then

$$3\%P_0 = z_{\alpha/2} * \sigma/\sqrt{n}$$

$$n = (z_{\alpha/2} * \sigma/0.03P_0)^2$$

Notes

The value of "σ" is estimated from a prior sample (of size 30 above).
The value of "n" obtained shall be rounded upward
P_r is the average of "n" samples after accounting for the light induced degradation.