

Bert Herteleer, Gabi Friesen, Flavio Valotti, Mauro Caccivio

SUPSI PVLab, University of Applied Sciences and Arts of Southern Switzerland, Mendrisio, Switzerland. Contact: bert.herteleer@supsi.ch

Motivation

Investors pay for PV modules which have been successfully qualified to IEC 61215, which specifies the requirements for measurement of power under Standard Testing Conditions (STC: 25°C module temperature, irradiance at 1000 W/m² with an AM1.5 spectrum). Since the 2016 edition, IEC 61215-1 discusses the importance of the production tolerance of the manufacturer, and the laboratory measurement uncertainty to see if a module's power is within specification, or not. The IEC 61215-1:2021 edition goes further: it specifies clearly the interpretation of datasheets and module labels, and reduces the potential for ambiguity. SUPSI's PVLAB is ISO17025 accredited for PV module measurements, achieving a P_{STC} uncertainty of ±1.1% (k=2) within the METRO-PV project. In this work, we show the importance of lower uncertainty to reduce PV financial risks for investors.

Understanding the standard over time: necessary for module warranties!

IEC edition	Equation	Interpretation
61215:2005 [1]	$P_{STC,lab} \geq P_{STC,NP} * 1 - t_1 $	Not specified in IEC 61215, instead in EN 50380
61215-1:2016 [2]	$P_{STC,lab} \geq P_{STC,NP} * \frac{1 - t_1 }{1 + u_{lab}}$	First introduction of gate No 1: P _{STC} as measured had to be greater than nameplate, including minimum P_{STC} production tolerance t₁ and laboratory uncertainty u_{lab}
61215-1:2021 [3]	$P_{STC,lab} \geq P_{STC,NP} * \frac{1 - t_1 }{1 + \frac{1.65}{2} * u_{lab}}$	Slightly tighter (~0.5%) threshold than 2016. Explicit examples to deal with ambiguities; skew against manufacturer: when in doubt, use smallest tolerance t₁ = 0.

u (k=2) [4]	Where	Requirements	Use
±1.1%	ISO17025 accredited lab	Needs spectral mismatch correction, calibrated sensor traceability to primary standards	Warranty claims, module acceptance, "golden module" calibration for manufacturers, P _{STC} verification
±2.5-3%	Standard lab	Calibrated sensors, traceable to ISO17025 references	Module lot acceptance, understanding behaviour and degradation, P _{STC} verification
±3.5-5%	Field with I-V tracer, string or module	High-quality calibrated sensors, stable weather conditions or mobile flasher	Understanding behaviour in the field, sometimes module lot acceptance (higher risk!)

Product Y series
Electrical Data at STC

	300	305	310
Peak power watts - P _{max} (W)	300	305	310
Power output tolerance (%)	-0 / +3	-0 / +3	-0 / +3
Maximum power voltage - V _{mp} (V)	37	37,2	37,5
Maximum power current (I _{mp}) (A)	8,1	8,2	8,27
Open circuit voltage - V _{oc} (V)	45,9	45,9	45,9
Short circuit current ^{a,b} - I _{sc} (A)	8,9	8,92	8,98
Module efficiency - η _m (%)	14	14,2	14,4

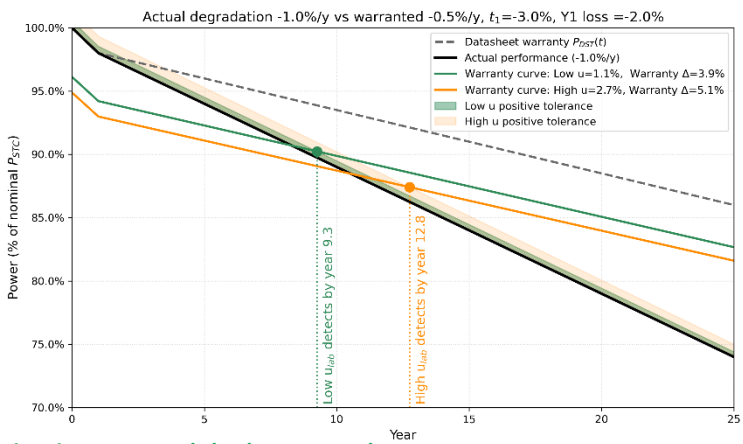
^a ±2 % measurement uncertainty
^b ±10 % tolerance on I_{sc} and V_{oc}

P_{max} (NP) = 300 W; t₁ = 0 %
V_{oc} (NP) = 45,9 V; t₂ = 2 %
I_{sc} (NP) = 8,9 A; t₃ = 2 %

t₂ is not reduced to a single value. Thus, the smaller value is chosen. The same situation exists for t₃.

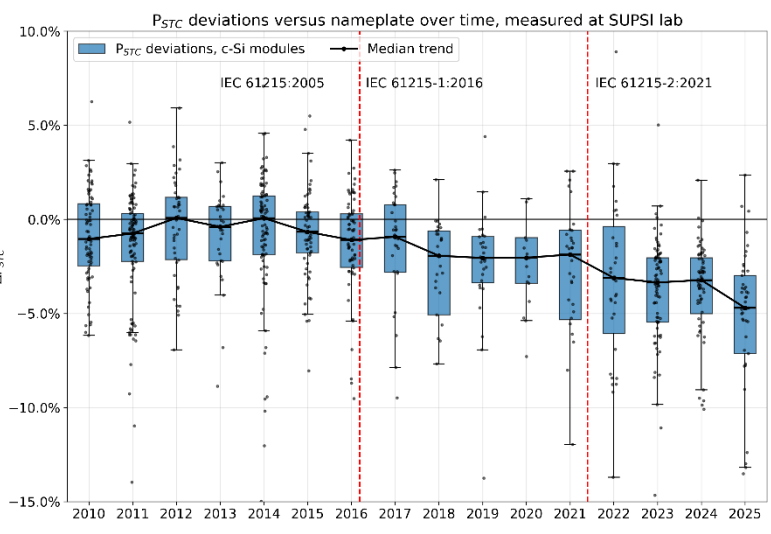
Example from IEC 61215-1:2021 [3]

Scenario 1: Actual degradation > warranted degradation



Time is money, and check warranty documents
In this example, a low uncertainty lab *definitively* detects degradation **3 years earlier** than the higher uncertainty measurement. In year 9, the module is *still* within specification (due to production tolerance and lab uncertainty). Payout is ΔP_{warranty} between *warranty curve* and *measured value*, at a point in time.
For u_{lab} = 1.1% in year 15: ΔP_{warranty} = 2.5% of P_{NP}
For u_{lab} = 2.7% in year 15: ΔP_{warranty} = 0.8% of P_{NP}
Time value of money: measuring earlier in life has much greater value (monetary payout is higher, and information to take action). A warranty payout is with **today's** module prices, **not the initial prices!** Check the manufacturer's tolerance: is it 0% (or 0 W), or -3%?

Scenario 2: Nameplate deviation at beginning of life



Trust, but verify
SUPSI PVLAB measurements since 2010 show a **decline in P_{STC}** for new modules, with **median deviations -3% to -4.5% in recent years**. This is a permanent yield and revenue loss over the full lifetime of the PV system. **Only when measuring before installation can the power warranty claim provide its best value.**

Payout = P_{NP}(W) * ΔP_{warranty}(%) * $\frac{CHF}{W}_{now}$ * $\frac{Years\ left}{Total\ years}$

Take-home messages

- **Check module warranty documents in detail:** production tolerances and lab uncertainties can make or break a power warranty claim.
- **Trust, but verify:** measuring P_{STC} *before acceptance and installation* in the field ensures you get what you paid for. Once modules are installed, the first-year power loss (-1% to -3%) is triggered.
- **Time is money:** Measure and act sooner rather than later. You lower financial risks and increase payouts when you test earlier in life.
- **Monitor system performance** with irradiance and temperature sensors, ideally meeting IEC 61724-1:2021 [5].

References: [1] IEC 61215:2005, Crystalline silicon terrestrial photovoltaic (PV) modules - Design qualification and type approval
[2] IEC 61215-1:2016, Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1: Test requirements, Geneva, Switzerland, 2016.
[3] IEC 61215-1:2021, Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1: Test requirements, Geneva, Switzerland, 2021.
[4] W. Herrmann, G. Eder, B. Farnung, G. Friesen, et al. Qualification of PV power plants using mobile test equipment, Report IEA-VPVS T13-24:2021, 2021.
[5] IEC 61724-1:2021: Photovoltaic system performance monitoring – Guidelines for measurement, data exchange and analysis, Geneva, Switzerland, 2021.

Acknowledgements: This project 19ENG01 Metro-PV has received funding from the EMPiR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme.