Bifacial silicon PV modules characterisation at the European Solar Test Installation

Juan Lopez-Garcia

European Commission, Joint Research Centre (JRC), Ispra, Italy

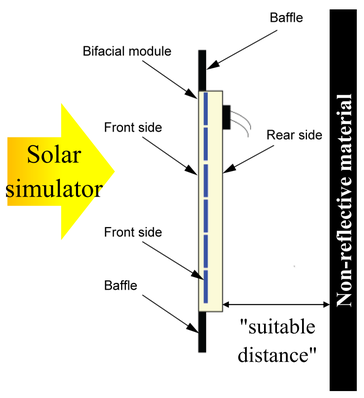
INTRODUCTION

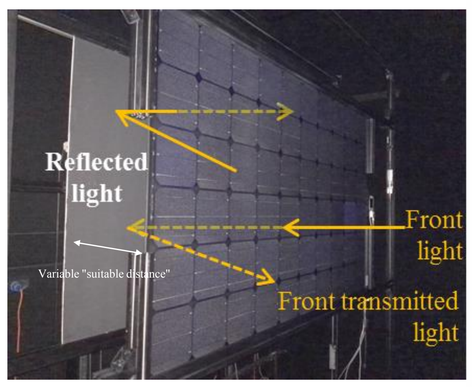
The European Solar Test Installation (ESTI) is a European reference laboratory for calibration of photovoltaic (PV) devices. Since its launch in the late 1970's, it also has been the forefront of the development of international standards for the assessment of electrical performance of PV products and their reliability. ESTI is located at the JRC Ispra site in Italy. The market share of bifacial crystalline Si PV modules has grown significantly over the last years, because they can produce additional output energy in comparison to conventional (monofacial) PV modules. ESTI is involved in the measurements of bifacial PV devices and the testing of the different approaches proposed in the recently published technical specification IEC TS 60904-1-2 for the measurement of current-voltage characteristics of bifacial photovoltaic devices.

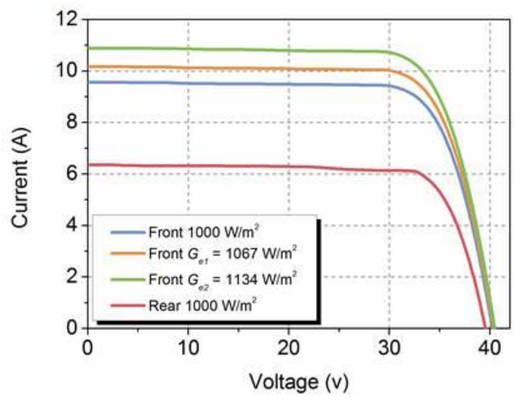
IEC TS 60904-1-2: I-V CHARACTERISTICS OF BIFACIAL PHOTOVOLTAIC (PV) DEVICES

SINGLE-SIDE ILLUMINATION: EQUIVALENT IRRADIANCE METHOD

- Bifaciality coefficients, at STC: $\varphi_{Pmax}\ (\%) = \mathrm{P_{max\ REAR}}/\mathrm{P_{max\ FRONT}}$; $\varphi_{Isc}\ (\%) = \mathrm{I_{sc\ REAR}}/\mathrm{I_{sc\ FRONT}}$
- Rear irradiance G_R and Equivalent irradiance level G_{Ei}: $G_{E_i} = 1000\,W/m^2 + \varphi \cdot G_{R_i}$
- $\varphi = Min(\varphi_{Isc}, \varphi_{Pmax})$
- Rear irradiance driven power gain yield, *BiFi*: linear fit's slope of the P_{max} versus G_R data series.
- Specific P_{max} for G_{R1}=100W/m², G_{R2}=200 W/m² ⇒ linear interpolation: $P_{max\ BiFi100} = P_{maxSTC} + BiFi \times 100$, $P_{max\ BiFi200} = P_{maxSTC} + BiFi \times 200$
- Non-irradiated background G_R < 3 W/m² at any point (black painted panel)
- Recommendation: Limit test area size ⇒ Baffles
- PASAN IIIB pulsed solar simulator with in-house multi-flash method (25.0±0.1 °C)







ESTI ISO/IEC 17025 accredited calibration laboratory:
accredited for single-side illumination I-V measurements of bifacial PV devices with a pulsed solar simulator

EUROPEAN COMMISSION — DIRECTORATE-GENERAL JOINT RESEARCH CENTRE — Dir. C – Energy, Transport and Climate — Energy Efficiency and Renewables Unit

ESTI — Op. Instruction — code: JRC.C.2.Q.ESTI | M64 — index: | a

I-V characteristic PASAN IIIb LAPSS LS-5 for Bifacial Photovoltaic Devices [PSP/PSM]

EUROPEAN COMMISSION — DG JRC - JOINT RESEARCH CENTRE — Dir. C - Energy Transport and Climate — Energy Efficiency and Renewables Unit — ESTI - European Solar Test Installation — Via Fermi 2749, TP450 — I-21027 Ispra (Va) Italy — e-mail: JRC-ESTI-SERVICES@ec.europa.eu

Centro di Taratura LAT N° 225 — Calibration Centre — Laboratorio Accreditato di Taratura

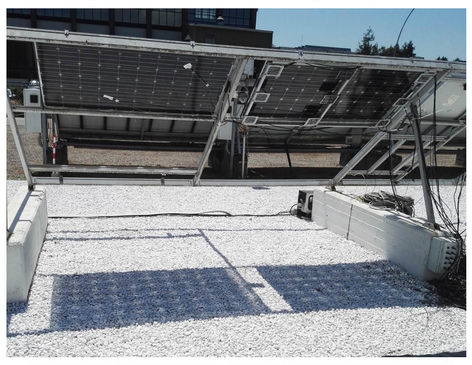
ACCREDIA — LAT N° 225 — Membro degli Accordi di Mutuo Riconoscimento EA, IAF e ILAC — Signatory of EA, IAF and ILAC Mutual Recognition Agreements — Pagina 1 di 5

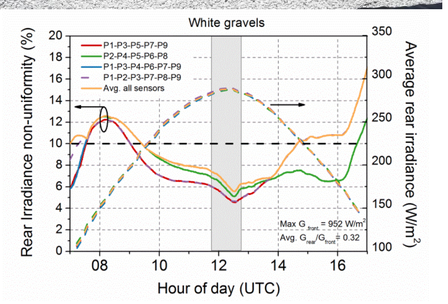
SERIS — Solar Energy Research Institute of Singapore

- Convenor TG82 WG 2 standards for modules, non-concentrating
- Participation as reference laboratory in the 1st International Round-Robin on Bifacial modules

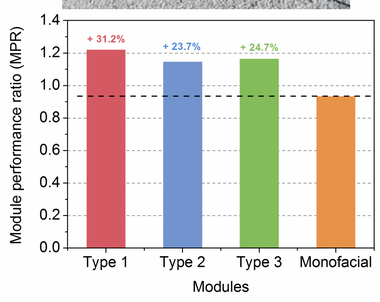
NATURAL SUNLIGHT: individual modules

- Natural sunlight rear irradiance driven power gain yield
- Bifacial Energy Yield and rating
- Vertical E-W oriented
- Rear irradiance measurements and modelling
- Log-term and soiling degradation study

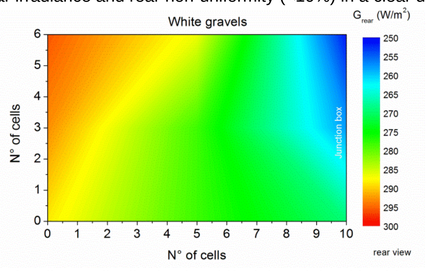




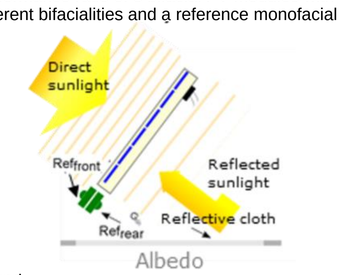
Rear irradiance and rear non-uniformity (<10%) in a clear day



Performance ratio of 3 bifacial PV modules with different bifacialities and a reference monofacial

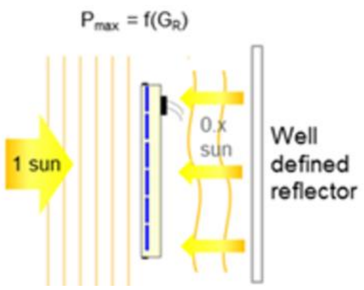


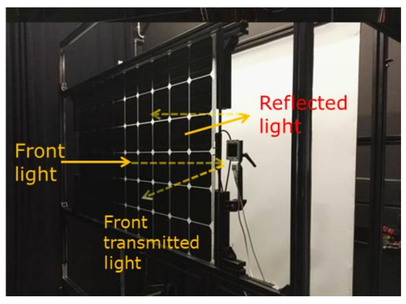
Rear irradiance distribution in a bifacial module with white gravels ground



DOUBLE-SIDE ILLUMINATION

Rear reflector





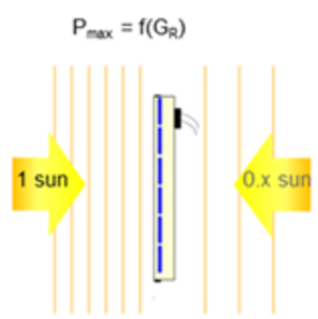
✗ Non-uniformity <5% ⇒ Improvement reflector
✓ Adjustable rear irradiance G_R (100-200 W/m²)

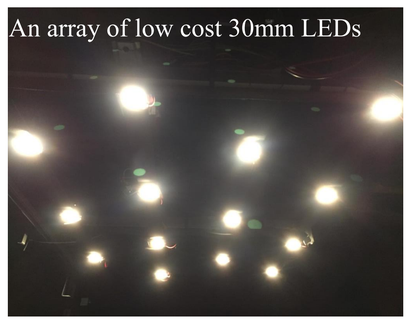
φ (%)	G_R (W/m²)	G_E (W/m²)	P_{max} G_E (W)	P_{max} $BiFi_{GR}$ (W)	ΔP_{max} (%)
98	0	1000	251.7	251.7	+0
	100	1098	273.4	271.9	+0.5
	200	1196	295.8	292.1	+1.3

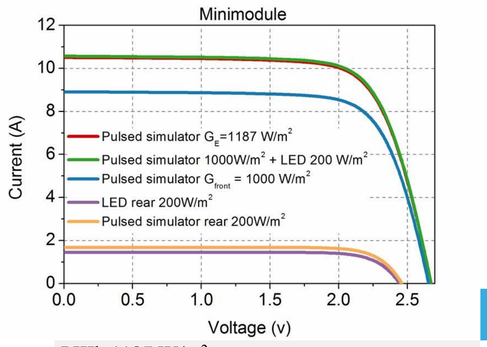
- Despite non-uniformity, P_{max} single-side ~ P_{max} double-sided
- Non–uniform G_{rear} affects I_{sc} and V up to V_{mpp} but to a much lesser extent the P_{max}

Suitable method for bifacial PV modules characterisation?

Simultaneous double source based on LED bias light (Prototype for minimodules 40x40cm²)







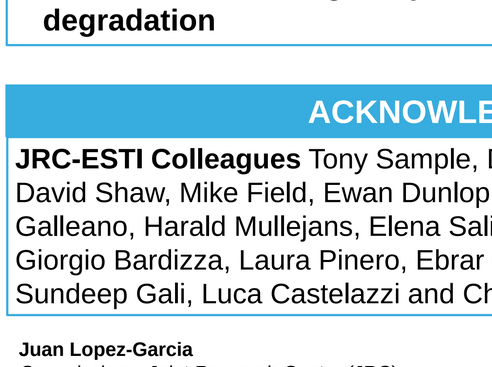
	ΔI_{sc} [%]	ΔP_{max} [%]
PIIIb 1187 W/m²	-	-
PIIIb 1000 W/m² + LED 200 W/m²	0.60	0.77
PIIIb 1000 W/m² + LED 200 W/m² corrected	0.20	0.29

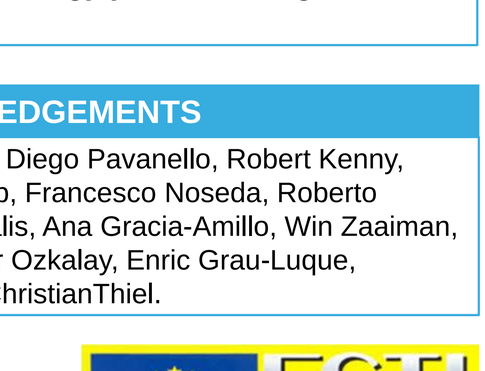
- ✓ Temporal stability: Class "A"
- ✓ Pulse to Pulse repeatability ~ 0.5%
- ✓ Irradiance non-uniformity: 4.45% Class "B"
- ✗ Spectral match: worse than class "C"

✓ compensated by a mismatch correction, or using the effective irradiance method (IEC 60904-7)

➢ Up-scaling for full size modules: ongoing

OUTDOOR TEST FIELD: array test





- Vertical E-W oriented and south oriented racks
- p-PERC 60 cells frameless modules with φ=67%
- Preliminary data from inverters in summer: +28% tilted vs vertical
- Long-term degradation and energy yield

CONCLUSIONS

- ✓ **Accredited calibration to IEC TS 60904-1-2 is now available**
- ✓ **Indoor and outdoor facilities for calibration using single-side and double-sided illumination**
- ✓ **Small bifacial testing array for energy yield and long-term degradation**

ACKNOWLEDGEMENTS

JRC-ESTI Colleagues Tony Sample, Diego Pavanello, Robert Kenny, David Shaw, Mike Field, Ewan Dunlop, Francesco Noseda, Roberto Galleano, Harald Mullejans, Elena Salis, Ana Gracia-Amillo, Win Zaaiman, Giorgio Bardizza, Laura Pinero, Ebrar Ozkalay, Enric Grau-Luque, Sundeep Gali, Luca Castelazzi and ChristianThiel.

Contact **Juan Lopez-Garcia**
European Commission – Joint Research Centre (JRC)
European Solar Test Installation (ESTI)
C.2 Energy Efficiency and Renewables unit
Via E. Fermi 2749, TP-450, I-21027 Ispra (VA), Italy.
Tel. +39 0332 783720 – Email: **juan.lopez-garcia@ec.europa.eu**

ESTI — European Solar Test Installation