BIPV Performance Failure Diagnosis

Jonathan Leloux$^{1,2}$, Luis Narvarte$^{1,2}$, Alberto Luna$^{1,2}$, Adrien Desportes$^3$

$^1$Instituto de Energía Solar – Universidad Politécnica de Madrid (IES-UPM), Spain
$^2$WebPV, Madrid, Spain
$^3$Rtone, Lyon, France

29th European PV Solar Energy Conference and Exhibition, September 2014, Amsterdam, Netherlands

Parallel event: Grid-connected PV systems: Field testing, performance monitoring, and energy storage
Frequently Asked Questions (FAQ)
from BIPV system owners

• How much energy can I expect to produce?
• Is my BIPV system performing well?
• When do I have to clean up my PV panels?
• Is this tree casting shading on my panels?
• How can I detect failures?
• What can I do in case of a failure?
• Can I trust my installer?

→ Difficult to answer all these questions

Guy Leloux, Belgium
BIPV system owner
since 2008
BDPV: A free Website used by 15,000 BIPV system owners in Europe

**CONNECTION DATE**: 09/2010
**REGION**: Lorraine
**COUNTY**: (55) Meuse
**PEAK POWER**: 2960 Wp
**EXPECTED PRODUCTION**: 2470 kWh/year
**INVERTER**: SMA - Sunny Boy 3000TL
**SURFACE AREA**: 21 m²
**PANELS**: 16xCP SOLAR - cps185w Building-integrated;
**TYPE OF SALE**: Sale of total.
**INSTALLATION TYPE**: Roof of a house
**SLOPE**: 30° (optimum: 35°) source PVGIS
**ORIENTATION**: 75°/South (optimum: 35°) source PVGIS
**ANNUAL LOSS IN COMPARISON TO THE OPTIMUM**: 12.4% source PVGIS
**INSTALLER**: MA Geothermie

**Year**: 2013

Min/Max et average for all years
Scale production numbers to Wh/Wp

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**Since September 2010**

Production of soleil_souilly
9324 kWh of electricity
9.324 Megawatt of electricity

**Nearby installations (maximum of 30)**
- vince100 - 8km
- remi55 - 11km
- nanard55 - 17km
- nouvelle_horizon - 18km
- wandlaincourt - 18km
- michlan55 - 19km
- ptitlouis55 - 23km
- wayne99 - 23km
- ipcoig55 - 27km
- nono57 - 28km
- grgrgr - 30km
- liliane - 31km
- loann - 31km
- stef55 - 32km
- findus - 34km
- bernard - 55

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Data Analysis?
Performance diagnosis?
On average, BIPV systems perform 15% below quality standards (Analysis of 10,000 BIPV systems from BDPV, France and Belgium)

Results published in 2 scientific publications:

Average PR ≈ 75%

Wide differences in PR (from 60% to 90%) (or 75% ± 15%)

For what reasons?
BIPV professionals looking for good monitoring solutions

Rbee Solar
10,000 BIPV systems monitored
1 energy data/10min

Data Analysis?
Performance Diagnosis?
Fault Detection?
### Data Monitoring:
Different systems ... and costs

<table>
<thead>
<tr>
<th>Material</th>
<th>Data</th>
<th>Measurement</th>
<th>Frequency</th>
<th>Error (%)</th>
<th>Cost (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meter</td>
<td>Accumulated energy</td>
<td>Manual</td>
<td>1/month</td>
<td>0.5%</td>
<td>0€</td>
</tr>
<tr>
<td>Smart meter</td>
<td>Output Power, Current, Voltage, Others,... (DC+ AC)</td>
<td>Remote</td>
<td>1/10 min, 1/h, 1/day</td>
<td>0.5%</td>
<td>50-100 €/year</td>
</tr>
<tr>
<td>Inverter</td>
<td></td>
<td>Manual, Remote, Internet, Inexistent</td>
<td>1/10 min, 1/h, 1/day Never</td>
<td>1-10%</td>
<td>0-50 €/year</td>
</tr>
</tbody>
</table>
WebPV = Spin-off company (PVCROPS – UPM)
Core business: PV performance diagnosis and fault detection
Monitoring data analyzed by WebPV - UPM
BIPV: 25,000 installations; PV Plants: 100 MW
State of the Art = PR (Performance Ratio) = Poor fault detector 😞

WANTED: A good fault detector!!!

What we want (ideally) 😊

What we get with PR (in reality) 😞

Time from April 2012 to March 2013
Novel fault detector: **Performance to Peers (P2P)**

\[ P2P = \frac{E_{\text{Focus System produced}}(T)}{E_{\text{Peer Systems produced}}(T)} \]

Technology patented
(Spanish Patent № P201430369)
HIDEY HO, NEIGHBOR
### Orientation distribution of BIPV systems and related energy losses

<table>
<thead>
<tr>
<th>Tilt angle (°)</th>
<th>Deviation from South (°)</th>
<th>(--- East)</th>
<th>(--- West)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0 0 0 0 0 0.1 0.1 0 0.2 0 0 0 0.1 0 0 0 0 0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>1 0.4 0.8 0.5 1 2 2 3 3 9 3 3 2 2 2 0.7 0.8 0.5 0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>0.2 0.3 0.5 0.4 0 1 2 2 2 7 2 2 1 1 1 0.5 0.3 0.4 0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>0.2 0.3 0.4 0.4 0 2 2 2 2 6 1 1 1 1 1 0.6 0.6 0.3 0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>0.2 0.1 0.2 0.5 0.3 1 0.8 1 1 3 1 2 0.8 0.6 1 0.5 0.1 0.1 0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>0 0 0 0 0 0 0.1 0.1 0.1 0.1 0.1 0.2 0.1 0 0 0 0 0 0 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Numbers:** Proportion of PV systems installed (%)

**Colors:** Annual energy production (E in %) relative to MAX = 100%

- E = 100
- 100 > E ≥ 95
- 95 > E ≥ 90
- 90 > E ≥ 80
- 80 > E ≥ 60
- E < 60
Performance to Peers (P2P) much more stable than Performance Ratio (PR)

Time from April 2012 to March 2013
When P2P value is far from normal → Fault detected!
PR vs P2P (daily data)
I

my neighbor.
Fault diagnosis from P2P: Grid-inverter problems

Time (min) during a day

P2P [%]
Fault diagnosis from P2P: Excessive soiling
Fault diagnosis from P2P: PV modules degradation
Quantification of energy losses due to faults detected by P2P

<table>
<thead>
<tr>
<th>Installation ID</th>
<th>Detected failures</th>
<th>Energy losses (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>211069313</td>
<td>1</td>
<td>0.10</td>
</tr>
<tr>
<td>211228133</td>
<td>1</td>
<td>0.10</td>
</tr>
<tr>
<td>211069307</td>
<td>1</td>
<td>0.10</td>
</tr>
<tr>
<td>210287006</td>
<td>1</td>
<td>0.10</td>
</tr>
<tr>
<td>210225602</td>
<td>1</td>
<td>0.12</td>
</tr>
<tr>
<td>210287091</td>
<td>3</td>
<td>0.17</td>
</tr>
<tr>
<td>211338662</td>
<td>1</td>
<td>0.24</td>
</tr>
<tr>
<td>211263097</td>
<td>2</td>
<td>0.33</td>
</tr>
<tr>
<td>210424083</td>
<td>13</td>
<td>1.13</td>
</tr>
<tr>
<td>211069267</td>
<td>19</td>
<td>2.81</td>
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<tr>
<td>211338680</td>
<td>17</td>
<td>2.82</td>
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<tr>
<td>210287089</td>
<td>30</td>
<td>3.01</td>
</tr>
<tr>
<td>211069304</td>
<td>24</td>
<td>3.09</td>
</tr>
<tr>
<td>211069276</td>
<td>35</td>
<td>5.64</td>
</tr>
</tbody>
</table>
Need accurate solar irradiation data? The energy produced by peer BIPV systems can also provide it!
We identified the main differences in performance between PV systems.
State of the art of PV modules:
Real power = (Contractual power – 5%)

- Majority of PV modules:
  - Important manufacturers
  - xSi technology
  - No correlation found between origin and performance

- Poor quality PV modules:
  - Small manufacturers
  - CIS modules

- Very good PV modules:
  - xSi modules with positive tolerances
  - HIT modules
Results on BIPV in North of Europe
SIMILAR TO Results on PV plants in South of Europe

<table>
<thead>
<tr>
<th>PV Module</th>
<th>( \Delta P ) (%)</th>
<th>( \Delta P ) (%) (In-field Meas.)</th>
<th>Diff (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV1</td>
<td>-6.4</td>
<td>-7.1</td>
<td>0.7</td>
</tr>
<tr>
<td>PV2</td>
<td>-4.6</td>
<td>-3.1</td>
<td>-1.5</td>
</tr>
<tr>
<td>PV3</td>
<td>-10.7</td>
<td>-12.3</td>
<td>1.6</td>
</tr>
<tr>
<td>PV4</td>
<td>-1.3</td>
<td>-2.1</td>
<td>0.8</td>
</tr>
<tr>
<td>PV5</td>
<td>-6.1</td>
<td>-4.7</td>
<td>-1.4</td>
</tr>
<tr>
<td>PV6</td>
<td>-2.9</td>
<td>-5.2</td>
<td>2.3</td>
</tr>
<tr>
<td>PV7</td>
<td>-2.1</td>
<td>-2.2</td>
<td>0.1</td>
</tr>
<tr>
<td>PV8</td>
<td>-4.2</td>
<td>-3.2</td>
<td>-1.0</td>
</tr>
<tr>
<td>PV9</td>
<td>-6.4</td>
<td>-6.6</td>
<td>0.2</td>
</tr>
</tbody>
</table>

[Statitics on BIPV]

- Weighted mean: -4.9 %
- N: 51

Todos los generadores medidos

Promedio = -5.4 %
Desviación típica = 3.8 %
P2P analyses are available through Web services.
Data analyses for PV plants operators and investors

SUMMARY

During the month of July 2013, the performance of the XXX PV plant has been in line with expectations.

a) Production results
   - AC Energy: 782.382 kWh
   - Yield: 174.1 kWh/kW
   - PR: 80.4%
   - PPR: 90.0%
   - Energy availability: 98.5%

b) No major incidences have been reported.

c) Losses diagram

- Final production
- Temperature losses
- AC/DC losses
- DC Generator losses
- Low irradiance losses
- Energy availability losses

- Historical energy data

Prepared by:
R. Moreno
Web PV S.L.

Reviewed by:
E. Lopez
IES-LPM
3D shading simulations – Residential PV with tree and streetlight
3D shading simulations – PV plants with trackers on uneven ground
3D shading simulations – A bike! (Useless, but we are in Amsterdam...)
3D shading simulations – Amsterdam RAI!!!
3D shading simulations: come listen to Jesus!

ORAL PRESENTATIONS 5CO.12

17:00 – 18:30 New Design and Planning Tools

Chairpersons:

G. Graditi
ENEA, Portici, Italy

C.2. Hansen
Sandia National Laboratories, Albuquerque, USA

5CO.12.1 Online Tool for Smart Selection of RES Solutions
I. Pinedo Pascua
European Commission DG JRC, Ispra, Italy

5CO.12.2 3D Simulation of Complex Shading Affecting PV Systems Taking Benefit from the Power of Graphics Cards Developed for the Video Game Industry
J. Robledo Bueno
WebPV, Madrid, Spain
J. Leloux & E. Lorenzo
UPM, Madrid, Spain

5CO.12.3 A Software-Based Planning Approach for Photovoltaic Power Plant Layouts
M. Bischoff
Siemens, Munich, Germany
I. Schüle & K. Plociennik
Fraunhofer ITWM, Kaiserslautern, Germany

5CO.12.4 A Physics Based GOES Satellite Product for Use in NREL’s National Solar Radiation Database
M. Sengupta, A. Habte, P. Gotseff, A. Weekley, A. Lopez & M. Anderberg
NREL, Golden, USA
C. Molling
University of Wisconsin, Madison, USA
A. Heidinger
NOAA, Madison, USA
Contact

Jonathan Leloux

Email   jonathan.leloux@webpv.net
Móvil   (+34) 61 68 556 69
Skype   jonathan.leloux.solar
Website www.webpv.net
LinkedIn www.linkedin.com/in/jonathanleloux

Two Solar Panels walk into an outdoor bar …

... and get lit.

(we can also have a beer to discuss all this...)