TASK 13: PERFORMANCE AND RELIABILITY OF PV SYSTEMS

Quality Assessment of PV systems by Analysis of System Performance

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Content

• Motivation

• Work from IEA-PVPS-Task 13
  – Performance database (small sample)
  – Statistical analysis (large sample)
  – “Counting the Sun” campaign

• Conclusion
Motivation

- PV is becoming a main energy harvesting option, 177 GWp power, end 2014.
- Optimal performance required.
- But, do they now

"How well is PV serving the world?"

Do good promises lead to good performance (= quality)?
Motivation

Shade is one reason for lower performance (inverter MPP)

[Netting, row shade] Netting, row shade

- no shade
- 3 BPD
- 6 BPD
- 12 BPD
- 20 BPD
- 60 BPD

Pannebakker, 2014
Monitoring Data: What to Measure?

- PV array
- Inverter
- Grid

- $G_i$
- $V_{DC}$
- $I_{DC}$
- $P_{DC}$
- $V_{AC}$
- $I_{AC}$
- $P_{AC}$

- $T_{amb}$, $T_{mod}$, $S_W$

- $y_r$: Reference yield
- $y_A$: Array yield
- $y_f$: System yield

- $I_c$: Array capture losses
- $I_s$: System losses

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Field performance analysis

**Analytical approach**: collecting and analyzing **validated** datasets in public database are contributed by all participants (e.g., monthly PR)

**Statistical approach**: collecting **huge amounts of system data** by using web scraping techniques followed by analyses.
Performance Data Base T13/2.1/ Topology
(10-2011 - 2017)

Task 13/2.1
- T13 Expert database input tool, since: 5-2011
- T13 partner database input tool,

Operator T13/1
- Quality Control
- Master DB

user
- www access with browser
- Export numeric info plant, several monitoring years ...
- graphic infos XY Info evaluation

direct www access with browser
www
www
www
www
www
www
www
www
Example of automated analysis in the DB
Analysing groups of PV systems using filter criteria

Figure 10: Final yield vs. reference yield for PV systems installed between 1983 and 1990 (Task 2).

Figure 11: Final yield vs. reference yield for PV systems installed between 2005 and 2012 (Task 2 & 13).

Performance improved
Analysing groups of PV systems using filter criteria

Figure 14: Monitored array efficiency vs. nominal array efficiency at standard test conditions STC; left: selected PV systems in Switzerland, right: PV systems in Italy.
Performance ratio is going up

PR from ~60% to >80% [Reich, 2012]
90% max?!

IEA – PVPS Task 2
[Nordmann, 2007]
Motivation

• Performance has been increasing in the past decades

• Still, reasons for lower performance than expected (or promised) are difficult to detect
  – due to insufficient monitoring in particular 1-5 kWp residential systems
Statistical approach

data per system size bins (<1 kWp -- >10 MWp)
supplied per region/country:

• **Annual Yield** (AC)
  kWh/y/installed kWp as a function of location, climate zone

• Annual average **performance ratio** PR
  Use measured irradiance from local sensor or satellite data

• **Degradation rate**
  For plants in the field for a 5-year period (if possible)

Focus on annual data is what the **customer** needs to know
Example: Statistical analysis Italy

- Example size bin: 10-100 kWp, installed in 2007, full year measurements for 2008-2012 (5 years)
- Courtesy: Francesca Tilli (GSE) [T13 participant]
Italy

All years averaged

Larger systems somewhat better performing

# systems
North: 58
Central: 48
South: 48
Statistical analysis: Data mining

- Market is introducing web tools for system owners to share monitor data, e.g., SolarLog

- Objective is to analyze PV performance data obtained by web scraping techniques that collect and organize these data automatically in databases

- “What you see, is what you can extract” [Legal]

- Developed Python scripts

- Accuracy?
### Results

<table>
<thead>
<tr>
<th>Country</th>
<th>Samples</th>
<th>System Size kWp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Netherlands</td>
<td>728</td>
<td>11.1</td>
</tr>
<tr>
<td>Germany</td>
<td>764</td>
<td>15.6</td>
</tr>
<tr>
<td>Italy</td>
<td>532</td>
<td>13.1</td>
</tr>
<tr>
<td>France</td>
<td>325</td>
<td>15.1</td>
</tr>
<tr>
<td>Belgium</td>
<td>565</td>
<td>6.5</td>
</tr>
</tbody>
</table>

![Graph showing the percentage of polycrystalline, monocrystalline, and amorphous solar panels in different countries.](chart.png)

- **GER (Germany)**: 50% polycrystalline, 40% monocrystalline, 10% amorphous
- **ITA (Italy)**: 60% polycrystalline, 30% monocrystalline, 10% amorphous
- **NL (Netherlands)**: 45% polycrystalline, 35% monocrystalline, 20% amorphous
- **FRA (France)**: 35% polycrystalline, 60% monocrystalline, 5% amorphous
- **BEL (Belgium)**: 40% polycrystalline, 50% monocrystalline, 10% amorphous
Results

- Yearly variation between 2011-2013 from 2-11%
### Annual yield (kWh/kWp) ±(stdev)

<table>
<thead>
<tr>
<th>Country</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North</td>
<td>979±153</td>
<td>937±126</td>
<td>882±109</td>
</tr>
<tr>
<td>South</td>
<td>1081±154</td>
<td>1044±121</td>
<td>992±125</td>
</tr>
<tr>
<td>France</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North</td>
<td>1030±362</td>
<td>993±201</td>
<td>959±154</td>
</tr>
<tr>
<td>South</td>
<td>1099±96</td>
<td>1092±224</td>
<td>1103±166</td>
</tr>
<tr>
<td>Italy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North</td>
<td>1219±170</td>
<td>1177±157</td>
<td>1094±148</td>
</tr>
<tr>
<td>South</td>
<td>1352±113</td>
<td>1337±199</td>
<td>1288±203</td>
</tr>
</tbody>
</table>

South: +6-18%
### Results: NL Geographical Variation

<table>
<thead>
<tr>
<th>Region</th>
<th>PR</th>
<th>Annual Yield kWh/kWp</th>
<th>Irradiation kWh/kWp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coast</td>
<td>79.3+/-2%</td>
<td>895+/-21</td>
<td>1165</td>
</tr>
<tr>
<td>Mainland</td>
<td>77.1+/-2%</td>
<td>833+/-19</td>
<td>1021</td>
</tr>
</tbody>
</table>

Temperature, wind?
1000 kWh/kWp

Netherlands

Belgium

Germany

France

Italy

Annual yield 2014

To be presented at IEEE PVSC 42, New Orleans, 14-18 June 2015
GIS mapping of yield 2014
in progress
“Counting the Sun”

- Dutch Solar Days 2014 (May 12 – May 18)
- Awareness campaign “How well is my system doing”
- Social media, national television show “Kassa”
  → >5000 systems spread over the country
  → “citizen science”

weekly yield average 33.4 kWh/kWp
“Counting the Sun”

- Most systems are performing well
- Average performance ratio $0.74 \pm 0.10$
- NO geographical variation in performance ratio
- Some 10% of participants indicated some form of shade, performance ratio: $0.70 \pm 0.10$. 
Conclusions

• Obviously, without DATA one cannot say anything about PERFORMANCE (=quality)

Reliability? = continuously high PR

• IEA PVPS Task 13
  – Collecting and analyzing data
  – From participants
  – Statistical analysis, web scraping
    • Irradiation data needed (JRC)

Please join!
Analysis of Long-Term Performance of PV Systems

Different Data Resolution for Different Purposes

Thank you for listening!

Q&A

http://www.iea-pvps.org/index.php?id=57
Reports by IEA PVPS Task 13
http://www.iea-pvps.org/index.php?id=57


