Operational performance of large fleet of PV systems

Seminar WG2

Jonathan Leloux (UPM)

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Malta
Data available for Pearl PV: 20,000+ PV systems

BDPV
- 15,000 PV systems
- France + Belgium
- Monthly energy data
- Period: 2007 – 2018
- Detailed metadata

Rtone Rbee Solar
- 6,000 PV systems
- Belgium + France
- 10-min energy data
- 1-hour GTI data (HelioClim/SoDa)
- Period: 2011 - 2018
- Basic Metadata
In the (raw) metadata you will not trust!
Overview of orientation losses for one country

<table>
<thead>
<tr>
<th>Tilt angle (°)</th>
<th>&lt;- East</th>
<th>Deviation from South (°)</th>
<th>West --&gt;</th>
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<td>0.1</td>
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<tr>
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</tbody>
</table>

Numbers: Proportion of PV systems installed (%)
Colors: Annual energy production (E in %) relative to MAX = 100%

\[ y = ax^b \]

R-Square = 98.6%
Monitoring data filtering and Quality Control (QC) – ETL

Team
- **Jonathan Leloux**, Penka Georgieva, Zlatica Marinkovic, Sascha Lindig, Jesús Robledo

Details
- Quality Control on metadata: azimuth, tilt and peak power of PV systems,…
- Different approaches: physical modelling, cost function, pattern recognition, ANN.
Mapping annual and seasonal soiling in Western Europe

Team

Leonardo Micheli, Joao Gabriel Bessa, Jonathan Leloux, Florencia Almonacid, Eduardo F. Fernandez

Details

Application of NREL’s and Kimber’s soiling estimation methodologies to several thousands of PV systems in Europe.
PV degradation vs stress factors (temp, RH%, UV, etc)

Team
- Sascha Lindig, David Moser, Jonathan Leloux

Details
- Degradation assessment using PVlib. Switch in paradigm from assessing a limited amount of data of high quality (typically lab data) to assessing a very large amount of data of lower quality (monitoring data).
Performance Ratio in Europe: 60%-90%

Yearly integrated Performance Ratio - Europe

Weibull
- Shape: 13.25
- Scale: 0.7871
- N: 55495

Source: Leloux 2015
The data follow a Weibull distribution for $0.6 < PR < 0.9$
Difference in PR between inverters: 1-5 %
Difference in PR between modules (no thin-film): 1-6%
PV modules technology greatly affects performance
PV systems performance has improved over time.

Yearly integrated Performance Ratio in 2013 vs year of installation of PV system - Europe
Some PV systems are clearly subject to faults
The monthly PR is influenced by several parameters
Beyond PR: PI and others
PV is still dependent on local regulation

Source: Leloux 2015

Peak power PV systems - Belgium

Source: Leloux 2015
The small PV systems have a lower PR.
Faut detection: not so simple with PR
Fault detection in a “perfect” world
Belgium: a wonderful play-field for PV fleets
Looking for the best peers in neighborhood
Constructing Performance to Peers (P2P)
P2P vs PR: more stable better signal/noise
Fault detection from P2P: “static” approach
Fault detection with P2P: dynamically
Fault detection with P2P on daily data
Fault detection with P2P on 10-min data
Fault detection with P2P under clear-sky
Shading detection from P2P vs sun position
Stability: P2P vs PR vs season of year

Boxplot of hourly MAD(P2P)

Boxplot of daily MAD(P2P)
P2P stability vs number of good peers
Thank you for your attention!