Tools for the High Penetration of PV Systems in the EU Electrical Networks:
Results of PVCROPS Project
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Objective 1: 
“enhance the integration of PV generation into the grid and demonstrate that PV could provide up to 12% of the EU electricity demand by 2020”

This means percentages of up to 30% in Southern European countries

Needs:
• technical solutions to avoid disturbances induced by the PV power fluctuations into the grid
• PV systems to assist the grid management when the DSO or the TSO ask for it.

Technical solutions:
• energy management and storage control in PV systems
• prediction and mitigation of PV power fluctuations
SET PLAN SEII

Objective 2:
“Improvement in the performance, reliability and lifetime of PV systems”
“Reduction in the cost of PV systems”

This means Reduction in the LCoE of PV generation

Needs:
• Increase the performance of PV systems

Technical solutions:
• advanced technical specifications in the design and procurement stage
• field testing at the commissioning stage
• monitoring for the diagnosis of hidden problems at the operational stage
PV CROPS – Fields of work

Reduction of the LCoE of PV generation

- Robust modelling, advanced simulation and design optimization
- Prediction of system output with respect to solar resource, local weather and system behaviour
- Integration of energy management and storage strategies for PV plants and BIPV
- Monitoring, real-time follow-up and advanced diagnoses of performance
- Hardware, software and contractual testing solutions

Enhancement of the integration of PV into the grid
Outstanding Results

1- Advanced design and simulation tool + Technical specifications and Quality control procedures

- Energy yield estimation
- Financing according $P_{90}$
- Low uncertainty

Contractual frameworks

- Quality control linked to payments
- Assign responsibilities
- Technical specifications
- Quality control procedures
- Parameters guaranteed by manufacturers

SISIFO

- Open source tool
- Free available
- Just inputs guaranteed by manufacturers
- and of course:
  - models tested in more than 70 PV plants
  - Shadowing models
  - trackers
  - …

Available at: www.sisifo.info

Bankability

- Energy yield estimation
- Financing according $P_{90}$
- Low uncertainty

Testing kits

- + hot spot rejection criteria
- + Spin-off

Available at: www.pvcrops.eu
Outstanding Results

2- Prediction of PV power production/fluctuations

PV power fluctuations characterization
- 1s PV power data in a PV fleet from 2008
- Synchronized

Mitigation of PV power fluctuations
- by PV plant size
  \( G(t) \)
  Smoothing due to area
  \( \sqrt{S} \)
  \( \Delta t \) 1 minute: 1 MW \( \rightarrow \) 80%
  40 MW \( \rightarrow \) 54%

- by PV plant aggregation
  \( G(t) \)
  Smoothing due to aggregation
  \( \sqrt{N} \)
  \( \Delta t \) 1 minute: 1 PV plant \( \rightarrow \) 80%
  6 PV plants \( \rightarrow \) 30%

Tollboxes for prediction
- Parametric: PV fleet model
- Non-parametric
  Quantile Regression Forest
  MBE < 1.3%; MAE < 9.5%

Open-source toolbox

Available at
http://vps156.cesvima.upm.es:3838/predictPac/
Outstanding Results

3- Integration of Batteries and Energy Management Strategies

Development of energy management strategies

- Ramp rate control
- Maximizing economic output
- Self-consumption
- Peak shaving / constant power
- ...

Battery sizing
Worst fluctuation model

- Strategy

Validation in demonstrators

<table>
<thead>
<tr>
<th>Li-ion</th>
<th>VRB</th>
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<tbody>
<tr>
<td>5kW / 6h</td>
<td>10kW / 6h</td>
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- Toolboxes for sizing and simulating PV systems with batteries
- Specific hardware for the energy management

Available at: [www.pvcrops.eu](http://www.pvcrops.eu)
Outstanding Results

4- Increasing the performance and reducing the cost of O&M

Automatic detection of Performance Failures

- Just energy meter readings
- No need of irradiation data

Huge database of BIPV production

- 30,000 BIPV systems

Performance failure indicator

- Stability in correct operation
- PR versus P2P

- No need of irradiation data
- Just energy meter readings
- Failure = P2P < threshold

Webservice for the automatic detection of performance failures

- Spin-off: Web PV
- www.webpv.net

Solar radiation data from PV systems

- Toolbox: www.SOWEDA.com
- on-line and free available (tilted radiation from weather information)
**Increase of PR and reduction of LCeE**

- Analysis of the state of the art of PR in Europe: PR= 76.5
- Increase due to:
  - Design tools
  - Automatic failure detection tool
- Increase of PR without increase of cost of PV system

<table>
<thead>
<tr>
<th>Scenario of improvement</th>
<th>Increase of PR due to our tools</th>
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<tbody>
<tr>
<td></td>
<td>Design</td>
</tr>
<tr>
<td>Current P50 (PR= 76.5)</td>
<td>1.7%</td>
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<tr>
<td>Current P90 (PR= 83.8)</td>
<td>6.81%</td>
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**Increase of penetration into the grid**

- Energy management strategies for 20% penetration
- Prediction tools for higher penetration