**PVSAT - 2**

**An automated performance check for photovoltaic systems based on solar irradiance information from satellite data**


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**Introduction**

Within the EU project PVSAT-2, a fully automated performance check for grid-connected photovoltaic (PV) systems has been developed to assure maximum energy yields and to optimize system maintainance. Aim is the early detection of system faults and therefore, the prevention from energy and lastly from financial losses. System failures can be hard to detect; solar irradiance information are necessary to calculate reference values of the expected energy yield. Solar radiation derived from data of the METEOSAT satellites play a major role in PV system surveillance. They are a cost-effective alternative for small PV systems (up to 5kW) compared to expensive on-site measurements.

The PVSAT-2 procedure

The actual power output of a PV system is automatically recorded on-site and transferred daily to a central server.

Solar irradiance is determined from METEOSAT images on an hourly basis and refined by combination with ground measurements from weather stations by kriging-of-differences.

Based on the derived irradiance values, an individual yield calculation for the PV system is performed daily by a PV simulation.

To detect system failures, the central system compares daily the actual and the simulated yield. The fully automated failure detection routine searches for causes of occurred malfunctions.

Information about the performance, detected system failures, and the probable causes for the malfunction are submitted to the operator.

**Irradiance data from satellite measurements**

- **Satellite Data:**
  - **Channel:** VIS (0.45–1.0 μm) – NIR (0.6–0.9 μm)
  - **Temporal Res.:** 30 minutes – 1.5 minutes
  - **Spatial Res.:** 2.5 x 2.5 km (sub-satellitepoint) – 1.0 x 1.0 km (sub-satellitepoint)

- **Method:** The solar irradiance for Europe at ground level is derived by the HELIOSAT-Method.

- **Accuracy:** Overall accuracy of the satellite data (Meteosat-7) compared to ground measurements of 20 DWD stations for the year 2000.
  - **RMSE, monthly:** 4.7 %
  - **RMSE, daily:** 9.9 %
  - **RMSE, hourly:** 21.3 %
  - **MBE:** 0.6 %

- **Kriging-of-differences:** The accuracy can be improved significantly for cloudy sky situations.

- **Weather-dependent accuracy:** The accuracy of the satellite-derived irradiance data is strongly dependent on sun elevation and the predominant weather situation. Errors decrease with higher irradiance.

**Simulating PV power output and automated failure detection**

- **PV simulation:** The irradiance data and a technical specification of the PV system are the basic input for the daily estimation of the expected power output. The quality of the PV simulation output depends highly on the accuracy of the irradiance data. Under clear sky conditions with low errors system faults can be detected fast.

- **Automated failure detection routine:**
  - **List of detectable malfunctions**
    - Module/cable related failures
    - String defect
    - Module defect
  - Power limitation of inverter
  - APR tracking
  - Shutdown, total blackout
  - Defect control devices
  - Defect inverter
  - Grid outage
  - Failures related to ambient conditions
    - Shading
    - High temperature
    - Snow cover

**Results and conclusion**

During a one-year test phase the functionality and applicability of the developed PVSAT-2 procedure is evaluated and improvements are introduced.

The first results prove the usability of satellite-derived solar irradiance data for the surveillance of PV systems. Malfunctions of a system as well as their most probable causes can be identified fast. PVSAT-2 will provide a cost-effective and user-friendly service.

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