Data analysis for effective monitoring of partially shaded photovoltaic systems

Odysseas Tsafarakis¹, Kostas Sinapis², Wilfried G.J.H.M. van Sark³

¹ Utrecht University, Copernicus Institute of Sustainable Development, Heidelberglaan 2, 3584 CS, Utrecht, The Netherlands
² Solar Energy Application Centre, HTC 21, 5656 AE, Eindhoven, The Netherlands
³ E: W.G.J.H.M.vansark@uu.nl

Motivation
Over 2GW of solar PV capacity is installed in The Netherlands, with average system capacity 3.5kW. The majority is monitored through simple Pac meter and without any further (solar) equipment [1].

70% of these PV systems are placed on rooftops [2], where different objects might obstruct the irradiance reaching the PV modules and affects their energy output.

Systems of Presented example[

Power measurements from 2 systems:
• Partially shaded PV panel (Pshade)
• Non shaded PV panel (Pref)
Same panels & Power Optimizers

Pole placed in front of the studied PV system

No object placed reference PV in the afternoon

• Pole placed in front of the studied PV system
• Reference PV in the afternoon

Step 1: Through Ransac [4] a threshold between the normal and not normal operation of the Error* is defined.
*Error = | Pref – Pshade |

Step 2: Concentration of Reds during the day is studied (appearances vs time plot) and the hours with higher red appearance are characterized as shadows. Start and end time of each shadow called Shadow Profile.

Step 3: DBSCAN is applied and groups the dates, based on the shadow occurrence. (Exp groups per shadow)

Step 4: Concentration of errors is studied, like step 2, but to each group of dates separately.

Conclusions
• The proposed method is offering a low cost monitoring solution, since it needs only a simple Pac data logger, to small residential PV systems, since it requires only Pac of two neighboring PV systems, with similar tilt and orientation.
• DHI measurements proved to prove that shadow not detected in all expected hours because of high DHI.
• For smaller time periods steps 1&2 are sufficient. For larger DBSCAN is required.

In Current form is perfect for malfunction detecting and performance analysis of systems with power optimizers and micro inverters.

References
[3] Sinapis K. et al, “outdoor characterization of three pv architectures under clear and shaded conditions”
[4] O. Tsafarakis@uu.com, 2E: sinapis@ecn.nl
[6] From 18:30 to 20:00
[7] From 9:00 to 12:00

Before process

After process

Reds are studied further for their repetition on time

Green : Error < Threshold, outside profile => malfunction

Reds are studied further for their repetition on time

Green : Error < Threshold, inside profile => malfunction

Study concentration of reds on time

Study concentration of reds on time

Shadow profiles
From 9:00 to 12:00
From 18:30 to 20:00

Grouping of shadows from DBSCAN

Verification Plot
DHI/GHI of Blue points

Final ScatterPlot

Final Shadow Story

In last plot, DHI used for verification.

Still many points show shadow that not seen (Blue)
DHI of these points is studied

For the strong majority of blue points (90%) the DHI < DNI. Thus the non observation of shadow is due to high DHI

Not expected shadow & malfunction recognized!

Shaded PV [W]

Partially shaded PV panel (Pshade)

Non shaded PV panel (Pref)

phantom object placed

Shadow Story

Motivation

Shadow Story

Research Target

An algorithm that:
Detects the energy loss due to an expected shadow
• Distincts it from any additional energy loss and alerts the owner for the real faults.
Use only Pac - the most common data
• Date vs Time plot
• Points' color based on: Error = | Pref – Pshade |

Conclusions

Study concentration of reds on time

Shaded PV [W]

Reference PV [W]

Green : Error < Threshold

Red : Error > threshold

P_ref vs P_shade Through steps

Shaded PV [W]

Reference PV [W]

Green : Error < Threshold

Red : Error > threshold, outside profile => malfunction

Shadow Story

Through steps

Shadow profiles
From 9:00 to 12:00
From 18:30 to 20:00

DBSCAN is applied and groups the dates, based on the shadow occurrence. (Exp groups per shadow)

DBSCAN is applied and groups the dates, based on the shadow occurrence. (Exp groups per shadow)

Verification Plot
DHI/GHI of Blue points

Final ScatterPlot

Final ScatterPlot

Final Shadow Story

Final ScatterPlot

Study concentration of reds on time

Study concentration of reds on time

Scatterplot & shadow story colors in steps 2,3,4

• Green : Error < Threshold
• Black Error > threshold, inside profile => SHADOW

Step 2

Concentration of Reds during the day is studied (appearances vs time plot) and the hours with higher red appearance are characterized as shadows. Start and end time of each shadow called Shadow Profile.

Step 3

DBSCAN is applied and groups the dates, based on the shadow occurrence. (Exp groups per shadow)

Step 4

Concentration of errors is studied, like step 2, but to each group of dates separately.

Conclusions

• The proposed method is offering a low cost monitoring solution, since it needs only a simple Pac data logger, to small residential PV systems, since it requires only Pac of two neighboring PV systems, with similar tilt and orientation.
• DHI measurements proved to prove that shadow not detected in all expected hours because of high DHI.
• For smaller time periods steps 1&2 are sufficient. For larger DBSCAN is required.

In Current form is perfect for malfunction detecting and performance analysis of systems with power optimizers and micro inverters.

References