Validation of an all-sky imager based nowcasting system for industrial PV plants

Pascal Kuhn, Pascal.Kuhn@dlr.de
Overview

1. Relevance of nowcasting systems
2. The WobaS nowcasting system
3. Validation of nowcasting systems
4. Conclusion and further work
Relevance of nowcasting systems
Both on plant and grid level, nowcasting systems are of interest

• Ramp rate penalties potentially reduce gross revenue of solar plants by 20%, only 10% with forecasts. [1]

• Solutions:
  1. Curtailment: dumping money
  3. Forecasts: e.g. camera-based nowcasts

  Combination might be optimum solution

• Both solar plants and grid operators benefit from forecasts [3]


Working principle of the WobaS-4cam nowcasting system

Standard surveillance cameras are used to derive short-term forecasts.

- 4 all-sky imagers take images
- Clouds are segmented
- Clouds are modelled
- Shadow maps are created
- Sensors provide irradiance data
- Cloud tracking
- Irradiance map is created

Also validated:
WobaS-1cam, WobaS-2cam, WobaS-3cam and shadow camera based systems
WobaS nowcasting system: User interface

WobaS can be linked to FoSyS, providing satellite and NWP forecasts.
Validation of nowcasting systems
Both final predictions and intermediate results are validated

- Cloud segmentation
- Cloud height
- Cloud tracking
- Transmittance
- ...

Benchmarking of subsystems

Reference
- Archives
- Ceilometer
- Cloud Speed Sensor
- ShadowCams
- >20 radiometers

Irradiance maps

Benchmarking of whole nowcasting systems
Validation of a submodule: Cloud segmentation

Cloud segmentation is validated on a manually segmented reference data set.

- Validation by comparison of automatic to manual cloud segmentation
- Reference-dataset of >600 images per camera model
- Performance is studied for various sun elevations and Linke turbidities
Validation of a submodule: Cloud segmentation results

Clear Sky Libraries are found to be best suited for cloud detection

- Cloud detection via 4-dimensional clear sky library based on air mass, Linke turbidity and pixel positions
- Simple approaches, e.g. Red-Blue-Ratio, are not feasible
- Low sun elevations and high Linke turbidities complicate cloud detection
Validation of all-sky imager based nowcasting systems
Spatial and temporal aggregation effects must be considered

Standard in literature:
Validations against (few) radiometers for one-minute averages

Temporal aggregation effects not considered, but relevant for PV-battery plants

Temporal aggregation effects change the behavior.
Validation of WobaS nowcasting maps

Temporal aggregation effects determine the size of buffers, e.g. batteries

- Temporal aggregation effects studied on 30 days
- Key finding: Deviations significantly reduced by aggregation

Investigation of temporal aggregation effects:

What about spatial aggregation effects?
Spatial aggregation effects: reference irradiance maps
Two options are available for highly spatially resolved irradiance maps

**Grid of irradiance sensors [4]**
- Straight forward approach
- Costly and labor intensive
- Limited spatial coverage

**Shadow camera system [5]**
- Fairly inexpensive
- Low maintenance
- Large imaged area


Shadow cameras provide reference irradiance maps
A shadow camera system derives spatially resolved maps for validations

GHI maps

Shadow map

>20 radiometers

sunny + shaded reference image
Considering spatial aggregation effects

A unique shadow camera system is available, providing reference maps

- Comparison between reference irradiance maps and nowcasted irradiance maps considering various field sizes
- Previously: Validations of nowcasting systems only against (few) radiometers
- Spatial aggregation effects significantly reduce deviations

200 MWp, China
Conclusion and further work

• Validations on extended validation periods and various weather conditions
• Validations of sub-modules
• Consideration of spatial aggregation effects
• Consideration of temporal aggregation effects
• Auto-validations of dubious value
• WobaS-4cam: state-of-the-art and commercially used
• Nowcasting systems both for plant and grid operations

Future work:
• WobaS system for grid operations, project has started

Pascal Kuhn
Pascal.Kuhn@dlr.de

Thank you! Questions?
Thank you!

Questions?

Pascal.Kuhn@dlr.de
Publications

Global horizontal irradiance (GHI)

Direct normal irradiance (DNI)

Cloud heights