Analysis of PV grid installations performance, comparing measured data to simulation results to identify problems in operation and monitoring

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Abstract

Combining measured monitoring data with detailed simulation results provides a wealth of information that can reveal subtle problems or help to track down the source of a complex malfunction on the module, string and inverter level.
Measured data can be compared to simulation results, taking into account the corresponding uncertainties. Discrepancies can point to problems either with the monitoring, the operation or the simulation results. The level of detail in the monitoring data determines how well this assignment can be done in an unambiguous way.

Variables:	measured and simulated PV production
Indicator:	Residuals of linear fit
Control variable:	Hour of Day

General approach

Simulation variables

Date and Sun Position
hour
day
month
sun height
sun azimuth
incidence angle
…

Irradiance
global horizontal *
diffuse horizontal
beam horizontal
global incident *
beam incident
diffuse incident
albedo incident
…

Optical Losses
horizon
shadings beam
shadings diffuse
global shading
transposition factor
incidence angle modifier
…

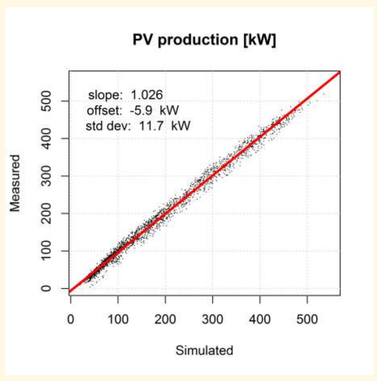
Effective Irradiance
global effective
beam effective
diffuse effective
albedo effective
…

Other Losses
ambient temperature *
wind speed
array temperature *
temperature loss
mismatch loss
ohmic loss
soiling loss
…

System Production
DC current *
DC voltage *
DC power
inverter losses
AC power *
performance ratio
…

*measured quantities

1. Variables for comparison



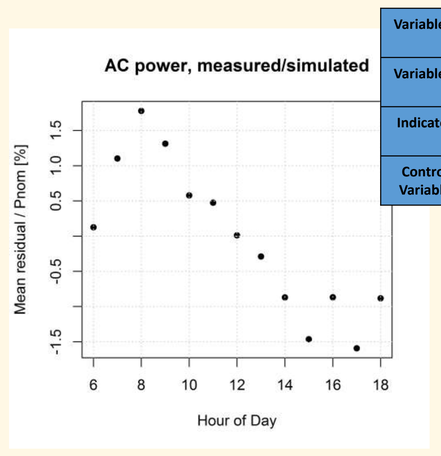
2. Indicator

- Differences
- Ratios
- Linear regression residuals

3. Control variable

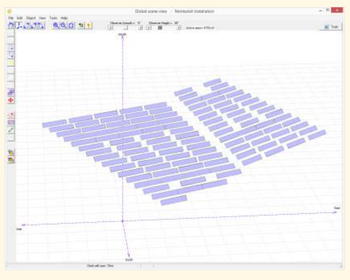
- Irradiance
- Temperature
- Time (hour of day, month, year)

Analysis Plot



Variable 1	Measured PV production
Variable 2	Simulated PV production
Indicator	Residuals of linear fit
Control Variable	Hour of day

PV Installation in this Study



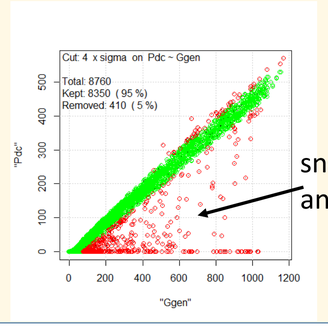
Montsoleil

- Pnom = 555 kWp
- Two different orientations
- Swiss mountains 47.2° N, 7.0° E

BFH Monitoring

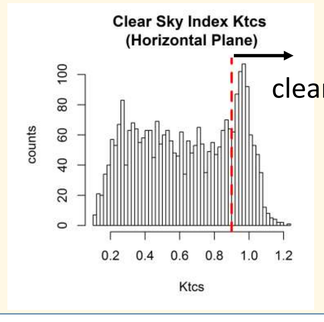
- Irradiance (Horizontal and PoA)
- Temperature
- DC Current and Voltage
- AC Power

Data Cuts



snow coverage and failures

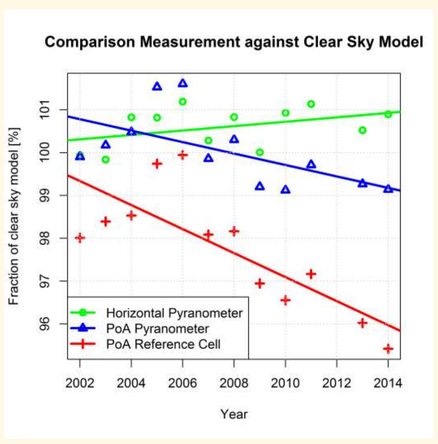
Clear Sky Selection



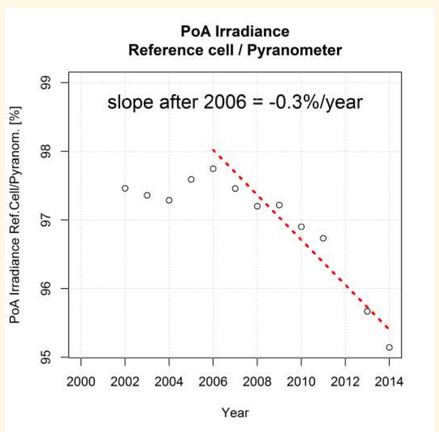
Example of analysis

Analysis Plot	Stability of irradiance measurement (1)	Ageing of Reference Cell (2)	Pyranometer Orientation (3)	Temp. dependence of irradiance measurement (4)	Fault Detection (5)	Seasonal variation of DC power simulation (6)	Simulation of PV production (7)	Ageing of Installation (8)
Data Cuts	Clear sky	No snow,	Clear sky	No snow	None	No snow, no faults	No snow, no faults	No snow, no faults
Variable 1	Measured Irradiance	PoA irradiance from Reference Cell	Measured PoA irradiance	PoA irradiance from Reference Cell	PoA irradiance	Measured DC power	Measured AC power	Measured AC power
Variable 2	Clear Sky Irradiance	PoA irradiance from pyranometer	Transposed PoA irradiance	PoA irradiance from pyranometer	Measured DC power	Simulated DC power	Simulated AC power	Simulated AC power
Indicator	Ratio	Ratio	σ of residuals	σ of residuals	Average ratio	Ratio	Difference	Average ratio
Control Variable	Year	Year	Tilt/Azimuth	Ambient temperature	Day	Month	Irradiance/ Temperature	Year

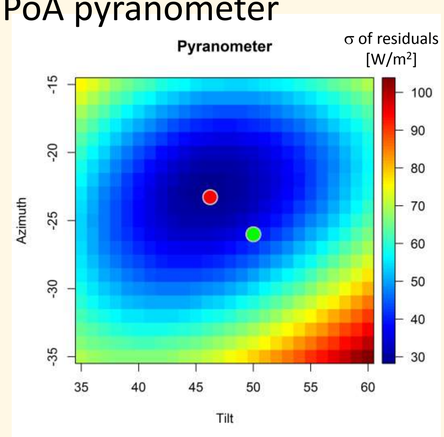
Irradiance measurement stability (1)



Ageing of reference cell (2)

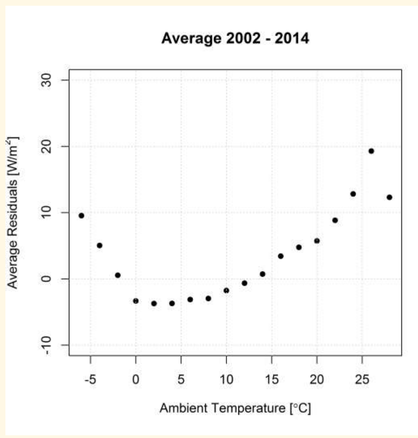


Orientation check of PoA pyranometer (3)

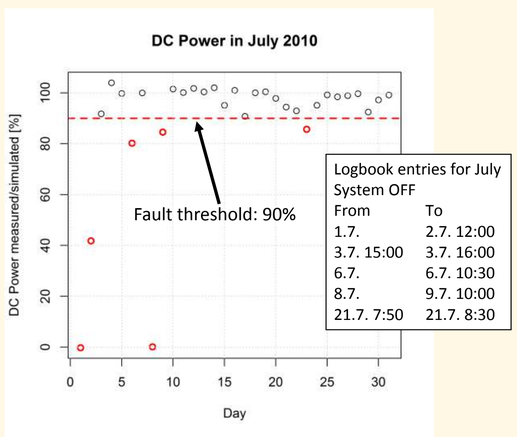


● : nominal 50° Tilt, -26° Azimuth
● : fitted 46° Tilt, -23° Azimuth

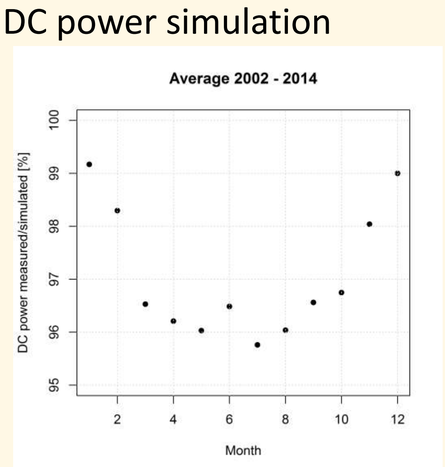
Temperature dependence of irradiance measurements (4)



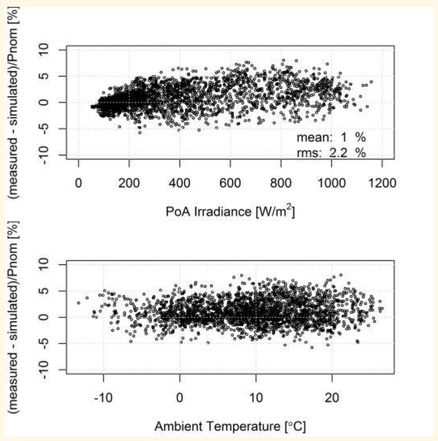
Fault detection (5)



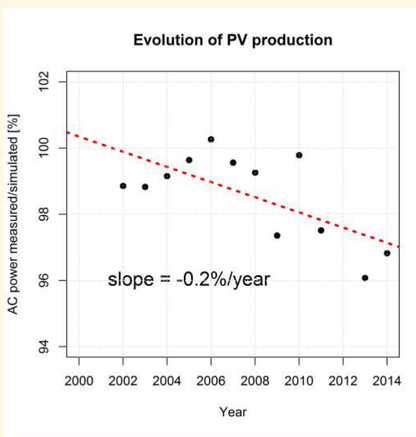
Seasonal dependence of DC power simulation (6)



PV production (7)



Ageing of installation (8)



A tool allowing this kind of analysis is currently being implemented in the PVsyst software and its capabilities to compare monitoring data to the simulation results are being expanded.