#PVPMC2026

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Probabilistic reconstruction of unknown tracker angles for sub-hourly loss quantification

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PREVIOUS WORK AND GOAL(S) OF THIS STUDY

"A method for estimating time series PV production loss from solar tracking failures", *Anderson et al.*, ***IEEE Journal of Photovoltaics*, 2021**

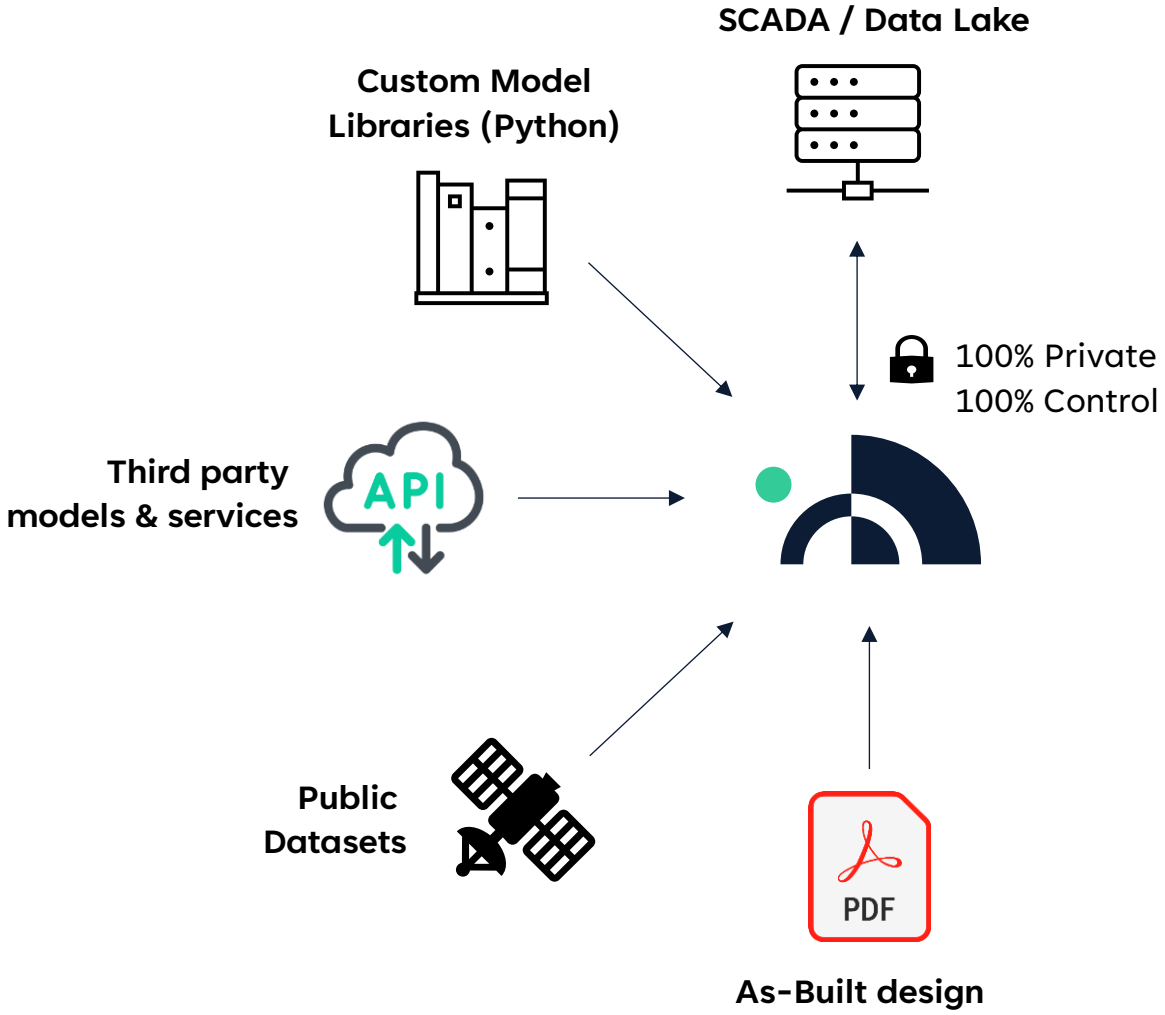
1. Model power time series for:
   - Proper tracking
   - Fixed orientations (every 5°)
2. Compare to power measurement
3. Classify entire day as "Tracking" or "Stalled" (at angle)

✓ Fleet-level analysis
✓ Daily resolution
× Performance analytics
× Sub-hourly resolution

This work: Is it possible to …

1. **Decide if a tracker is stuck at minute level?**
2. **Reconstruct tracker angles without measurement?**
3. **Apply methods at scale over thousands of trackers and strings?**

PVRADAR MODELING FRAMEWORK



Our goal is to alloy you to ...

- ✓ **Create internal tools**
- ✓ **Apply at scale**
- ✓ **Automate manual tasks**

Much easier and faster.

Use-cases PV + BESS:

1. performance analytics
2. design optimization

METHODOLOGY

Hypothetical 2.7 MWp / 2.25 MW power plant
placed in Nye county, Nevada

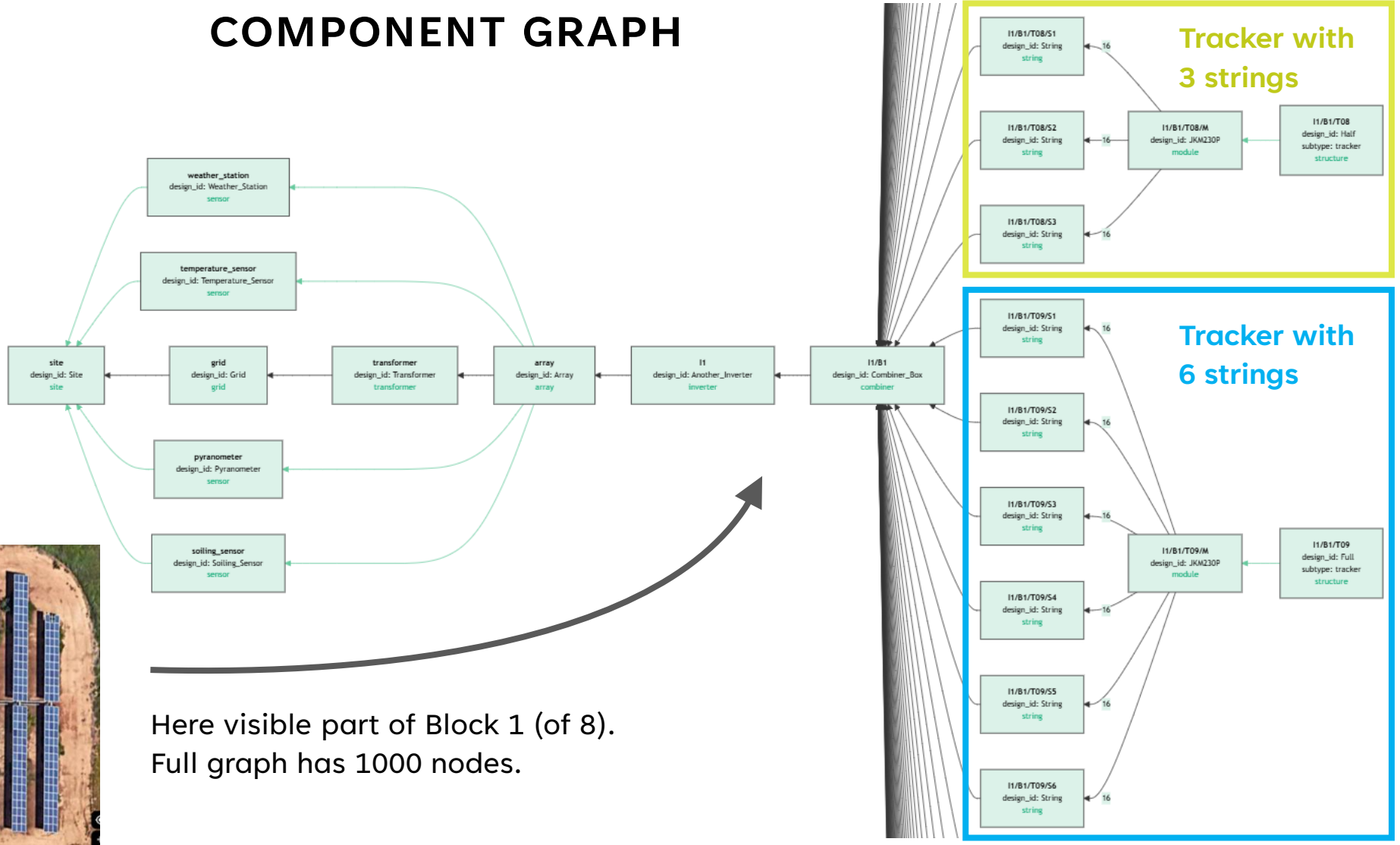
Image: Google Earth

1. **Meteo data for exact location**
   - GHI from BSRN “Desert Rock”
   - Wind speed and air temp. from ERA5
   - Soiling from PVRADAR soiling model
2. **Tracker angles**
   - Ideal angles from pvlib
   - Small chance tracker stops communicating (angles are NaN)
   - Small chance to be stuck
3. **Calc. component current, voltage, power**
4. **Add measurement error as noise**

Example: Module design

JKM235P
manufacturer: Jinko Solar
model: JKM235P-60
rated_module_power: 235
module_eff_value: 0.1435
bifaciality_factor: 0
degradation_rate: 0.7
light_induced_degradation: 2.5
temperature_coefficient_power: -0.0045
temperature_coefficient_isc: 0.0005
temperature_coefficient_voc: -0.0027
cell_string_count: 3
half_cell: 0
module_construction: glass_polymer
short_side: 0.992
long_side: 1.65
nominal_operating_cell_temp: 45
cells_per_cell_string: 20
mpp_voltage_stc: 29.8
mpp_current_stc: 7.89
open_circuit_voltage_stc: 36.9
short_circuit_current_stc: 8.47
bandgap_energy: 1.121
bandgap_energy_temp_coef: -0.0002677
surface_area: 1.6368
module

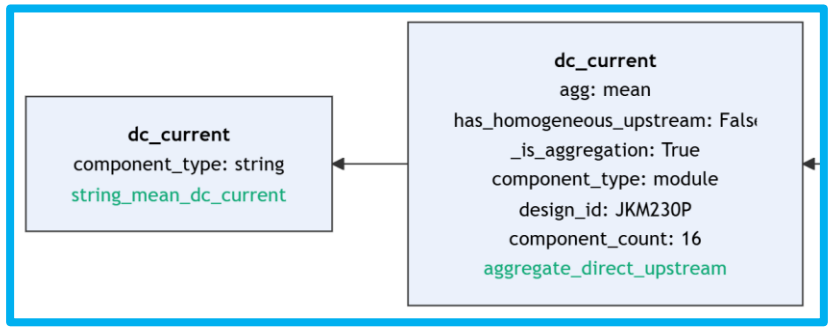
FROM LAYOUT TO COMPONENT GRAPH



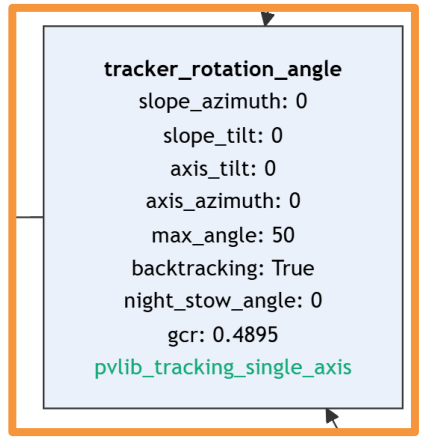
Here visible part of Block 1 (of 8).
Full graph has 1000 nodes.

MODEL CHAIN

Aggregation: from 16 Module currents to 1 string



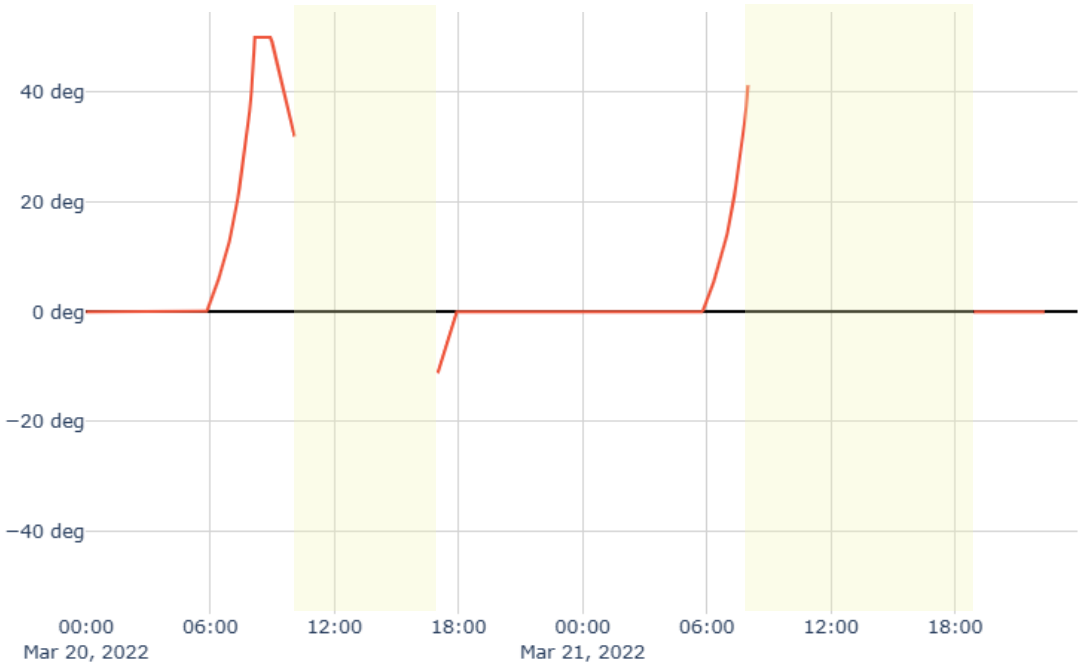
Pvlib wrappers



Insert measured data

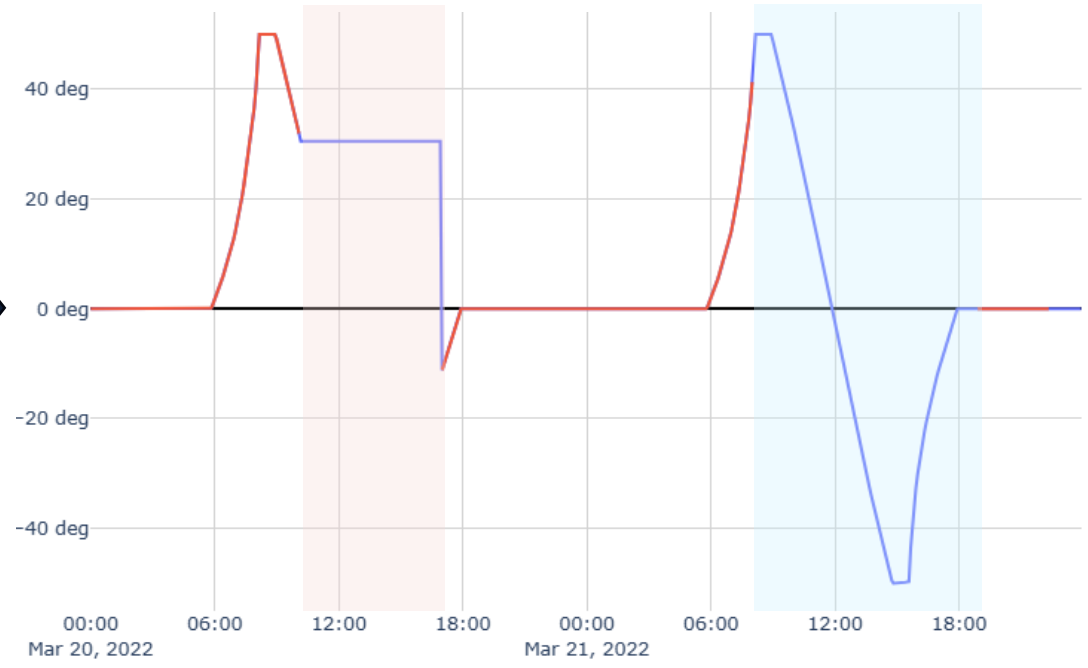
CASE 1: DATA GAPS MAY RESULT FROM EITHER A TRACKER STALL OR A COMMUNICATION LOSS

Tracking angles are available but **have gaps.**
Is the tracker stuck or just not communicating?



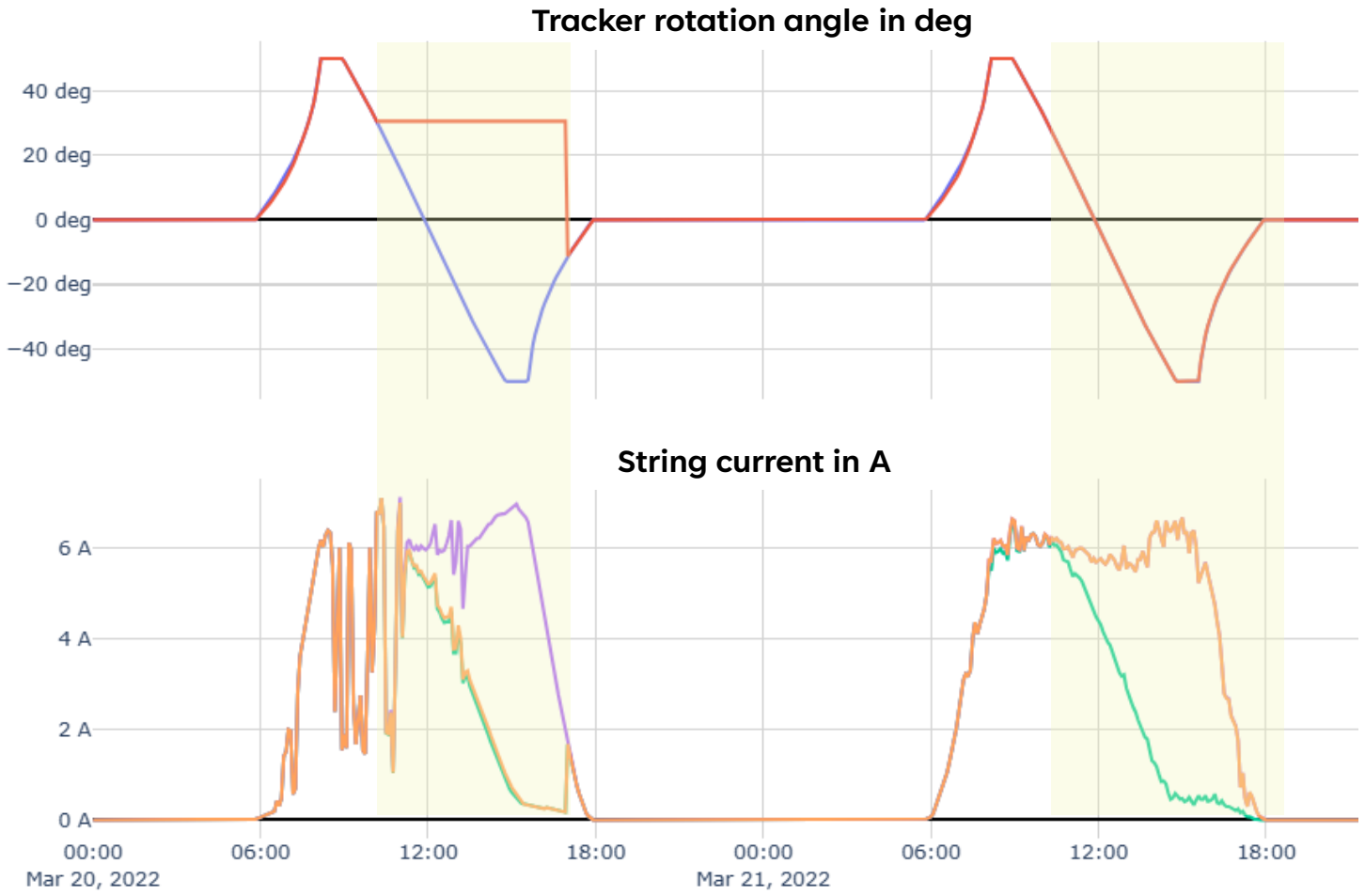
Tracker stall

Just communication error



Goal: Take decision for entire gap

CASE 1: COMPARE SCENARIOS WITH MEASUREMENT AND TAKE DECISION



Angle assumed **ideal** in gap

Angle assumed **stuck** in gap

Measured string current

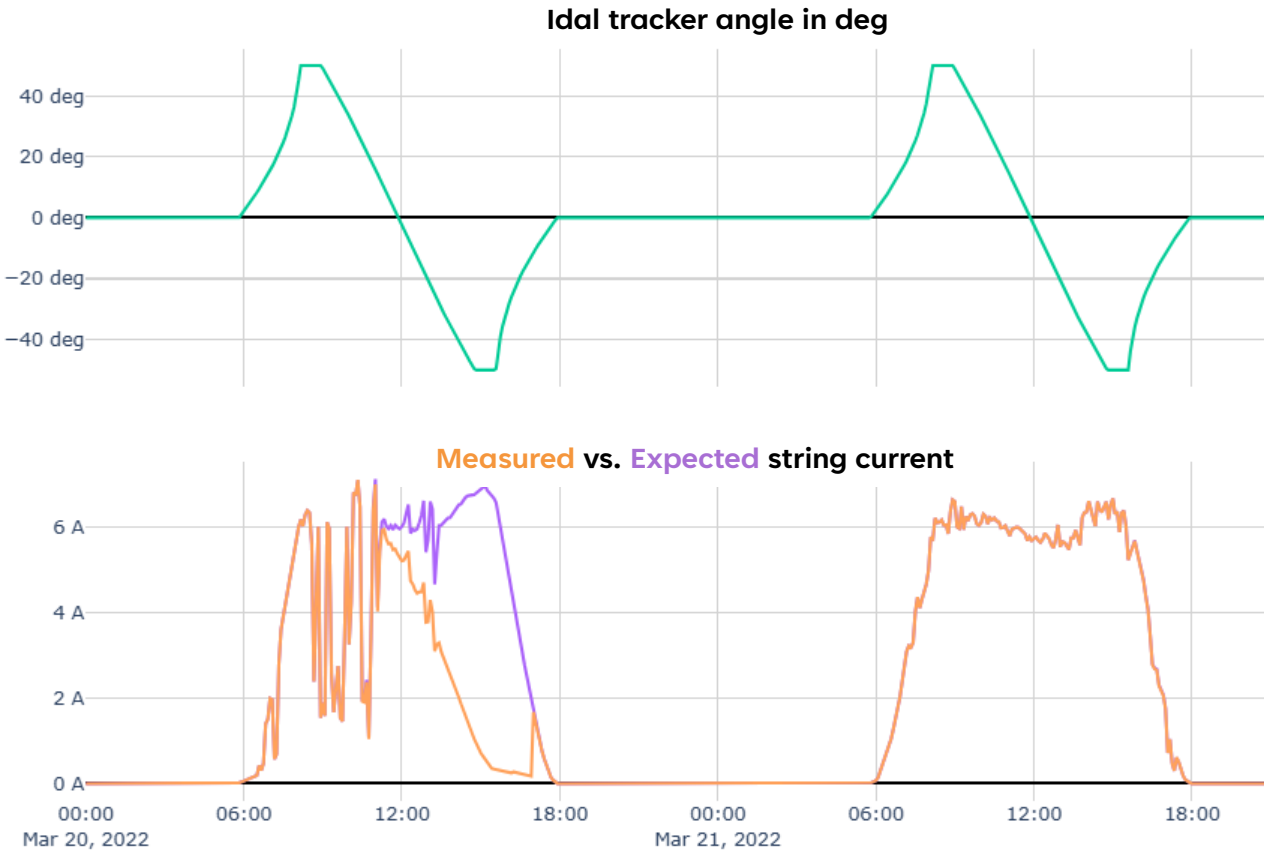
String current if ideal

String current if stuck

Decision: **stuck**

Decision: **communication**

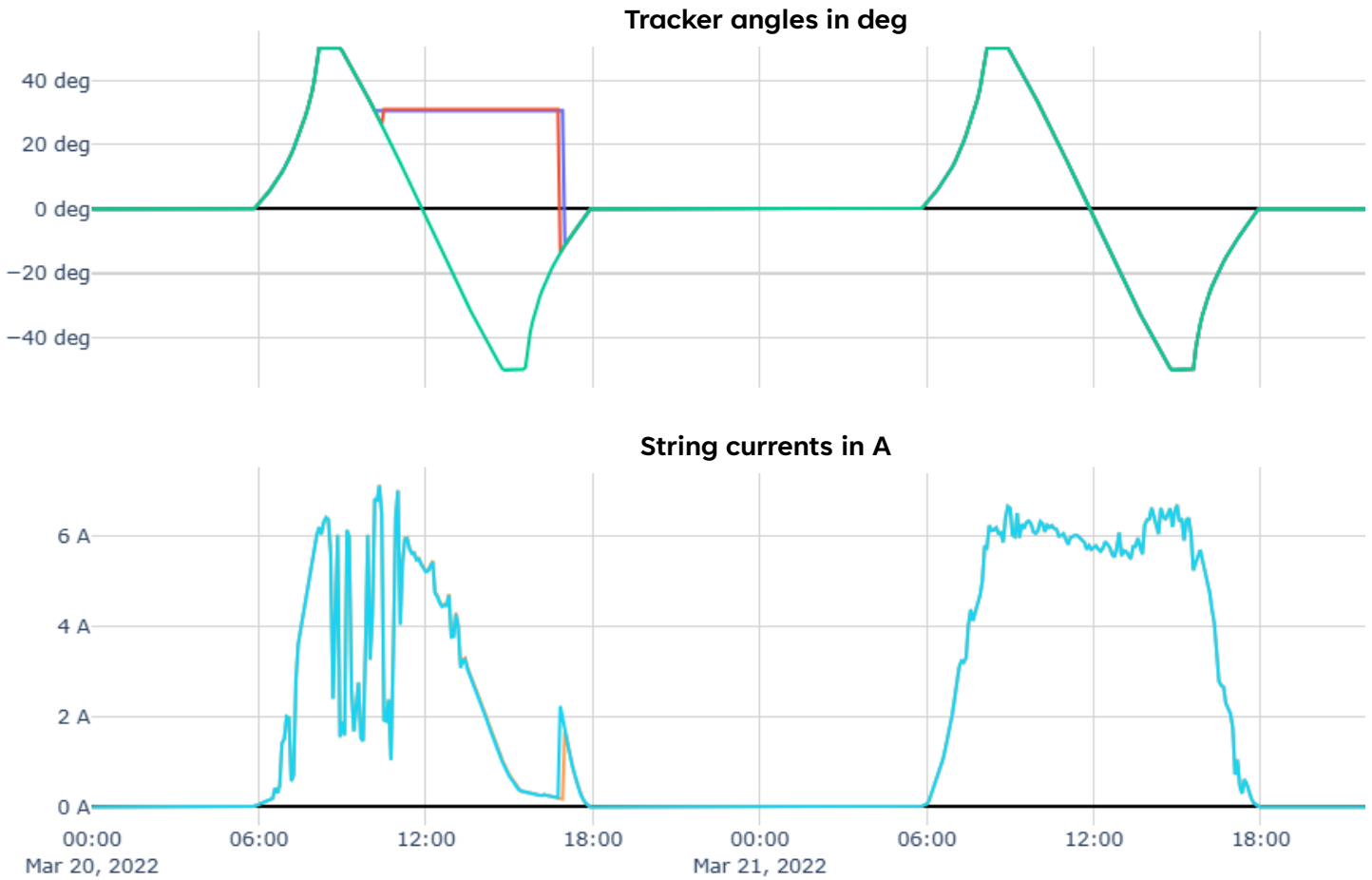
CASE 2: IS IT POSSIBLE TO RECONSTRUCT A TRACKER ANGLE WITHOUT ANY TRACKER ANGLE MEASUREMENTS?



Idea:

1. Go timestamp by timestamp
2. Compare measured and expected string current.
3. Detect persistent deviations
4. Calculate expected currents for all possible angles
5. For each stuck period, find best matching angle
6. Resume normal tracking once measured and expected behavior align again.

RECONSTRUCTED TRACKER ANGLES



True angle

Reconstructed angle

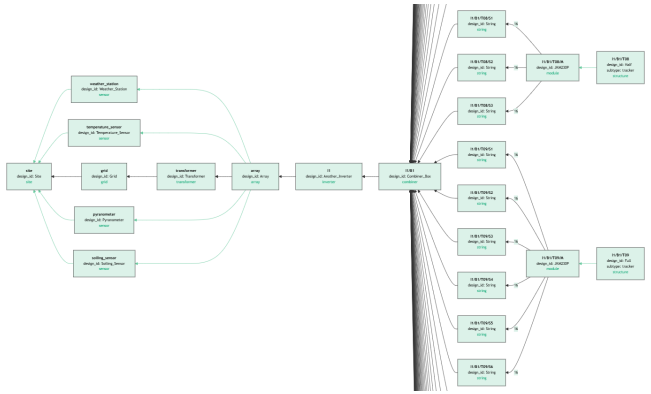
Ideal / Normal angle

Measured string current

Reconstructed string current

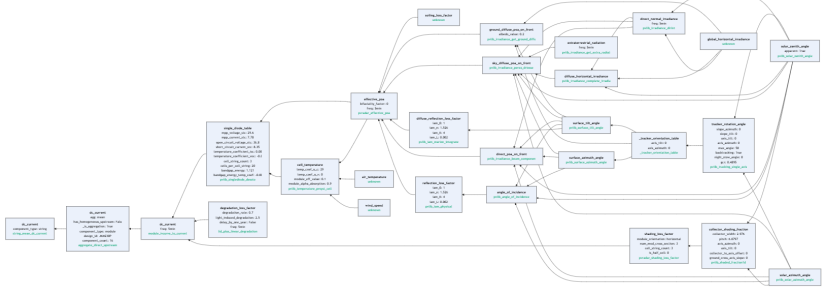
APPLY TO ENTIRE ASSET MODEL: FULL LOSS WATERFALL

Component Graph



+

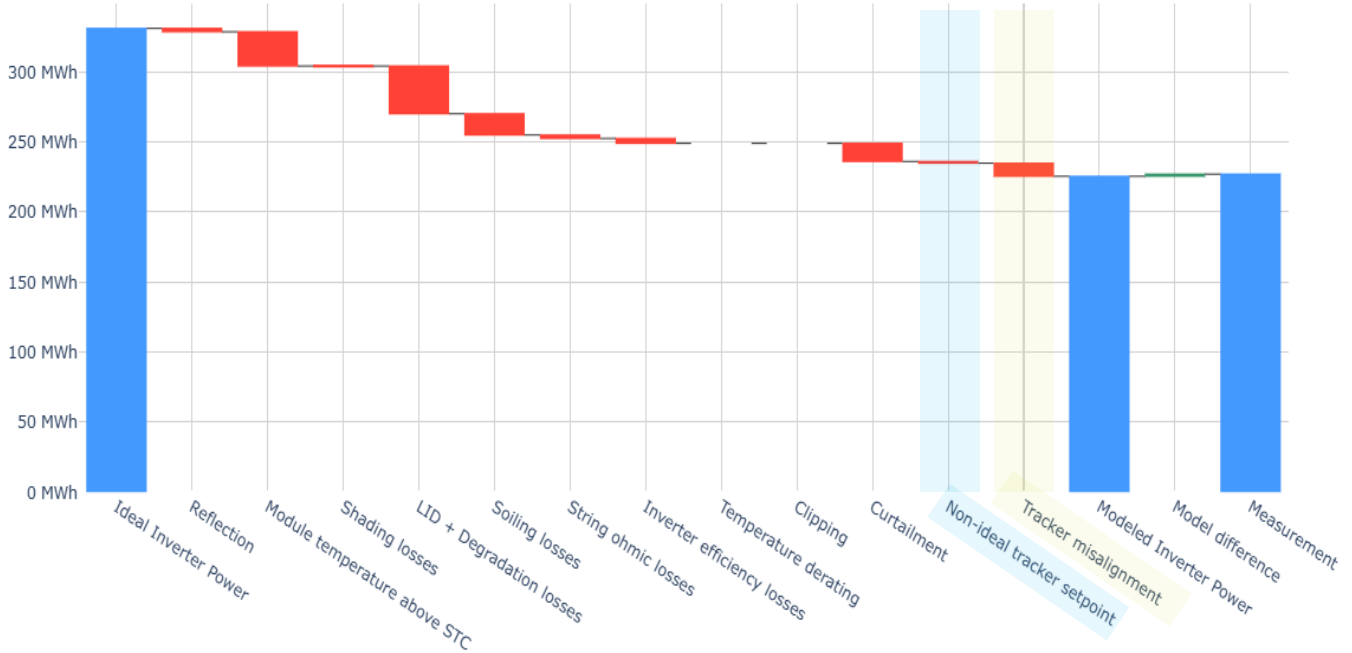
Model Chain



User defined loss waterfall

```
site.step_table(
    steps=my_custom_steps
    ).make_waterfall_table()
```

Python



SUMMARY OF RESULTS FOR 1-YEAR OF SYNTHETIC DATA

		Case 1	Case 2
Accuracy	% classified correctly	96.8%	96.5%
Precision	% predicted stuck correct	93.6%	100.0%
Recall	% actual stuck correct	89.5%	70.5%
Specificity	% actual normal correct	98.6%	100.0%

Case 1 Decision based on data gap beign either stuck or normal

Case 2 Decision for every timestep based on reconstructed tracker angles

Requirements: Good quality high resolution data
Good undestanding of other losses

Would you like to see this approach applied to your data? Contact us!

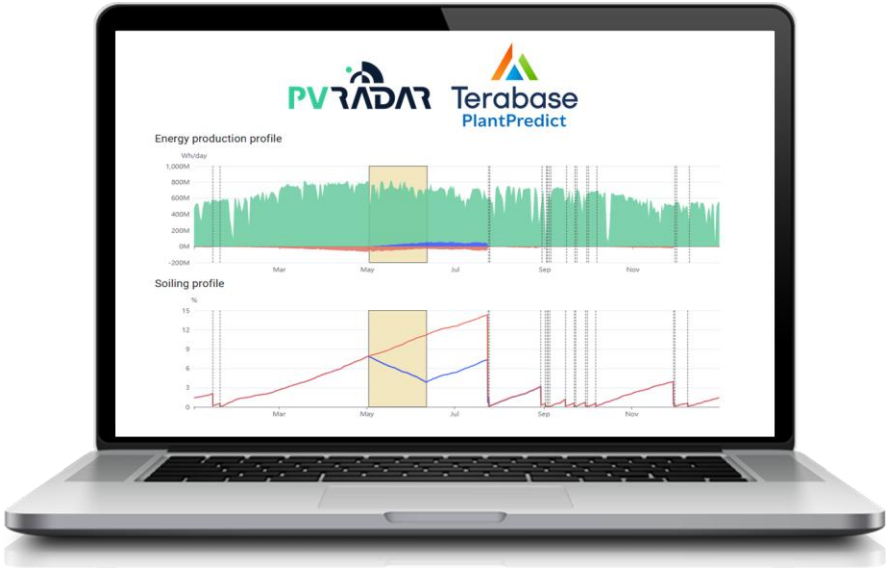
START USING PVRADAR TODAY

Build internal tools

- **SDK available on PyPI**
  pip install pvradar-sdk
- **Request free API key**
  from pvradar.com
- **Example notebooks**
  available for download
- **Component-based modeling approach requires additional packages,** contact us for a demo

Model soiling based on our proven soiling model

De-risking soiling from day 1 of development



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Thank you!

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