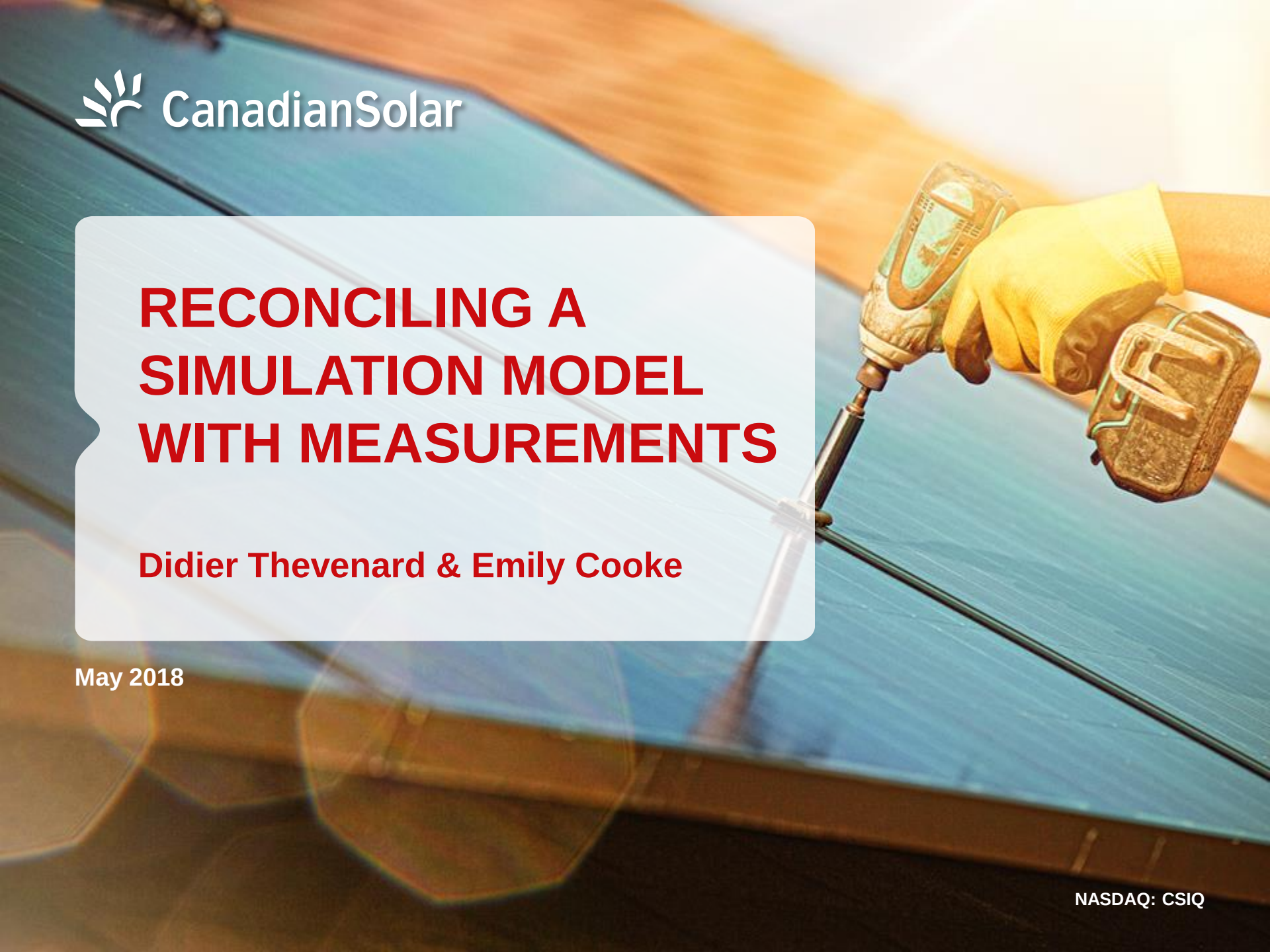


CanadianSolar

RECONCILING A SIMULATION MODEL WITH MEASUREMENTS

Didier Thevenard & Emily Cooke

May 2018

Objective

- **Starting point: as-built PVsyst model**
  - Typically used in financial model
  - Has two major components:
    - The climate file (with horizontal irradiance)
    - The plant model itself
- **The question: do operational data agree with the plant model?**
  - The original model is run with actual weather data
  - Some parameters are adjusted until the simulation agrees with measured data
- **Method**
  - Canadian Solar's own simulation tool, CASSYS, is used
  - Freeware and open-source: **http://canadiansolar.github.io/CASSYS/**
  - Program was developed first and foremost for use in Operations
  - Inputs and underlying model are very similar to PVsyst
    - Some alternate models are available
    - Can be run with any time step and in batch mode

Test dataset and original PVsyst model

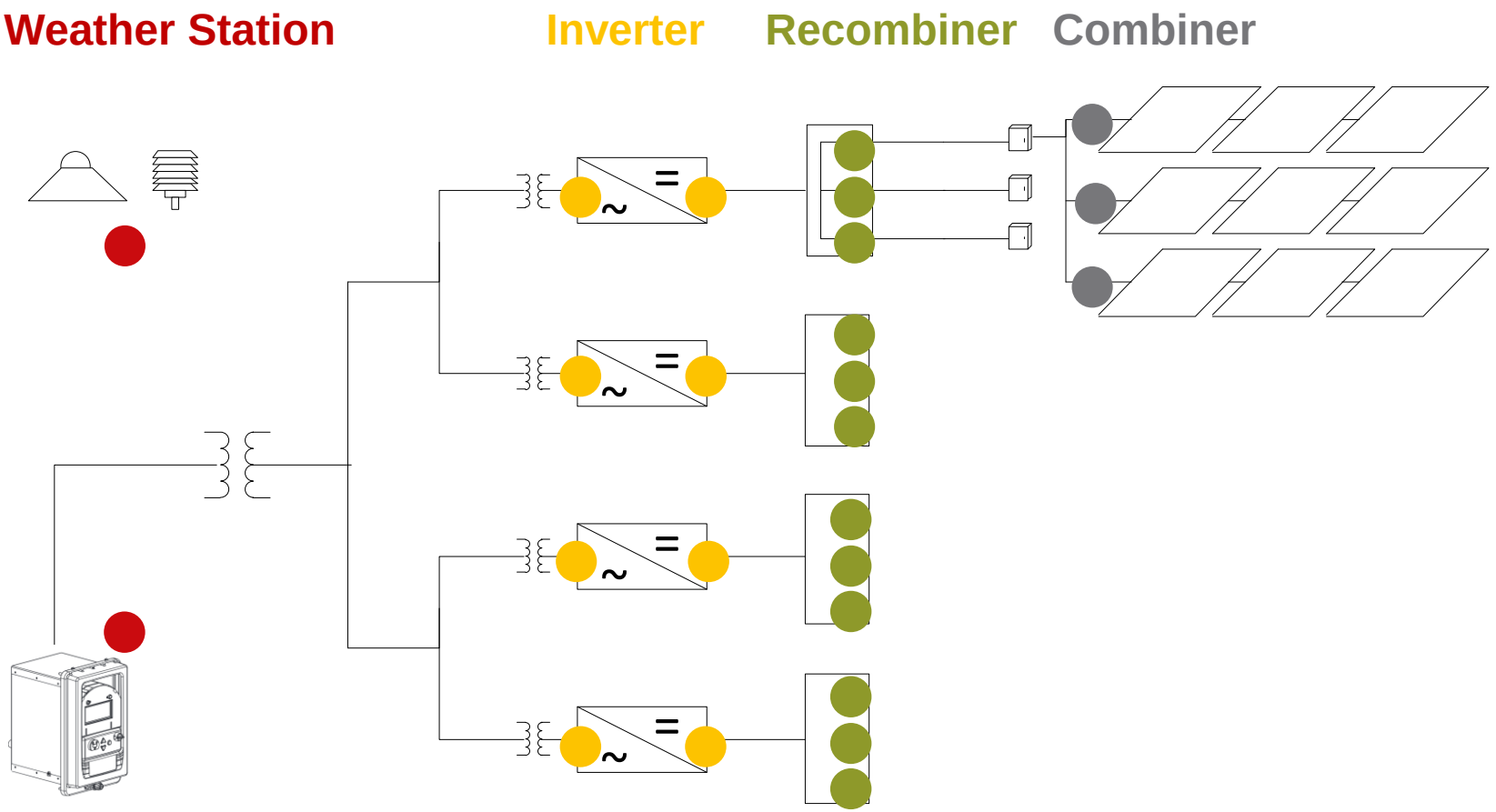
The test dataset

- Site in Eastern Ontario
- 10 MWac, 14 MWdc
- 13 x 769 kW SMA inverters
- 46,656 Canadian Solar CS6X panels
- Fixed orientation (28° facing South)
- Data averaged and recorded every **5 minutes**
- **Year 2** of operation is used

The original PVsyst model

- Heat loss factor: 29 W/m2·K
- DC losses: 1.5% at STC
- AC losses: 1.5% at STC
- Transformer losses: 0.3% iron loss, 1.6% resistive/inductive loss
- Other losses: Quality: 1.6%, Mismatch: 1%, Soiling: 0.5%
- Hourly data

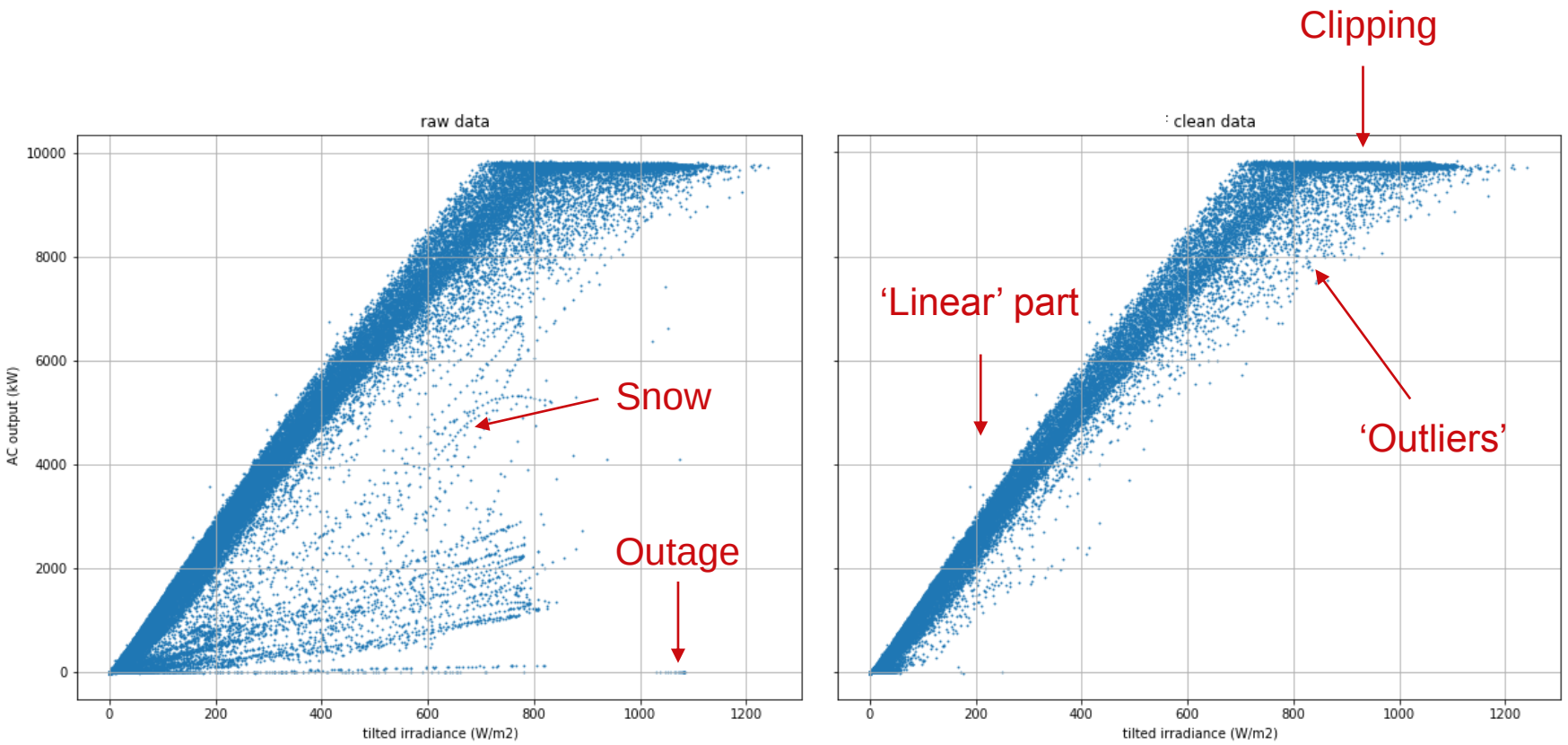
Instrumentation and Data Collection



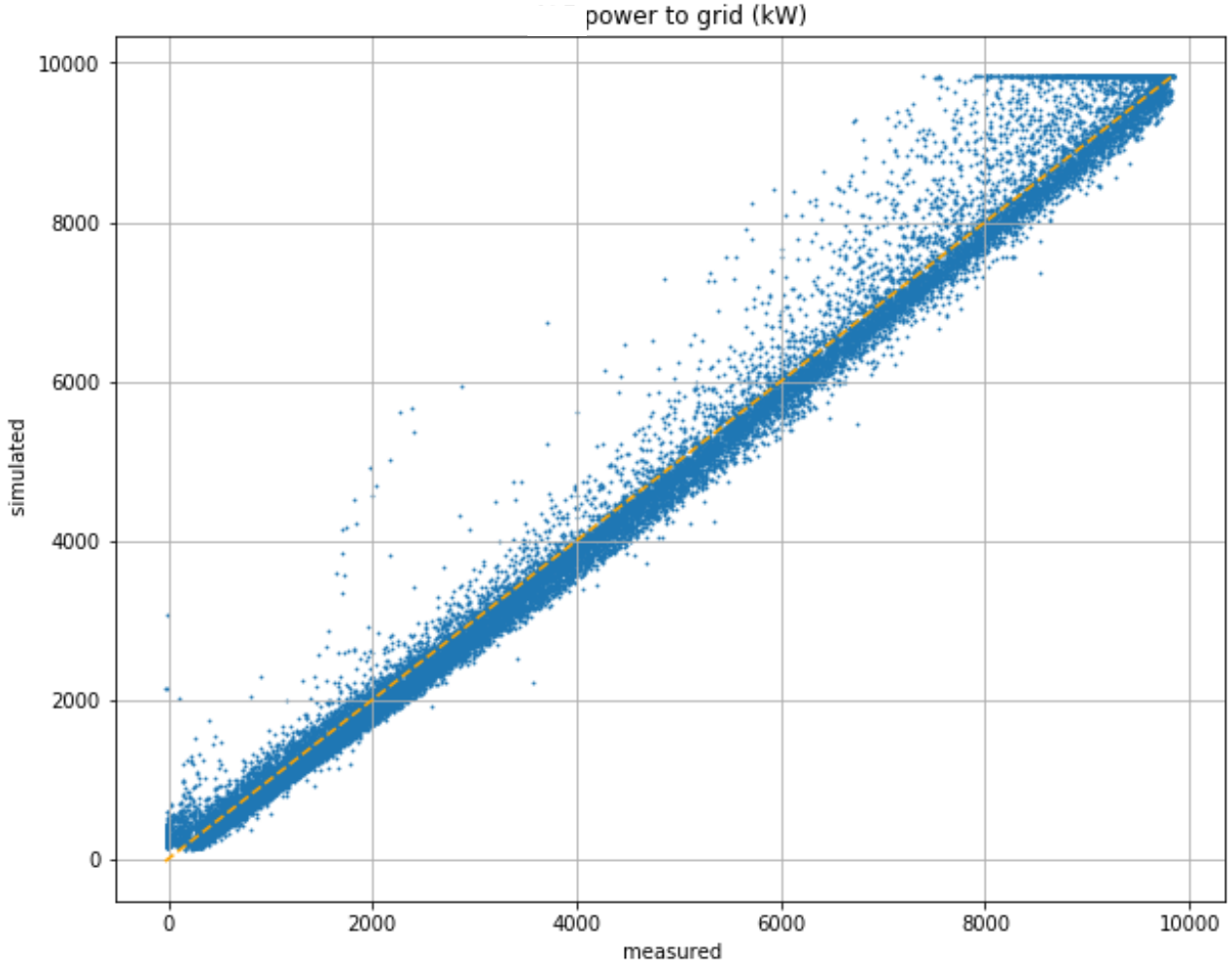
Increasing number of sensors, decreasing quality of measurement

Data cleaning

Periods with events are removed to obtain a clean dataset

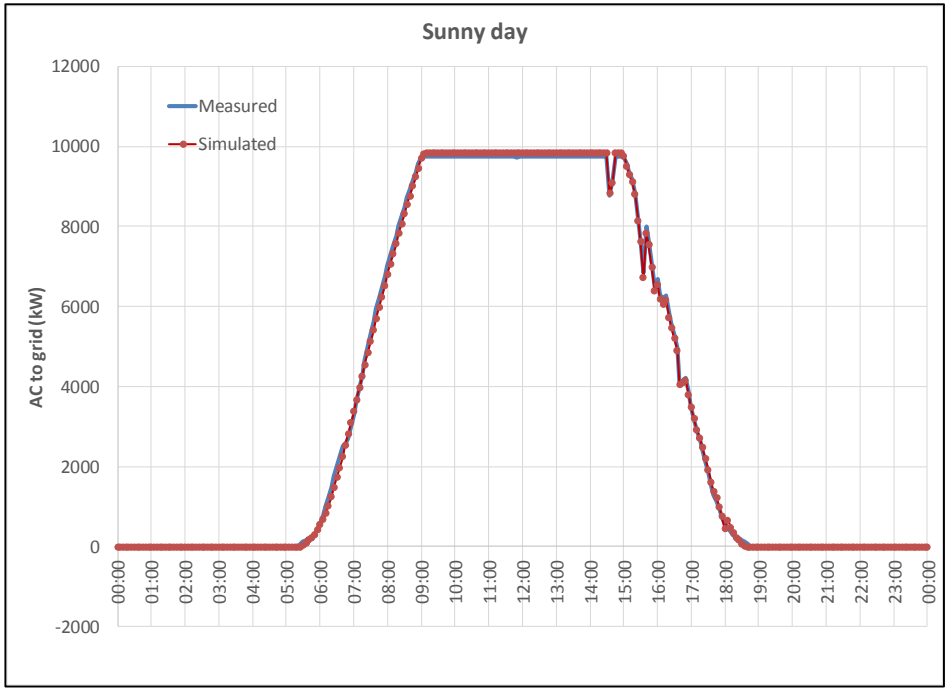


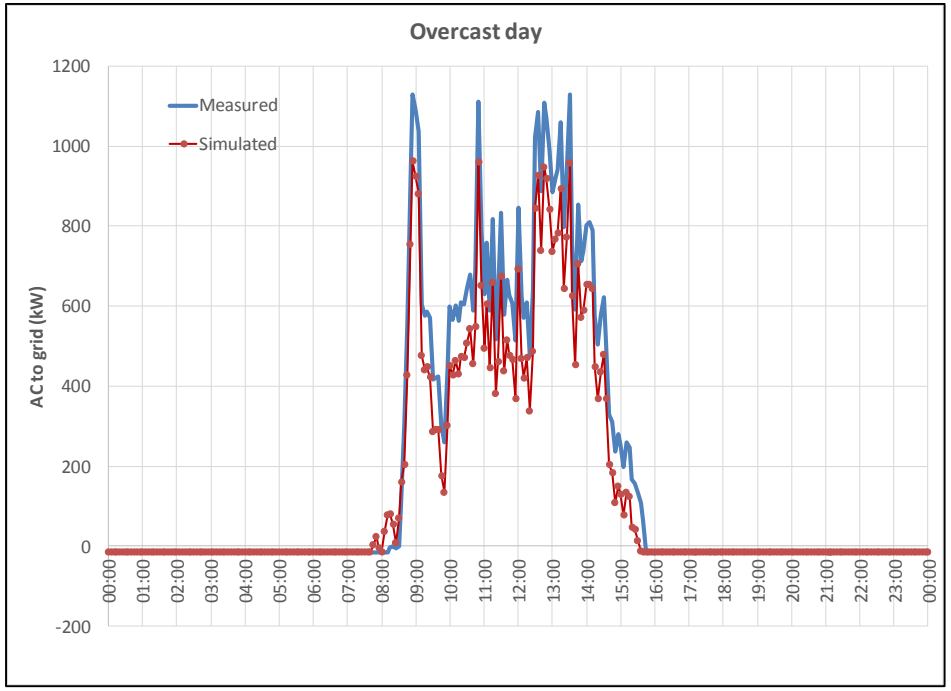
The unadjusted simulation



MBE = -0.48%
RMSE = 6.5%

The unadjusted simulation (cont'd)





Step-by-step adjustment

Step 1: POA irradiance calculation

Step 2: DC side

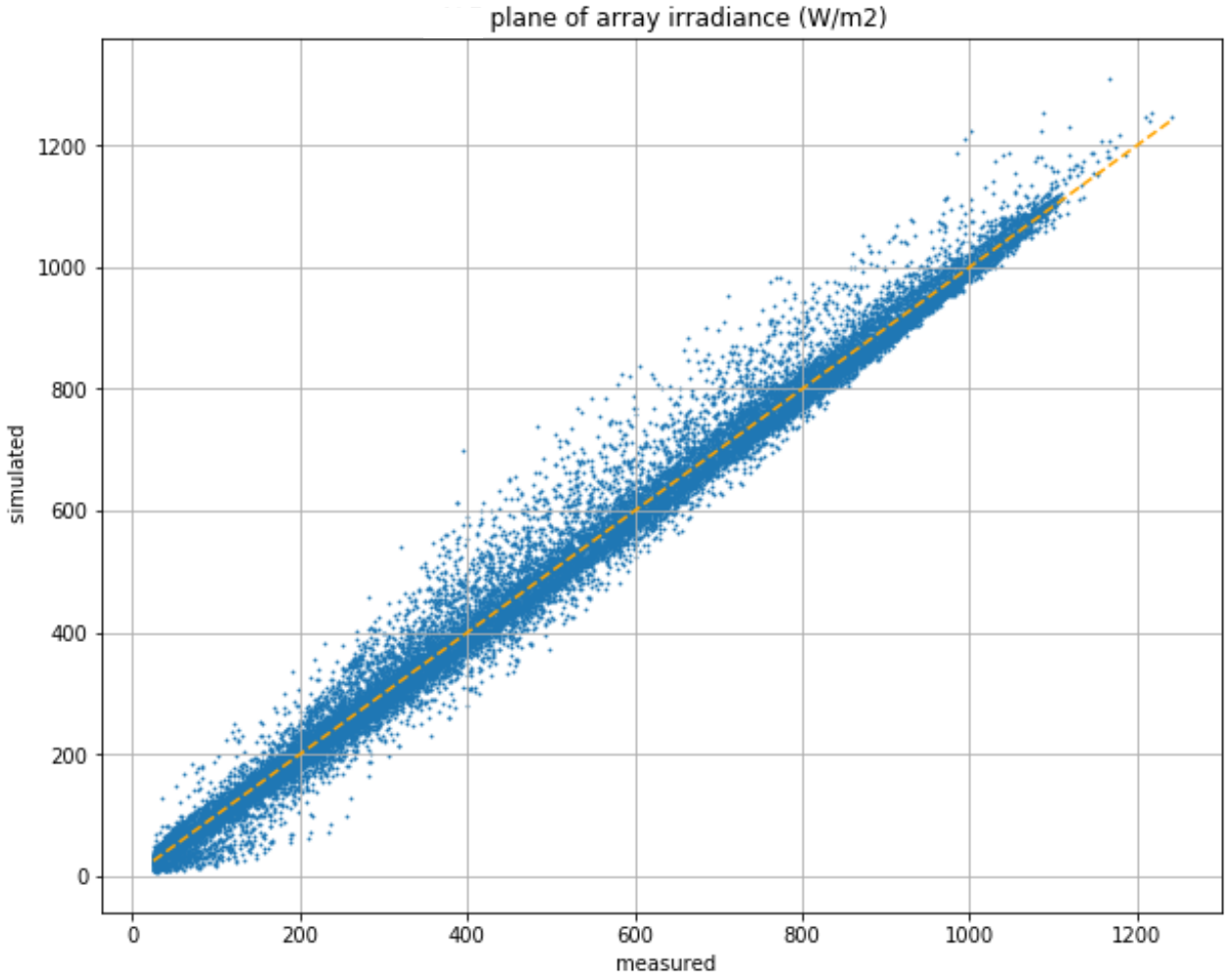
Step 3: Inverter

Step 4: AC side

Step 5: Effect of averaging period

Conclusion

POA irradiance

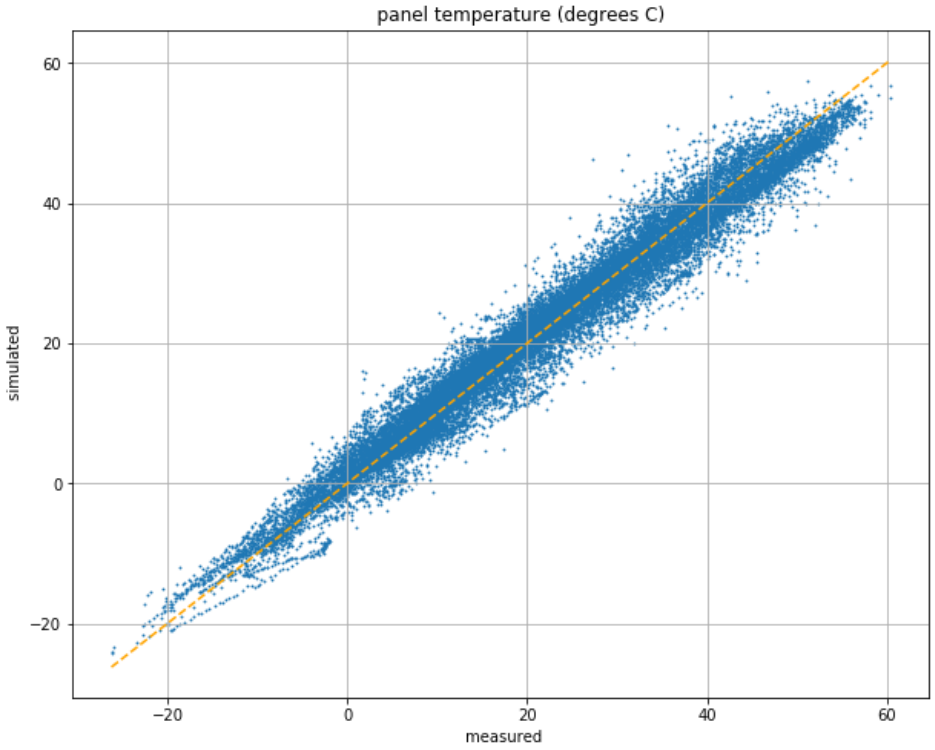


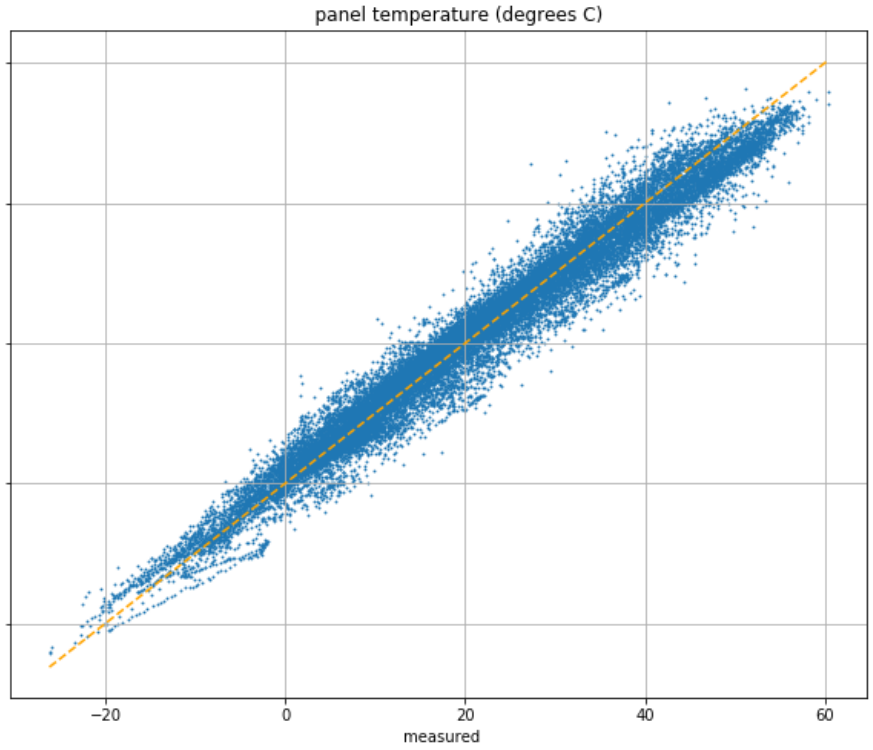
MBE = 0.83%
RMSE = 7.8%

Step-by-step adjustment

- Step 1: POA irradiance calculation
- **Step 2: DC side**
- Step 3: Inverter
- Step 4: AC side
- Step 5: Effect of averaging period
- Conclusion

Panel temperature

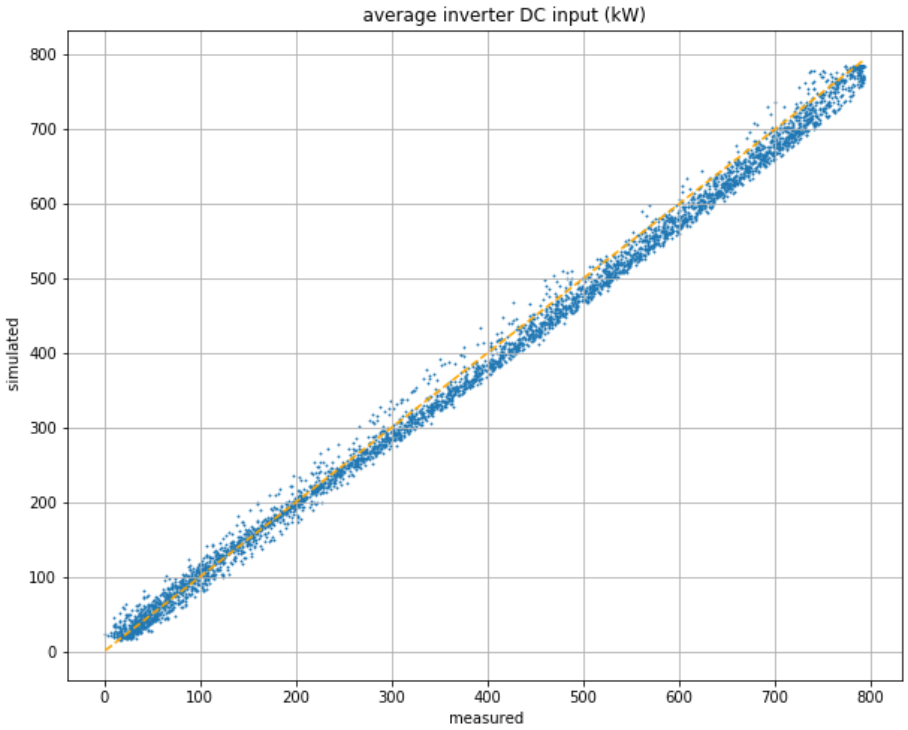


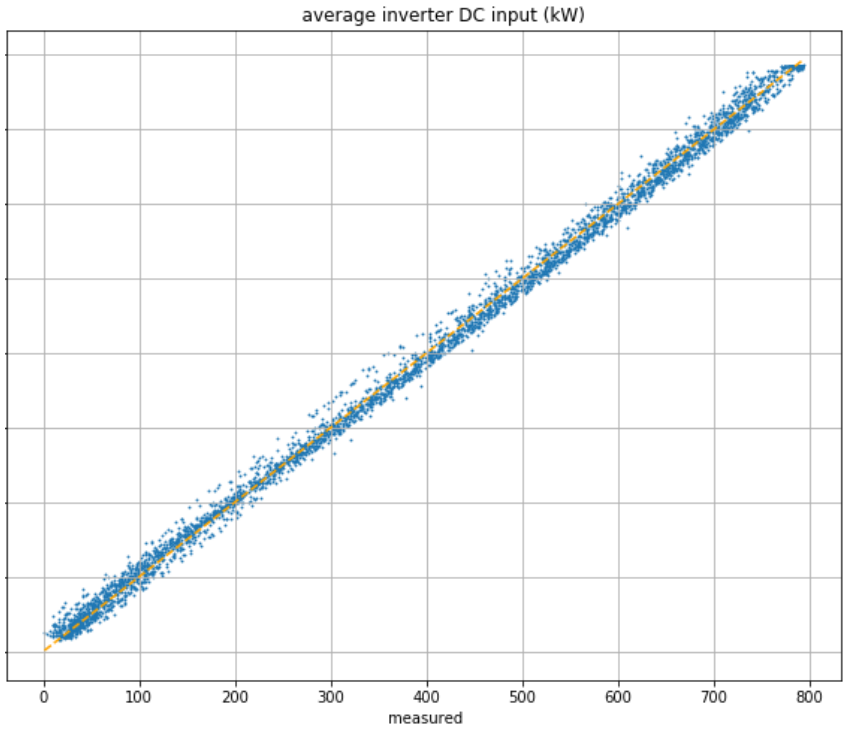


Heat loss factor = 29 W/m²/K
MBE = 0.3 °C
RMSE = 2.8 °C

Heat loss factor = 29.9 W/m²/K
MBE = 0.0 °C
RMSE = 2.8 °C

DC calculations – clear day, non clipping

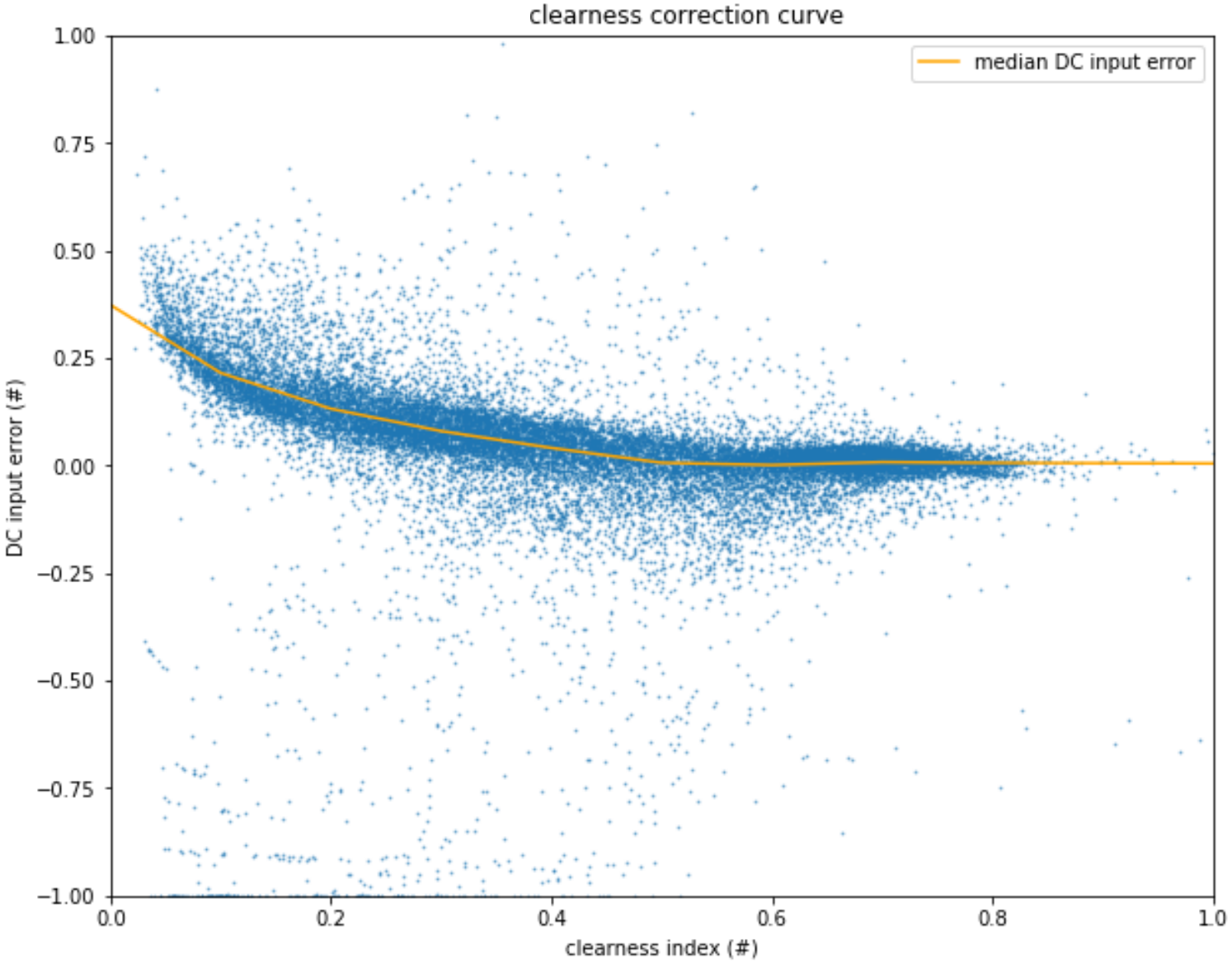




Quality loss = 1.6%, mismatch loss = 1%
MBE = -2.5%
RMSE = 4.7%

Quality loss = -1.3%, mismatch loss = 0%
MBE = 0%
RMSE = 3.2%

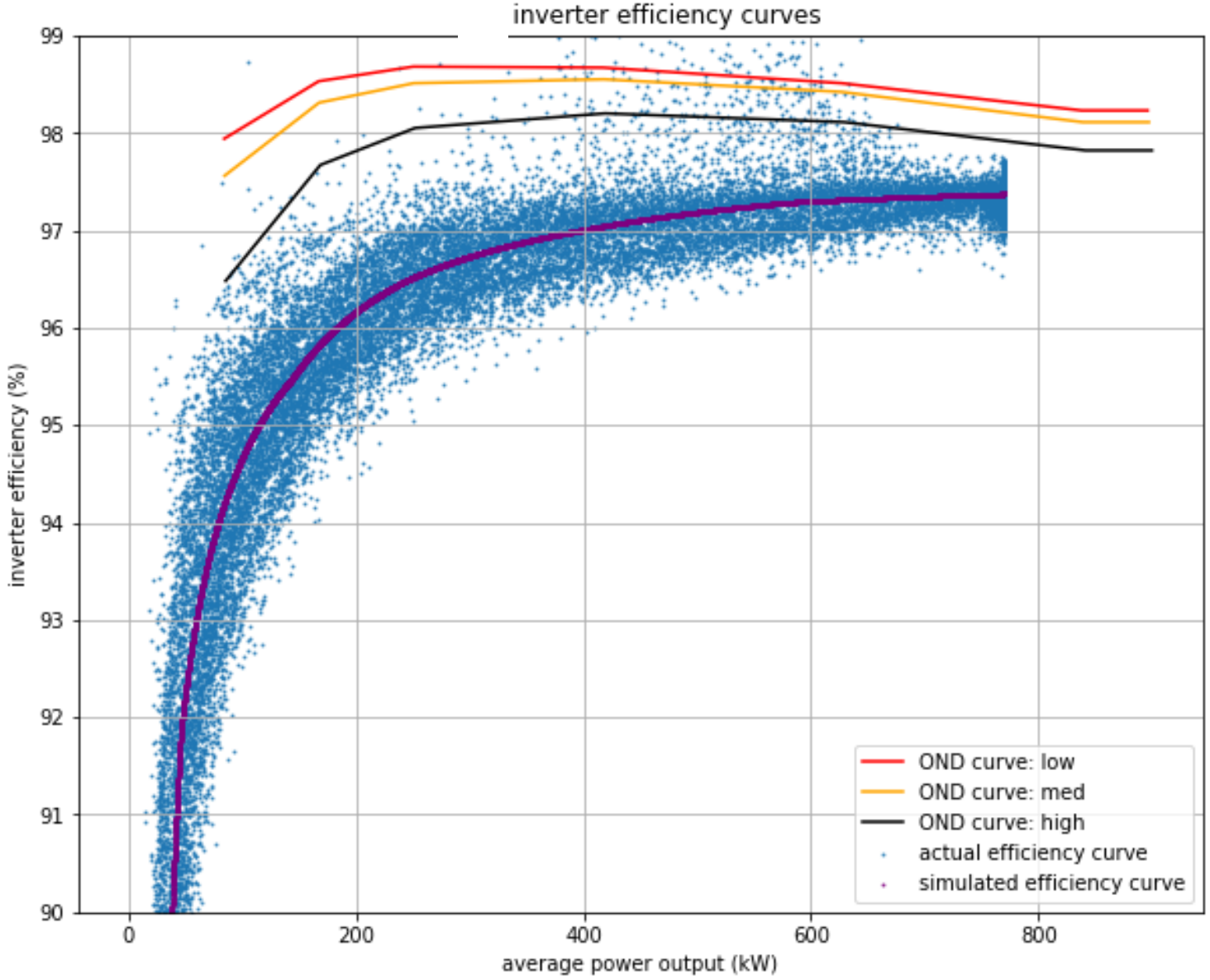
‘Spectral’ correction



Step-by-step adjustment

- Step 1: POA irradiance calculation
- Step 2: DC side
- **Step 3: Inverter**
- Step 4: AC side
- Step 5: Effect of averaging period
- Conclusion

Inverter


inverter efficiency curves
inverter efficiency (%)
average power output (kW)
99
98
97
96
95
94
93
92
91
90
0
200
400
600
800
OND curve: low
OND curve: med
OND curve: high
actual efficiency curve
simulated efficiency curve

Step-by-step adjustment

- Step 1: POA irradiance calculation
- Step 2: DC side
- Step 3: Inverter
- **Step 4: AC side**
- Step 5: Effect of averaging period
- Conclusion

AC side – Transformer Info

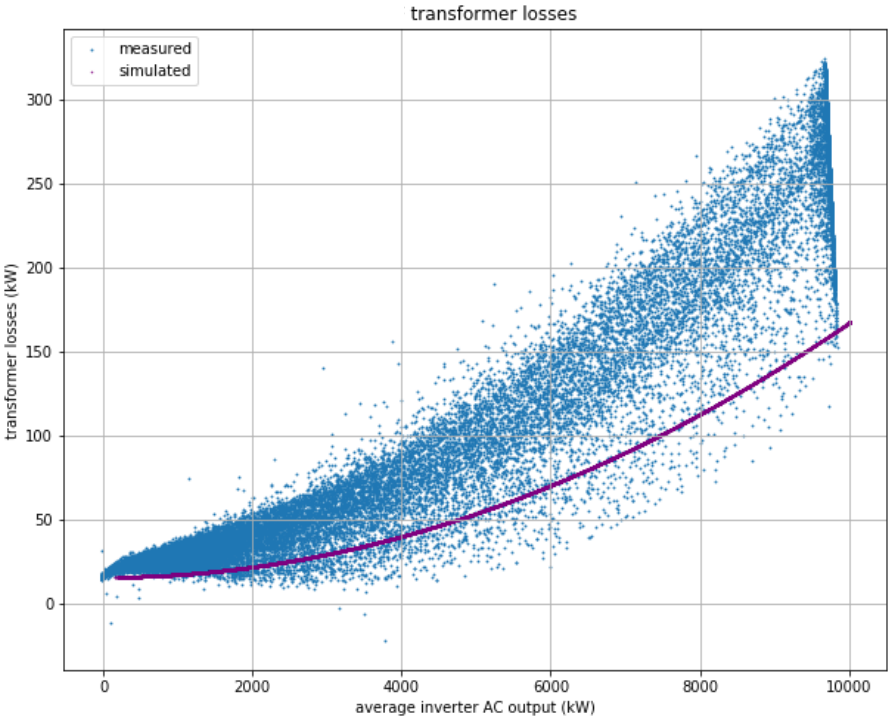
- Transformer test data is available from as-built documentation
- Provides no-load loss and full-load loss

RFORMANCE DATA

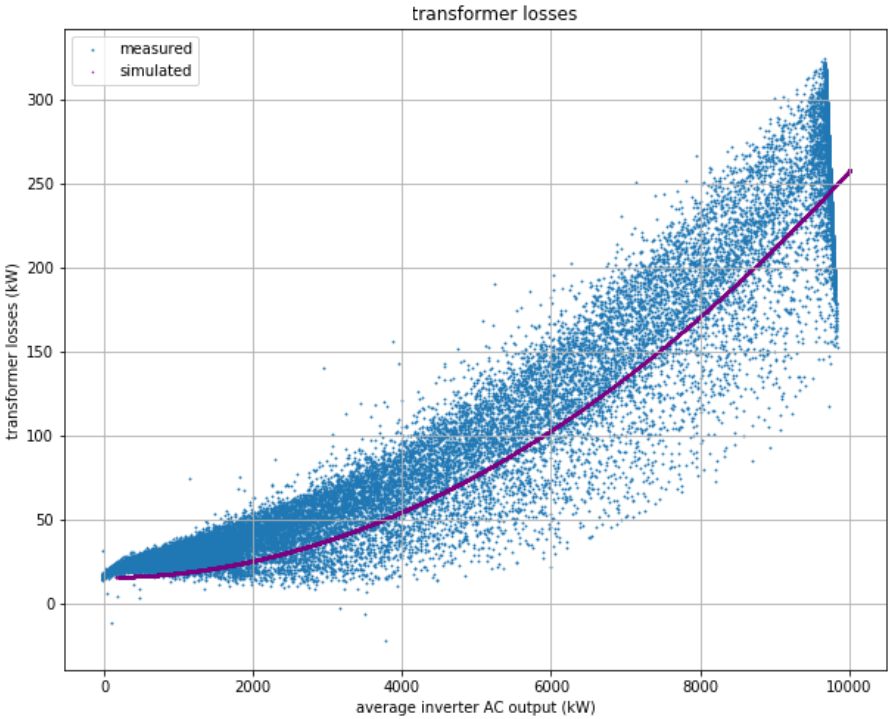
Test Title	Result		Test Title	Result
Core Loss (watts)	**1282**	@ 85 deg. C	IX (%):	**4.06**
Winding Loss (watts)	**13814**	@ 85 deg. C	IR (%):	**0.86**
Total Loss (watts)	**15096**		X / R Ratio	**4.72**
Efficiency @ 25%:	**99.46%**		System Impedance (%):	**4.15**
Efficiency @ 50%:	**99.41**		Impedance (%) HL1:	**4.41**
Efficiency @ 100%:	**99.06**			

- Values can be entered directly into CASSYS
  - No-load loss **15.6 kW**
  - Total loss **132.1 kW**

AC side



AC wiring losses = 0.5%



AC wiring losses = 1.8%

Step-by-step adjustment

- Step 1: POA irradiance calculation
- Step 2: DC side
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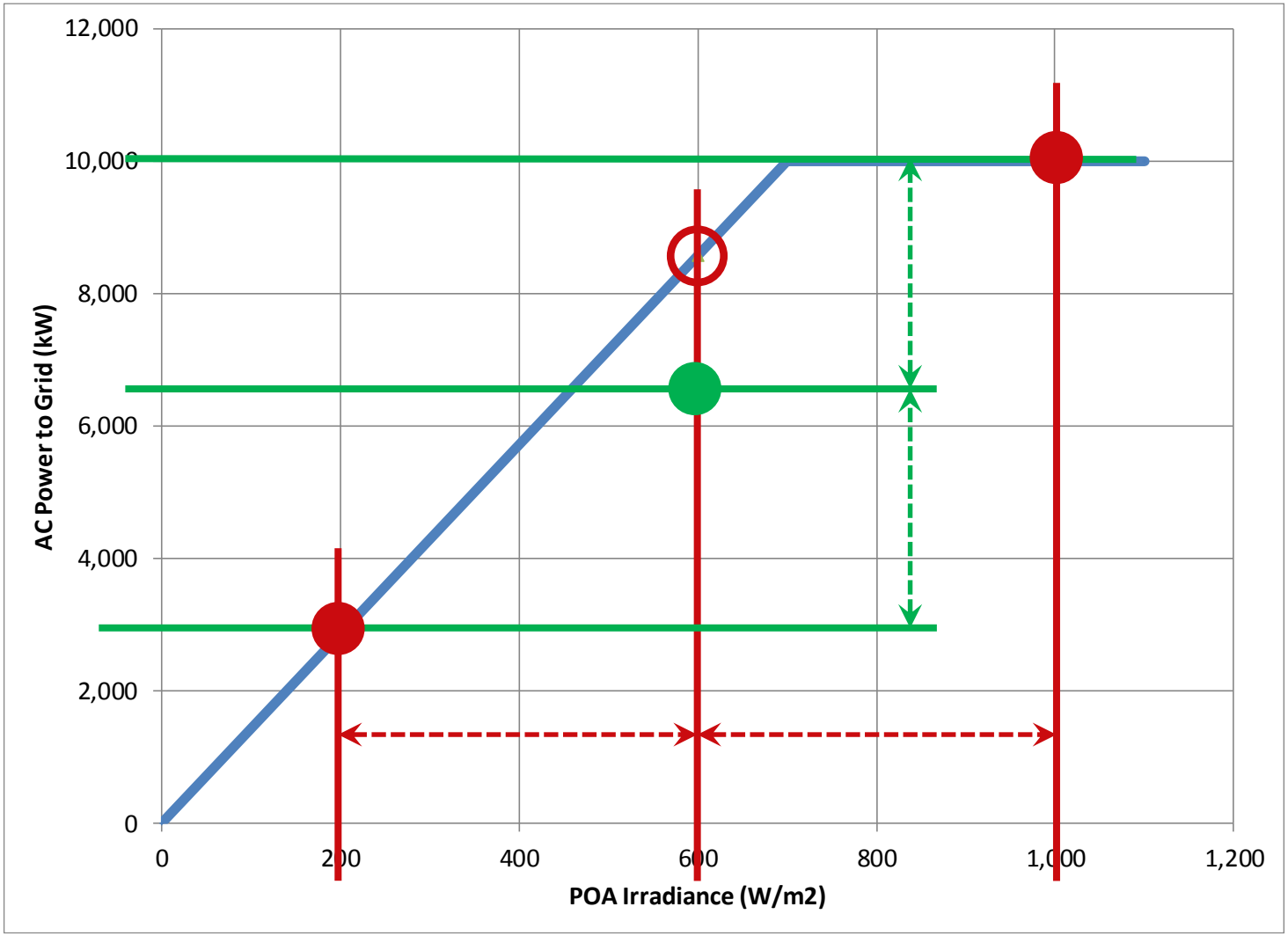
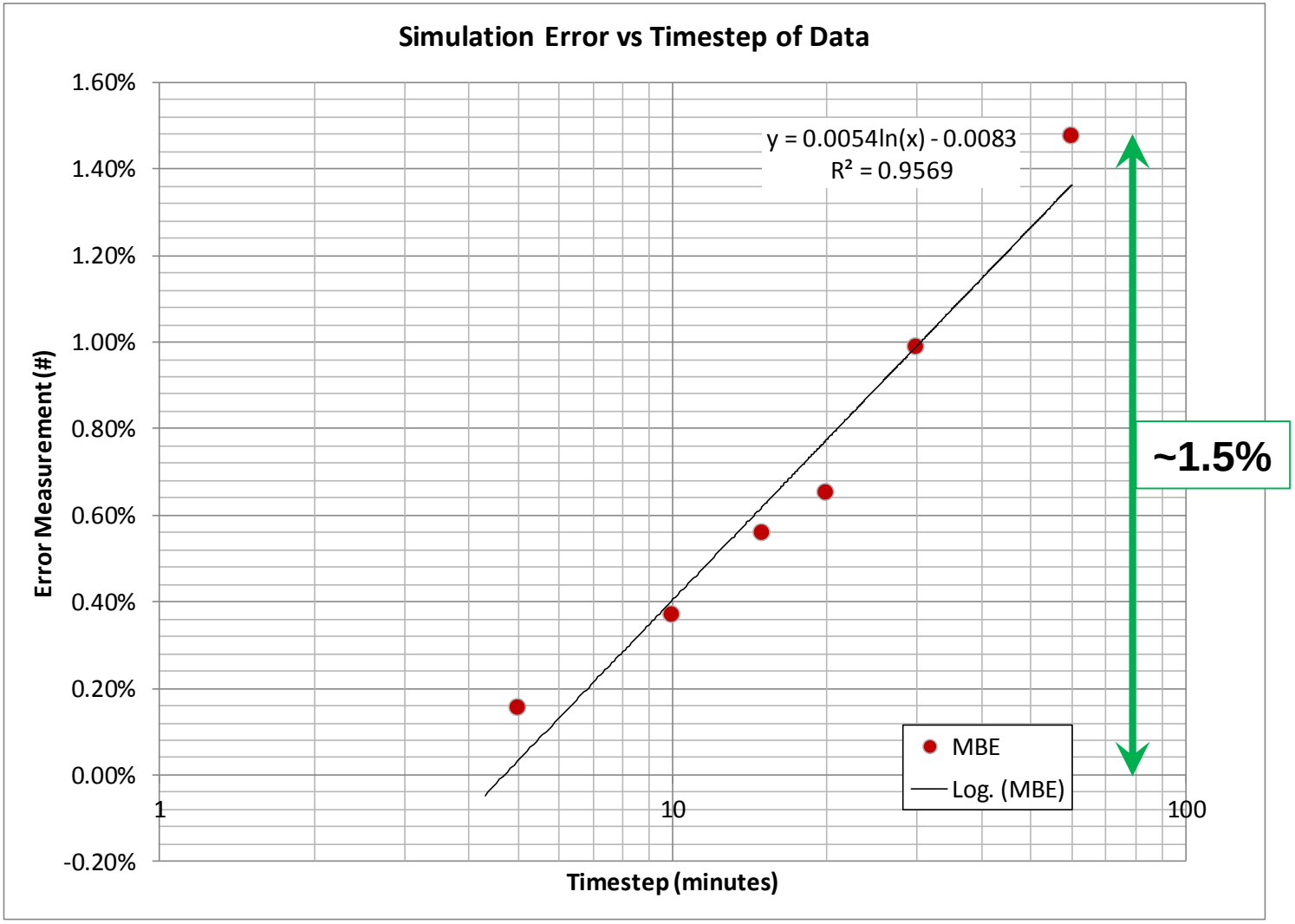
- Step 4: AC side
- **Step 5: Effect of averaging period**
- Conclusion

Effect of averaging period



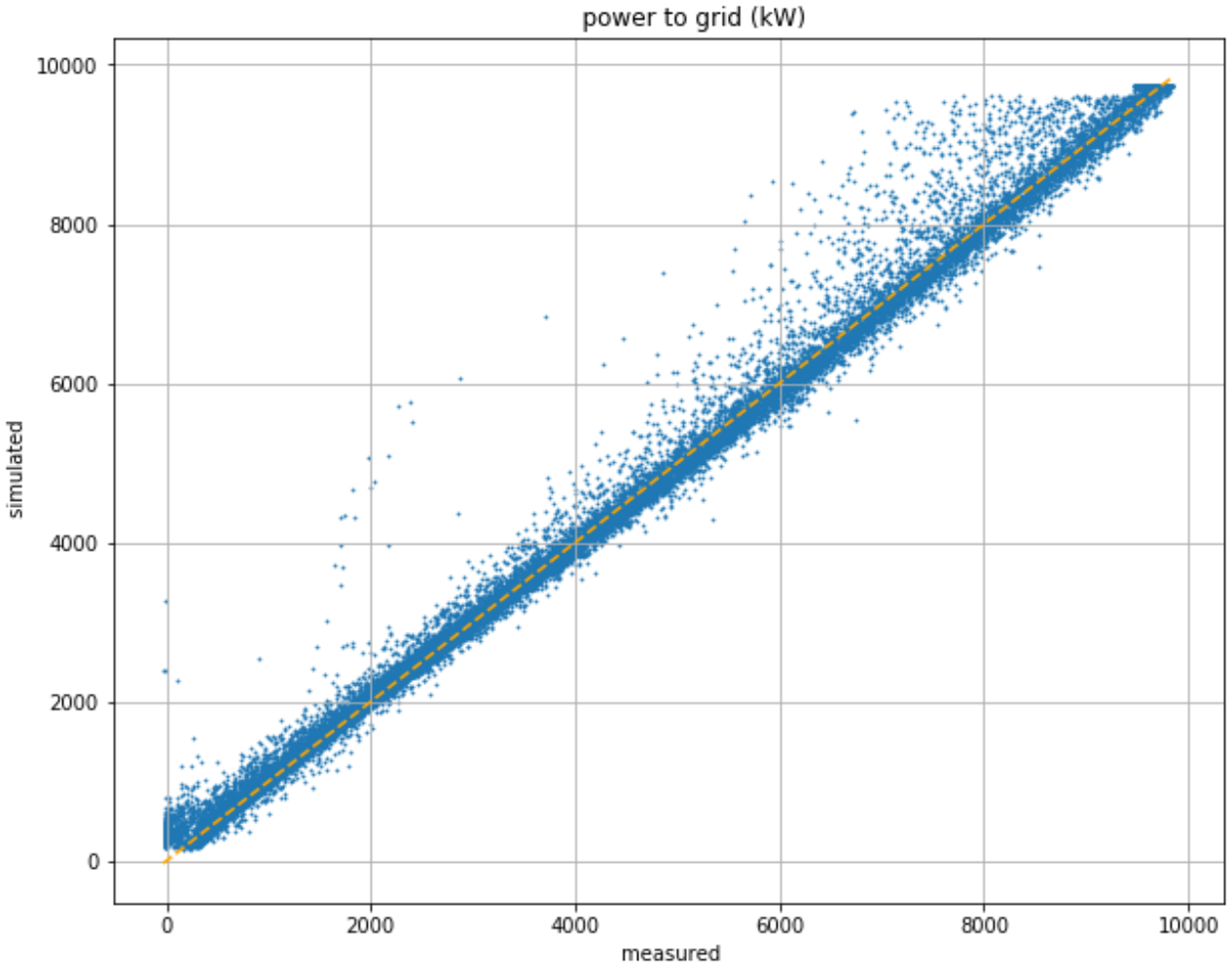
Effect of averaging period (cont'd)



Step-by-step adjustment

- Step 1: POA irradiance calculation
- Step 2: DC side
- Step 3: Inverter
- Step 4: AC side
- Step 5: Effect of averaging period
- **Conclusion**

The adjusted simulation



MBE = 0%
RMSE = 5%

Conclusions

Adjustment procedure

- Enables to match simulation results to actual data
- Creates model that can be used for operational purposes

Don’t trust inverter data

- Even when averaging across all inverters, inaccuracy is high
- Resulting adjusted parameters are physically questionable
- Adjusting without using inverter data may actually lead to better results

Major takeaways from this exercise

- System efficiency varies significantly with clearness index (+1.5%)
- Use of hourly data leads to overestimation of output (-1.5%)

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QUESTIONS AND COMMENTS ARE WELCOME!

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