

Seesaw Algorithm: Data-Derived Clipping Irradiance Threshold

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INTRODUCTION

Popular approaches to assessing PV plant health include removal of timestamps where clipping occurs [1]. One technique, given in the RdTools Python package, is to filter power or energy data using a percentile cutoff [2].

This approach is overly simplistic because it fails to account for the fact that not all timestamps with sufficiently high irradiance are successful clipping events. Clipping is an instantaneous phenomenon. The true irradiance at which clipping occurs is unknown and changes in response to site conditions. A novel seesaw algorithm (SS) is proposed here to empirically derive the clipping threshold.

SETUP AND DATA

Experiment conditions

- 1MW site in SE USA
- 15 minutes data from 2018-2022
- Data filtered for missing irradiance and $POA > 825 \text{ W/m}^2$ [3]

Reference Equations

Clipping event =
 $\begin{cases} \text{True} & \text{AC Power} > \text{Max output}_{\text{INV}} * 0.98 \\ \text{False} & \text{AC Power} \leq \text{Max output}_{\text{INV}} * 0.98 \end{cases}$

Loss_{tot} = Modeled total losses up to inverter

Availability = String and inverters availability ratio

SS_{error} = Error adjusted by user-defined value [4] as per algorithm

I_{mes} = Measured irradiance

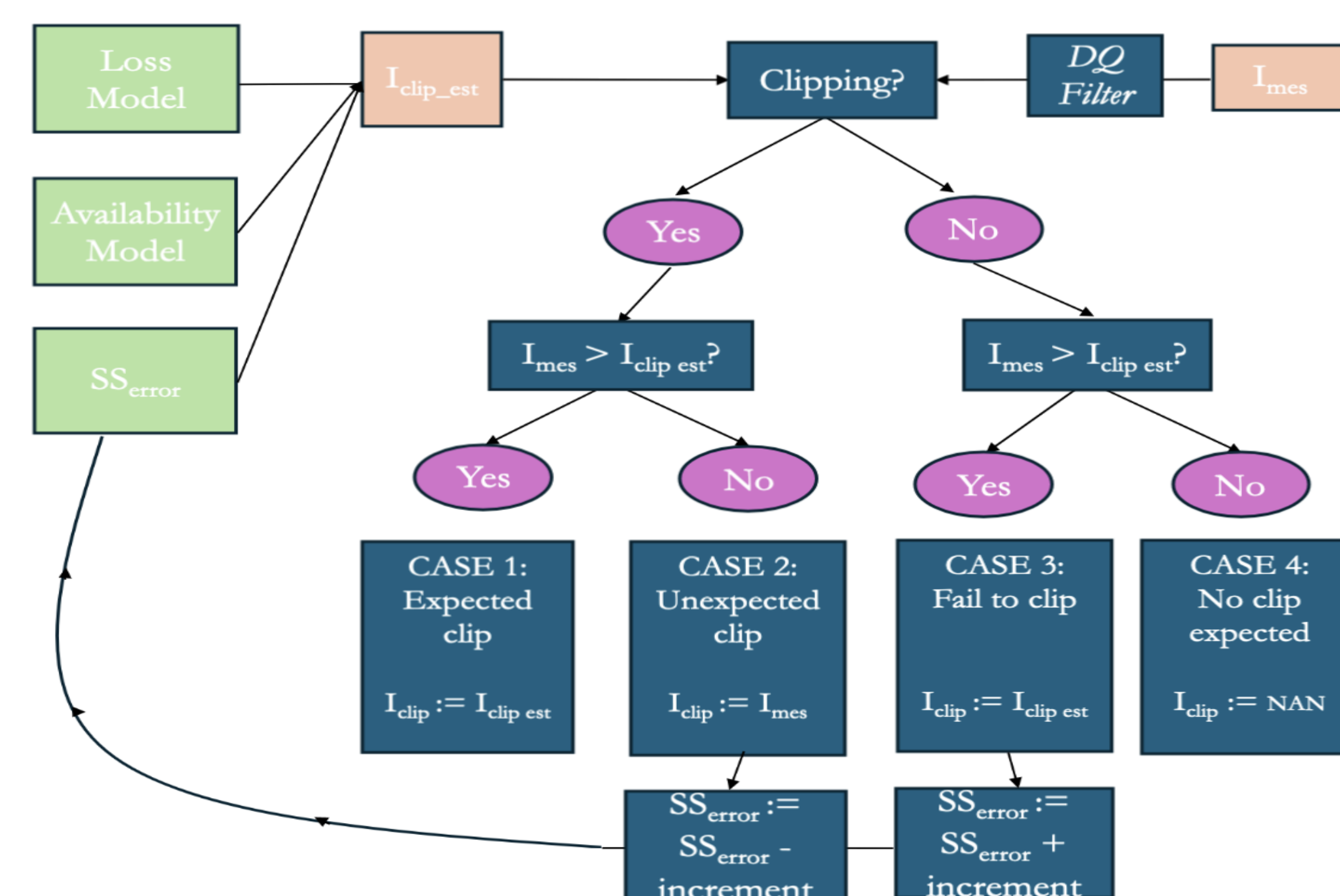
$$I_{\text{clip initial}} = \frac{\text{Plant capacity}_{\text{AC}} * 1000}{(1 - \text{Loss}_{\text{tot}}) * \text{Plant area}}$$

$$I_{\text{clip proj}} = I_{\text{clip initial}} * \left(1 + \frac{\text{Days of operation} * \text{Module degradation rate}}{365}\right)$$

$$I_{\text{clip est}} = \frac{\text{Plant capacity}_{\text{AC}} * 1000}{(1 - \text{Loss}_{\text{tot}}) * \text{Plant area} * \text{Availability}}$$

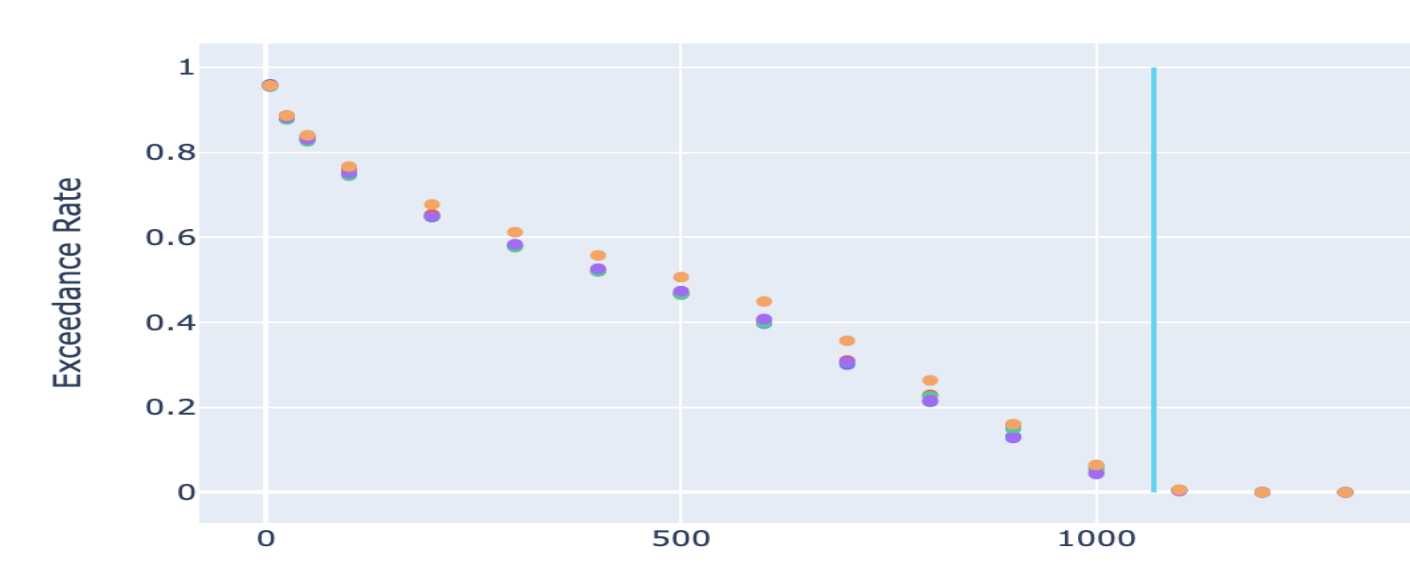
SEESAW ALGORITHM

The seesaw algorithm dynamically adjusts the irradiance at which clipping occurs (I_{clip}) by comparing the estimated clipping threshold to the measured irradiance at clipping success and failures. The algorithm enables a data-driven quantification of clipping losses, in contrast with a degradation-based assumption that the site data may not reflect.



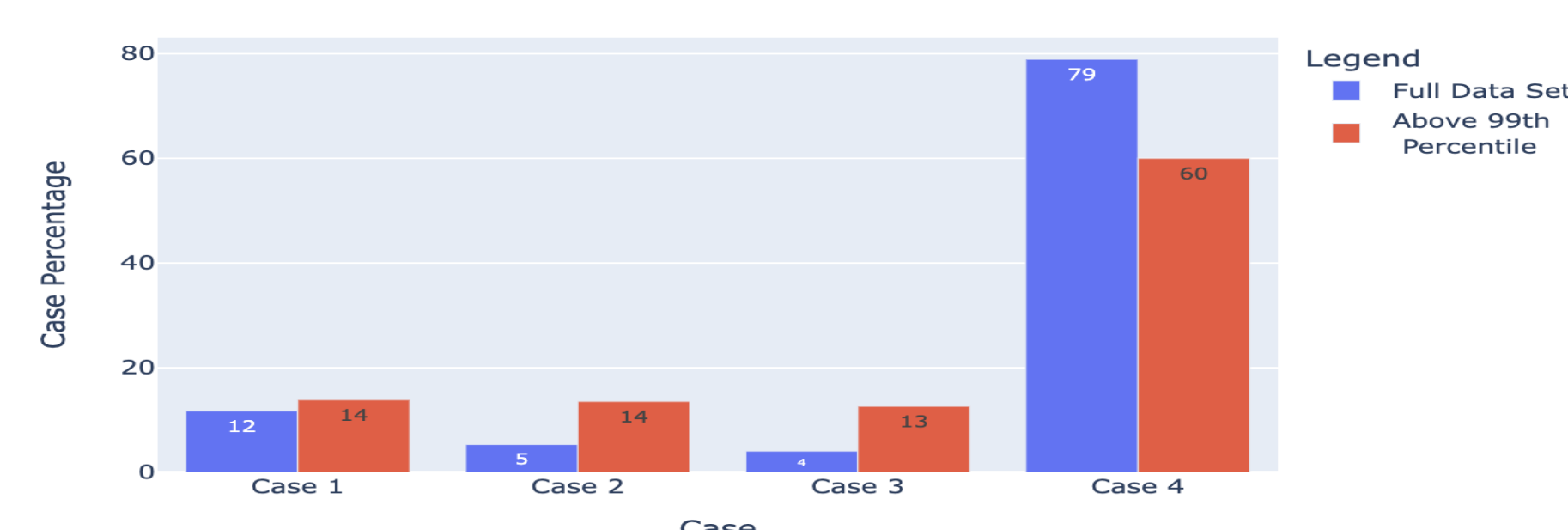
DATA OVERVIEW

Irradiance Exceedance Statistics



99th percentile irradiance varies from year to year.

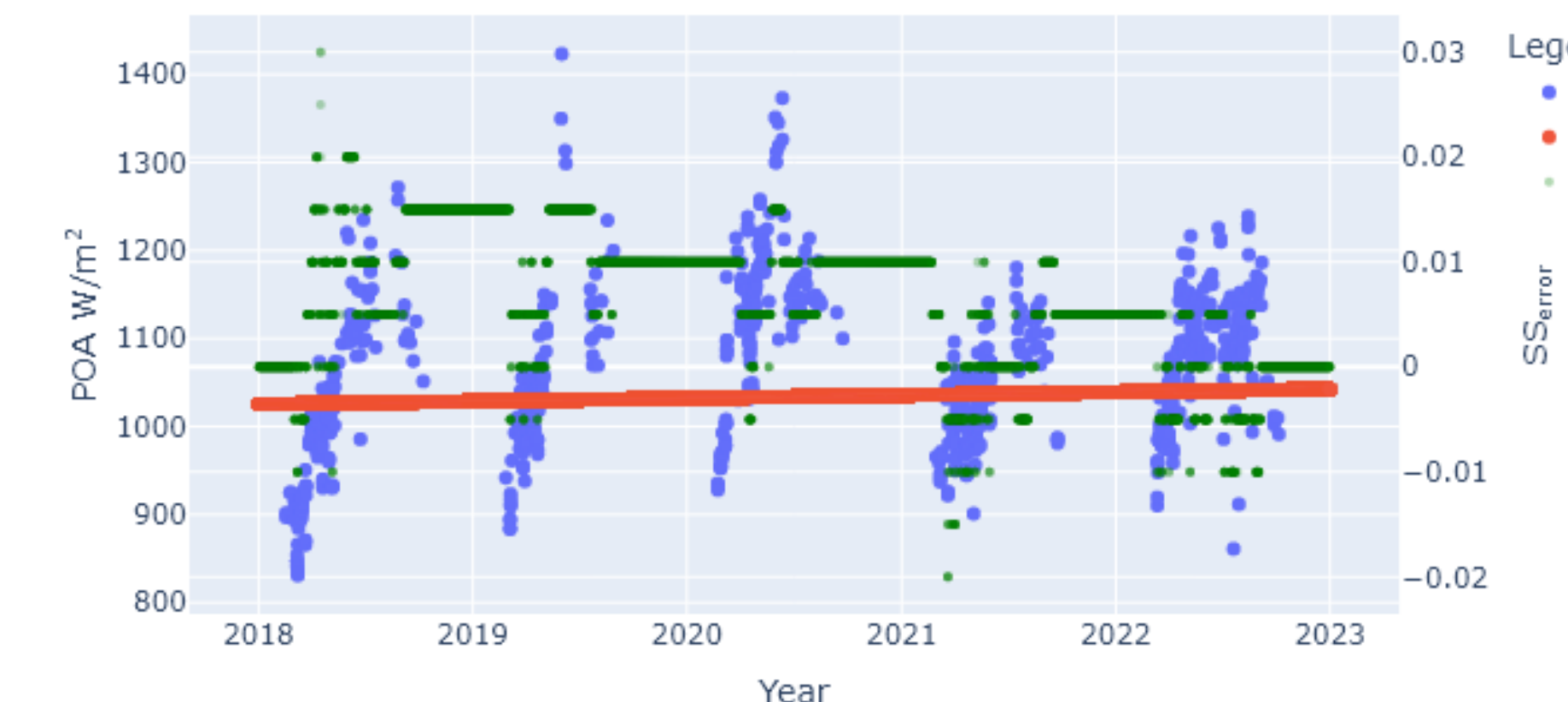
Relative Frequency of Seesaw Cases



Cases 2 & 3 are roughly equal on the full data - and 99 percentile exceedance sets. This undermines the assumption that clipping success is taken as a given at these levels of irradiance.

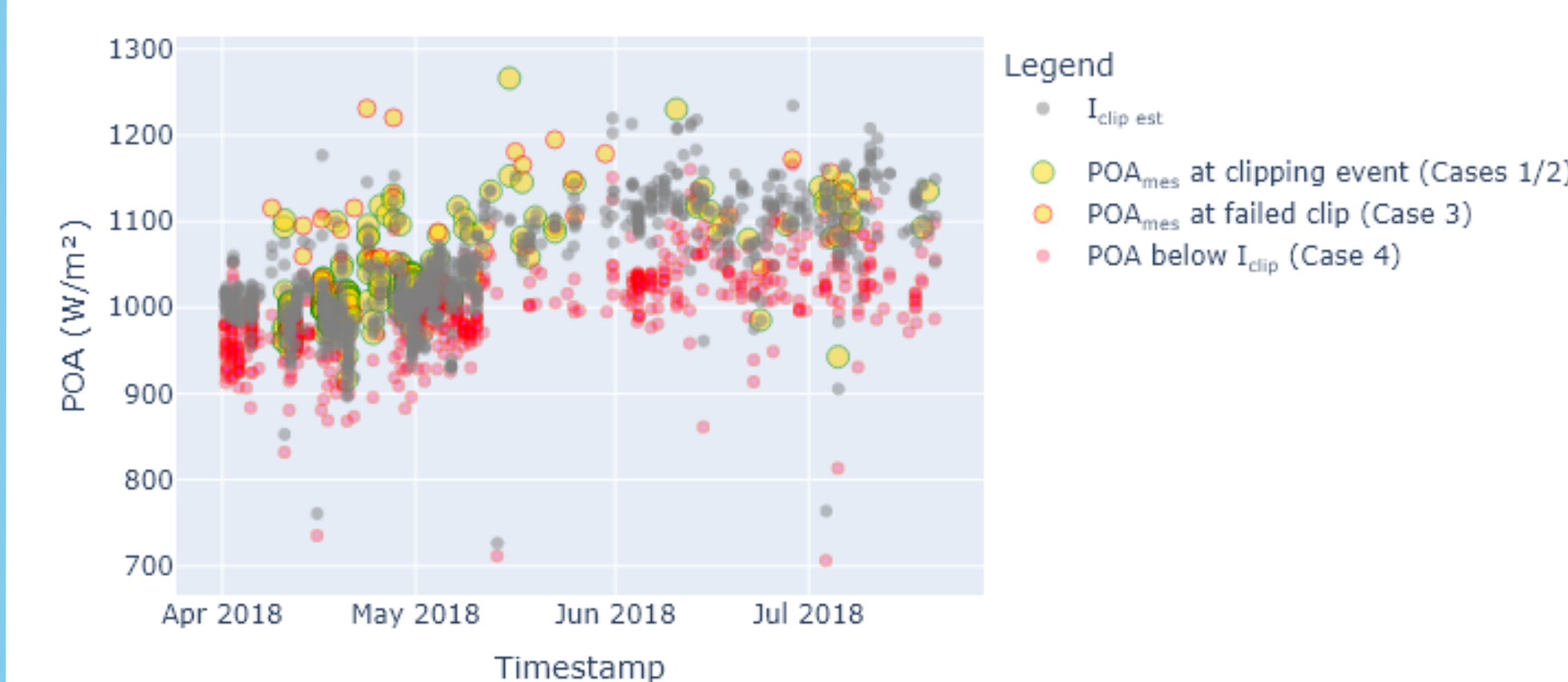
RESULTS

I_{CLIP} VS. $I_{\text{CLIP PROJ}}$



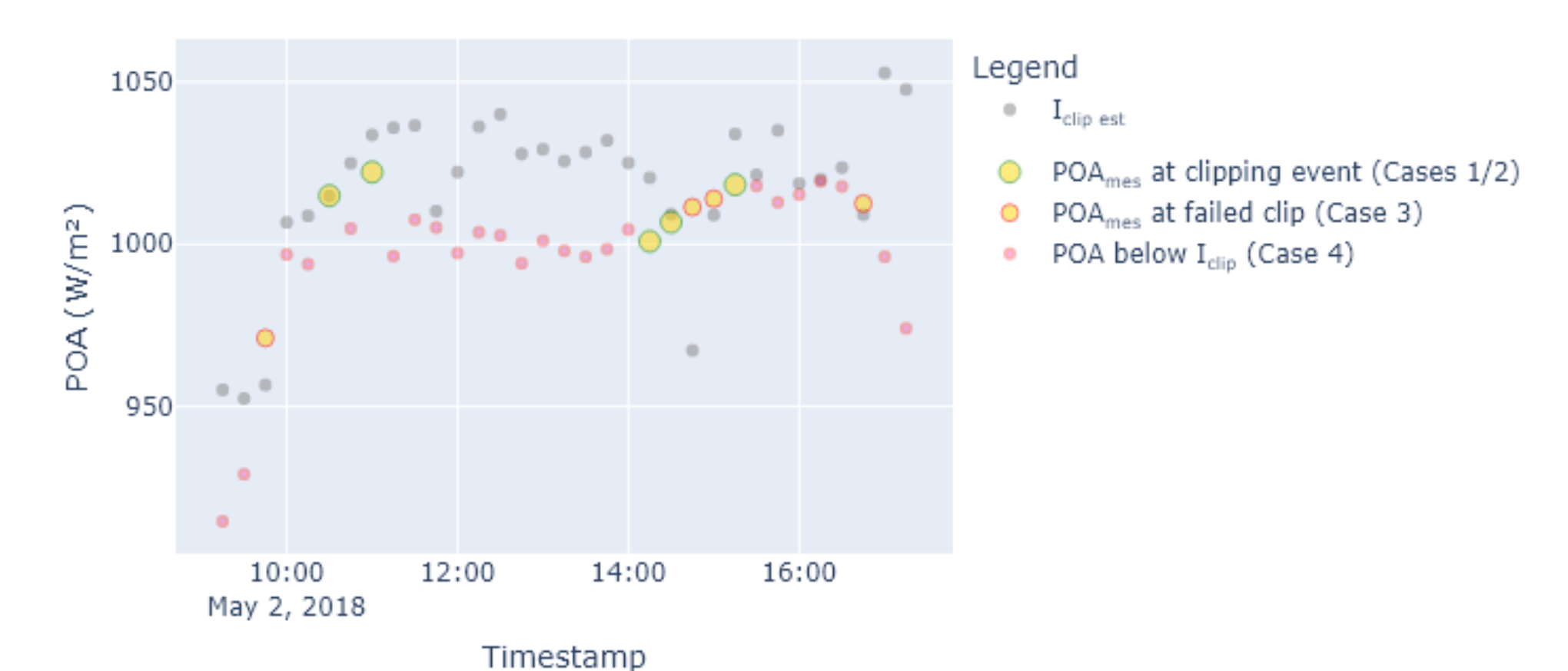
In contrast to the projection, I_{clip} does not increase constantly but varies based upon loss and availability models. The seesaw error rises and falls depending on whether I_{clip} is an accurate indicator of the clipping threshold.

Summer 2018 Seesaw Results



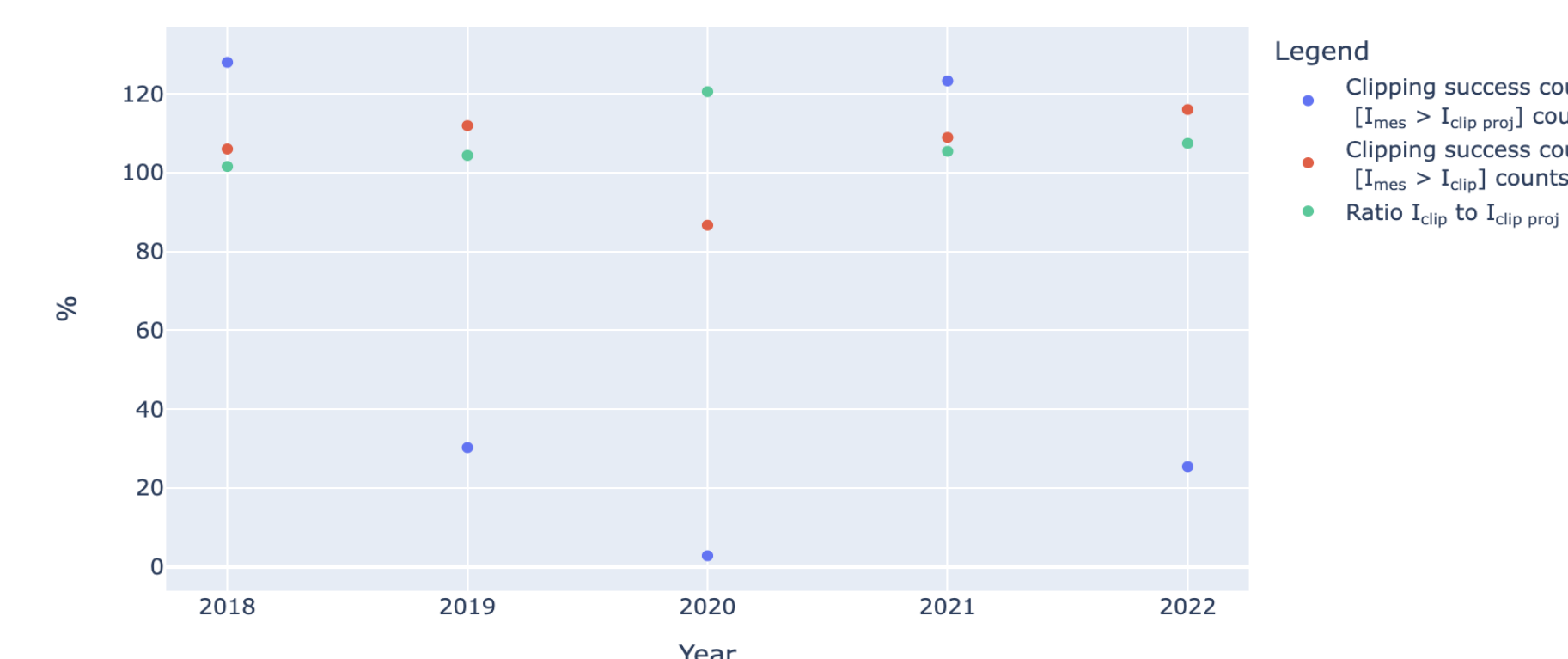
There are 16 instances of irradiance above 1100 W/m² where the plant fails to clip.

May 2, 2018 Deep-Dive



Plant has clipping success and failures at similar irradiance levels.

Actual Clipping Success Versus Projected



Plant's clipping success rates and energy harvests vary from year to year. Calculation of I_{clip} allows for a more accurate accounting of losses at high irradiance. Future work will leverage this new metric to investigate root causes of clipping failures.

DISCUSSION

Does your model assume all irradiance above a threshold is clipped?
How important is the accuracy of clipping performance to your financial model or storage dispatch algorithm?



[1] Perry, Kirsten, Matthew Muller, and Kevin Anderson. 2021. Performance Comparison of Clipping Detection Techniques in AC Power Time Series: Preprint. Golden, CO: National Renewable Energy Laboratory. NREL/CP-5K00-78954. <https://www.nrel.gov/docs/fy22osti/78954.pdf>.

[2] Michael G. Deceglie, Ambarish Nag, Adam Shinn, Gregory Kimball, Daniel Ruth, Dirk Jordan, Jiyang Yan, Kevin Anderson, Kirsten Perry, Mark Mikofski, Matthew Muller, Will Vining, and Chris Deline RdTools, version 2.2.0-beta.2, Computer Software, <https://github.com/NREL/rdtools>

[3] This minimum irradiance of a successful clipping event

[4] 0.005