CPV Module Acceptance Angle Characterization

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Introduction

While angle of incidence effect on flat plate PV modules can be modeled as a simple cosine response, CPV modules have a much greater sensitivity to misalignment. Presently there are no standard methods for measuring the acceptance angle of CPV modules. Not even a standard, CPV-specific definition for acceptance angle exists. Nameplate power ratings for CPV modules are essentially meaningless without an understanding of how misalignment will affect module performance. The expression of acceptance angle as a single value provides only a mere glimpse into the much more complicated quantification of misalignment sensitivity.

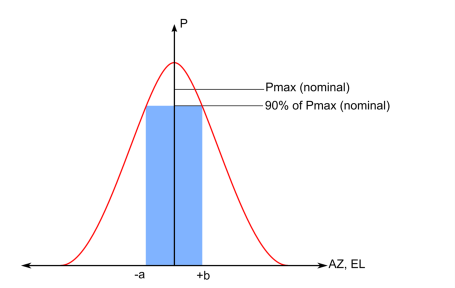
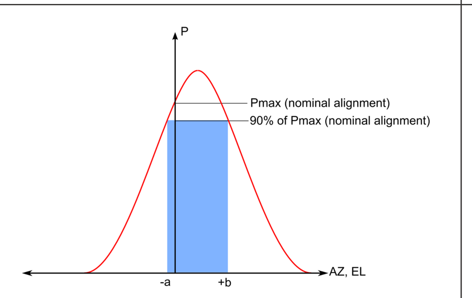
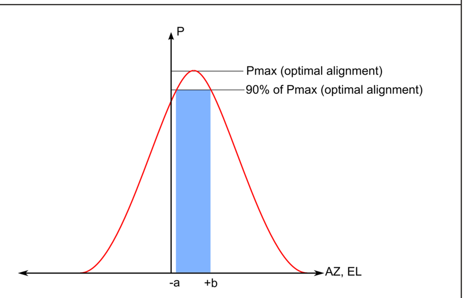
The Current Situation

The generally accepted definition for acceptance angle is:

> "The angular misalignment that a module can tolerate while still delivering at least 90% of its maximum power"

There are some problems with this definition:

- What is maximum power? Is it:

A Nominal Value	Max Power at Nominal Alignment	Max Power at Optimal Alignment
		
A module vendor may wish to "de-rate" their power rating to inflate their acceptance angle. E.g a 100W module with ± 0.2° acceptance angle could be restated as a 80W module with ±5° acceptance angle.	For a customer to achieve the stated performance in this case, they would have to individually align every module on their tracker.	In this case, the customer need not align each module—the modules can simply be installed onto a tracker. However, the power output may be in excess of the stated max power.

- A single value does not communicate the asymmetry of misalignment sensitivity between the module's axes (and all angles in between).
- Misalignment sensitivity at other percentages of max power can affect tracker and inverter selection and configuration.

Proposed Procedure

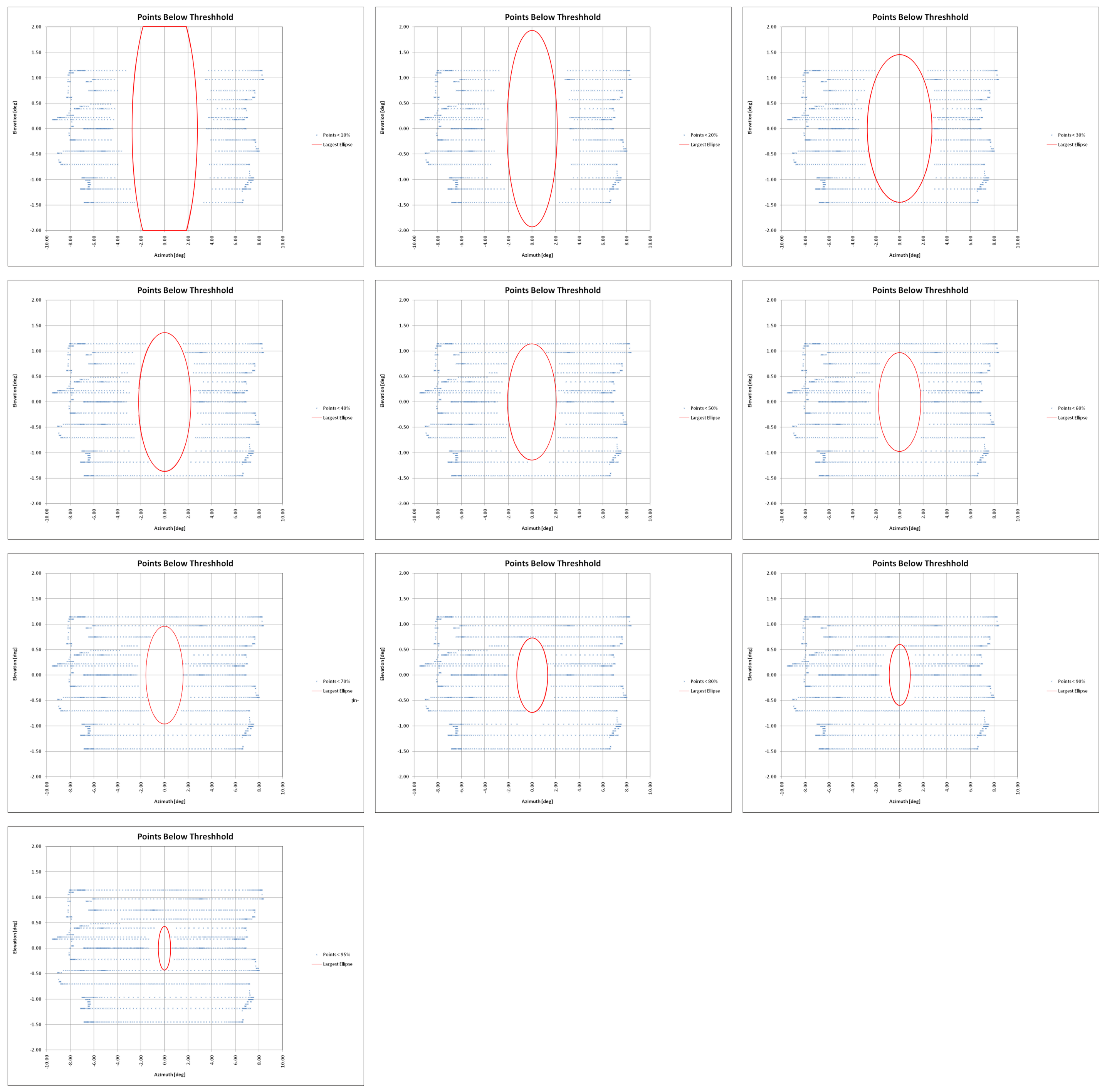
<u>Measurement</u>

1. Mount module and instruments on tracker per respective manufacturers' recommendations
2. Allow module to thermally equilibrate while tracking sun
3. Snap IV curve, determine V_{mpnom}
4. Intentionally misalign module in various orientations while <u>synchronously</u> sampling environmental conditions, tracker orientation, and module output (P_{max} or I @ V_{mpnom})

<u>Analysis</u>

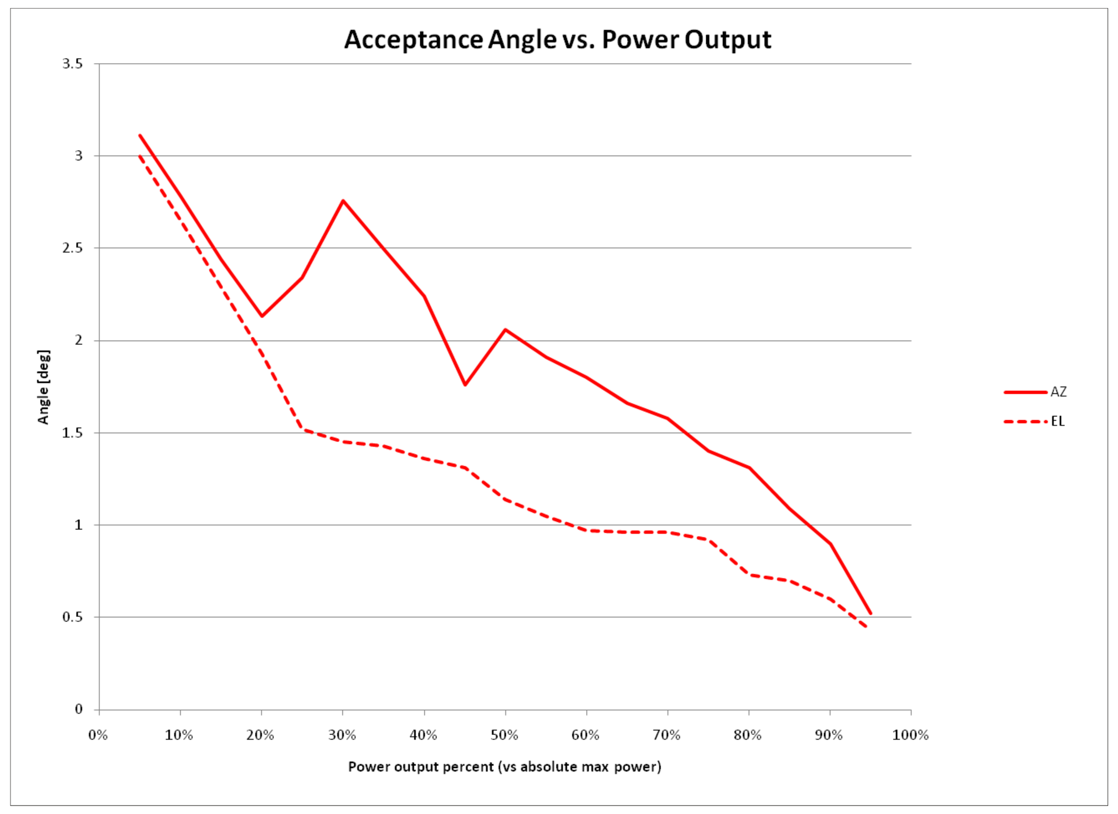
1. Correct data for movement of sun (if necessary) and variations in environmental conditions
2. Plot points on axis 1 vs. axis 2 (e.g. AZ vs. EL)
3. Filter out points with P_{max} greater than various thresholds
4. Inscribe largest ellipse possible not containing plotted points
5. Plot ellipse semi-axis lengths vs. various thresholds

Sample Data & Analysis



Data courtesy of SolarMation

Sample Results



Outstanding Questions

- What is the algorithm for maximizing the ellipse size?
- How to ensure sufficient point density?
- How to communicate results?
  - Acceptance Angle = f(Power Out)
  - Power Out = f(Acceptance Angle)

Conclusions

This is a simple and effective method for assessing the complete characterization of a CPV module's acceptance angle. In doing so, it defines acceptance angle as:

> "The relationship between a module's output power and its misalignment to the sun vector"

Knowing this relationship will be critical for CPV integrators to know which modules have acceptance angles that are not just *sufficiently*, but *optimally* accommodated by which trackers.