Modeling and Estimating the Impact of Shadow Flicker on PV Performance

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TEM#101 Day 2: Microgrids

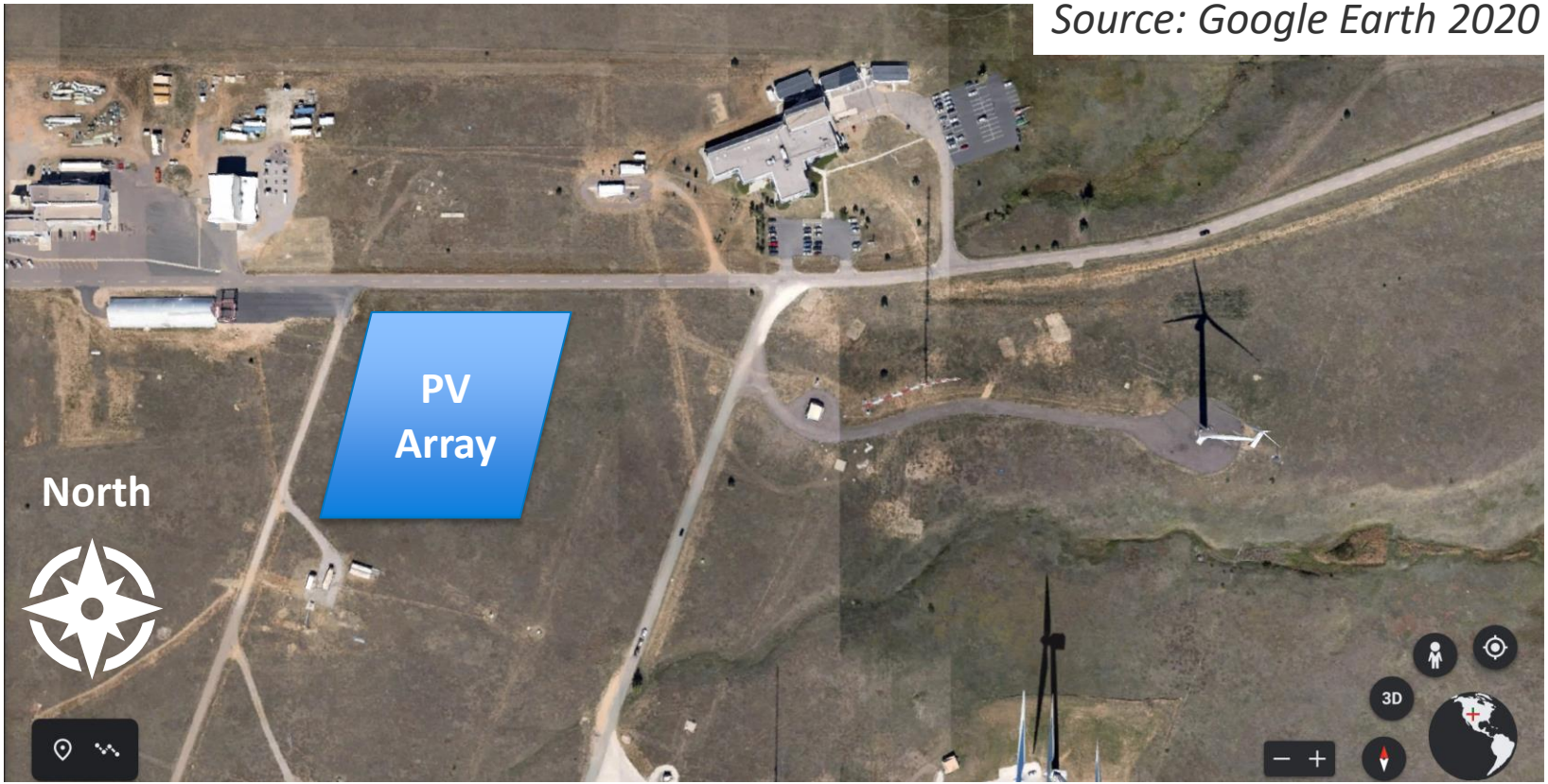
August 2020

Contents

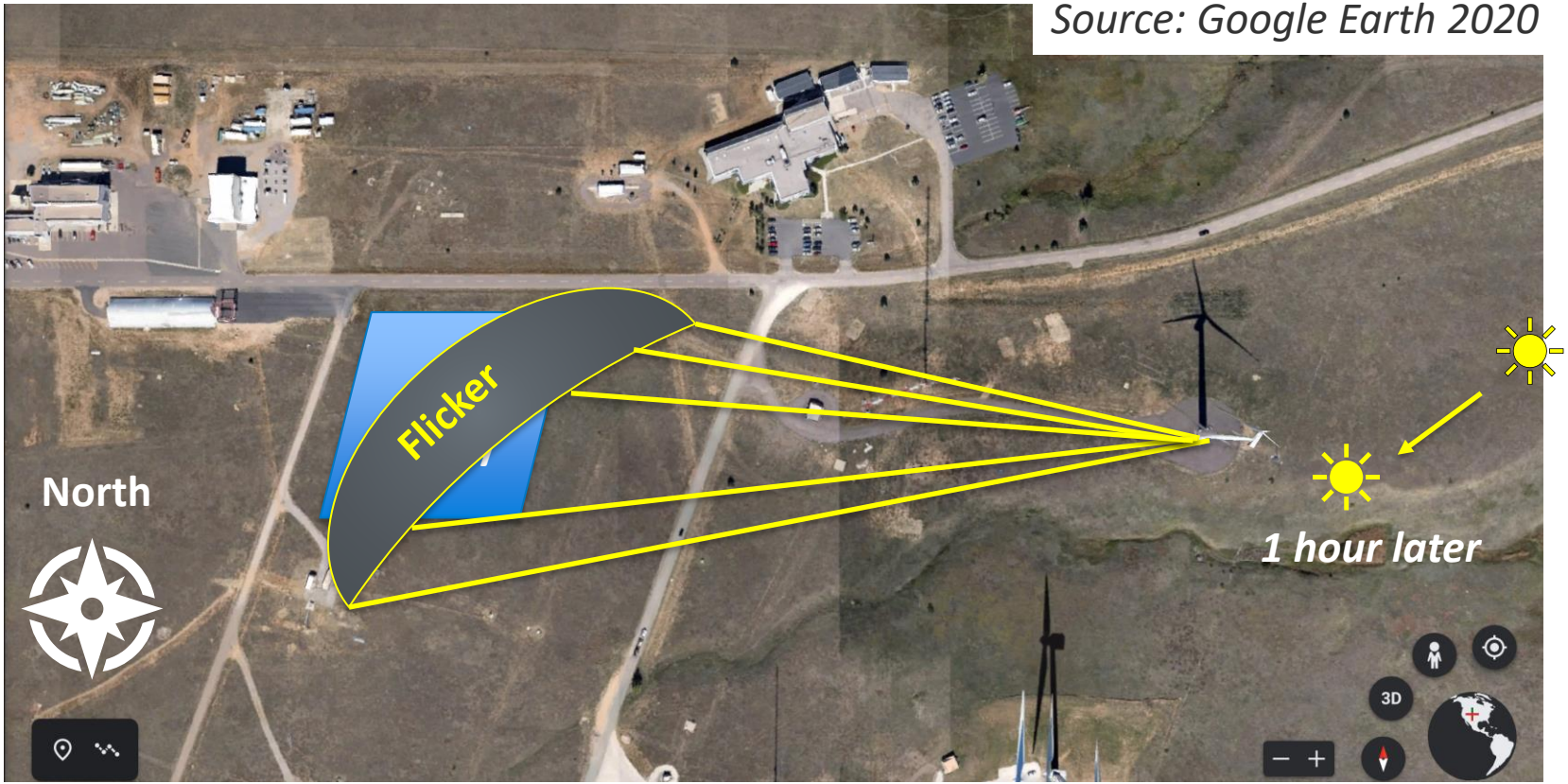
Motivation for the flicker study

Inspiration? NREL's Campus

Source: Google Earth 2020

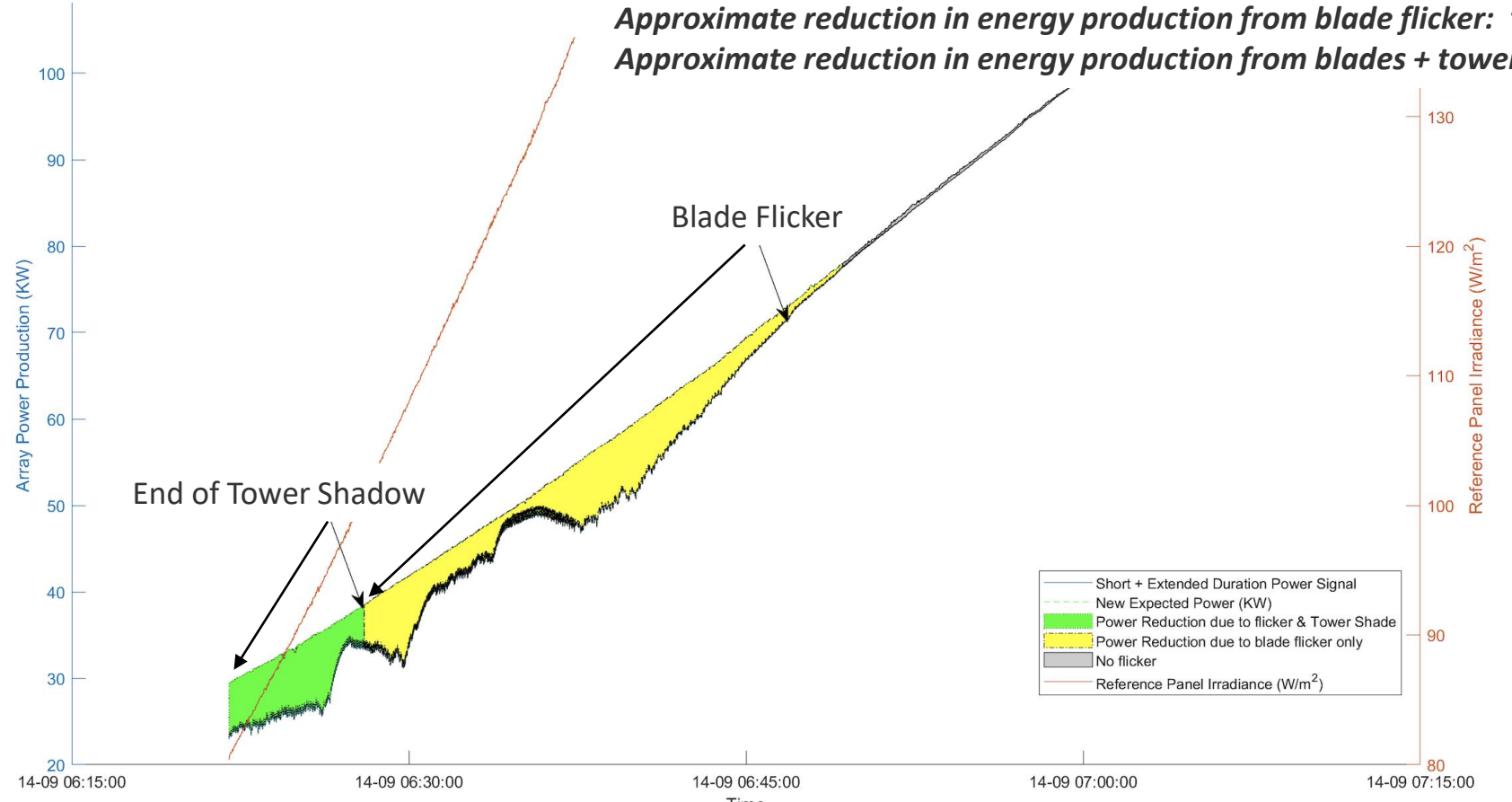


Flicker From Turbine – Early September



Impact on Power Production Due to Flicker

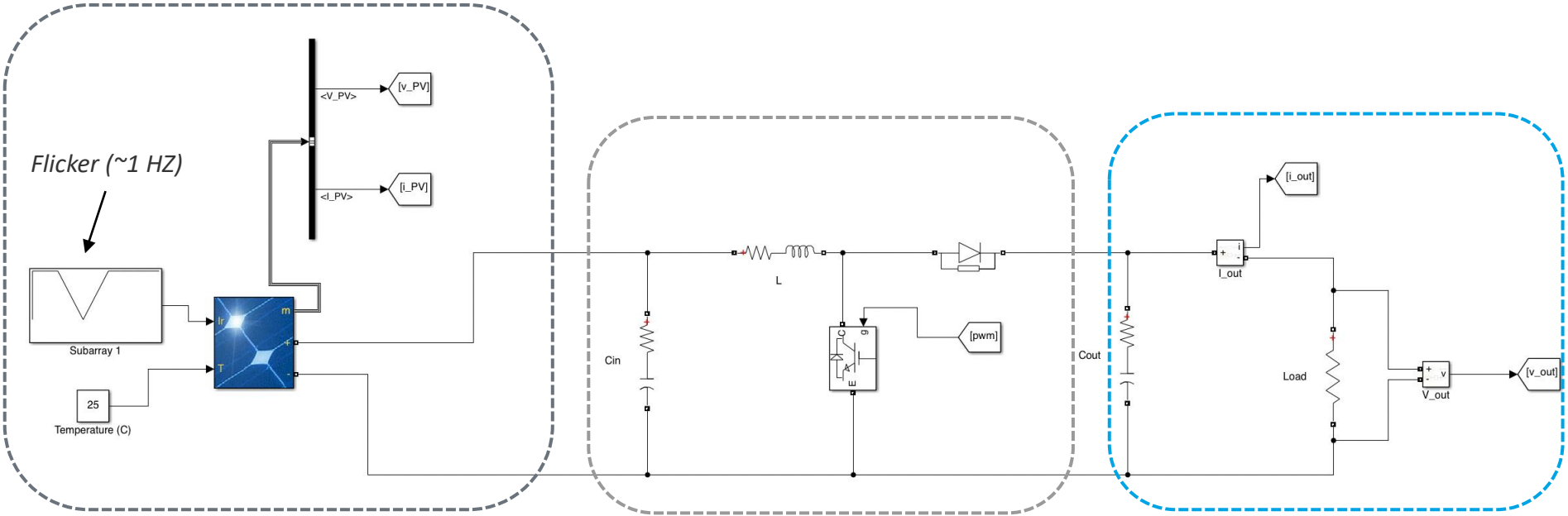
Approximate reduction in energy production from blade flicker: ~7.38%
Approximate reduction in energy production from blades + tower: ~ 18.67%



Modeling Flicker Using Simulink

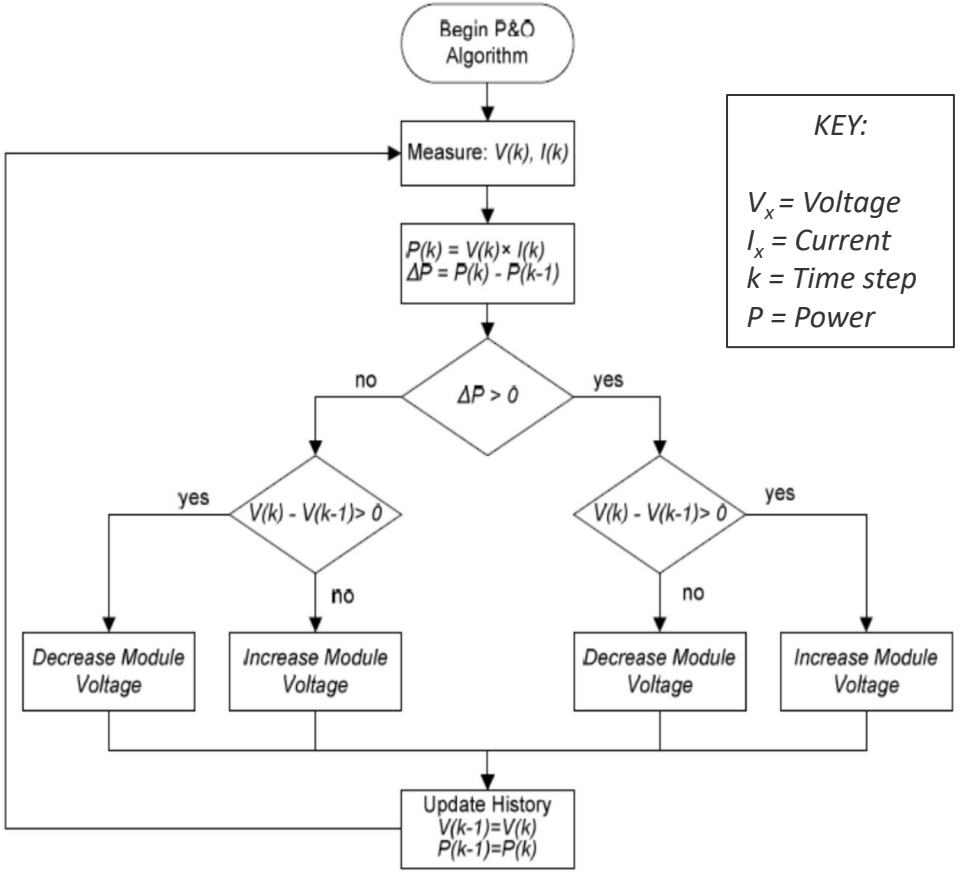
Shadow Flicker Testing Architecture in MATLAB|Simulink

- Generator (PV) is fed a cyclic flickered irradiance. It is assumed that shadow flicker results in maximum drop in irradiance of 40%
- DC-DC converter transforms the output current and voltage signal; and implements an MPPT algorithm for maximum power production
- Resistive load attached to current and voltage measurement devices



MPPT Algorithm Used in Analysis - **Perturb & Observe (P&O)**

- Multiple Power Point Tracking (MPPT) is a technique implemented in the power electronics of a PV systems; to maximize power extraction under all conditions.
- In the P&O MPPT algorithm, the inverter/charge controller adjusts the string/system voltage by a small amount and measures power
  - if the power increases, further adjustments in that direction are tried until power no longer increases.
- Most common algorithm in implementation due to ease of implementation. ***Although, this method can result in oscillations of power output.***
- It is referred to as a hill climbing method, because it depends on the rise of the curve of power against voltage below the maximum power point, and the fall above that point.

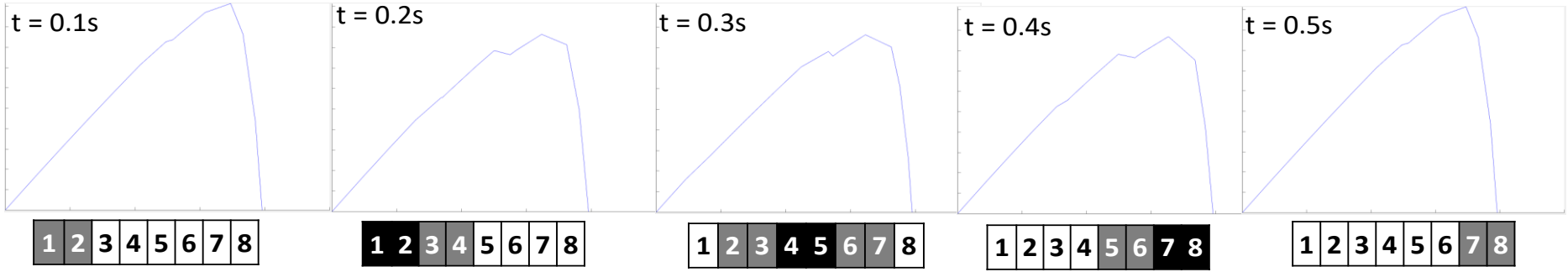


Discussion of Preliminary Results

Power vs. Voltage curves under shadow flicker

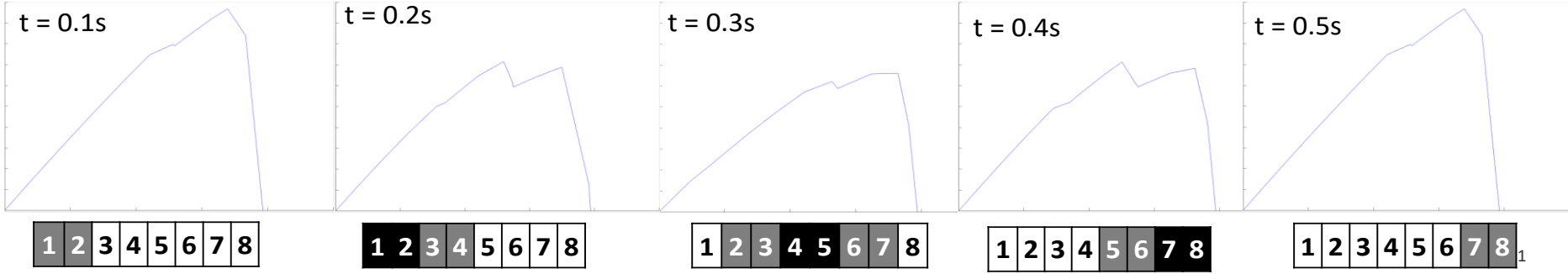
***[KEY]** Drop in irradiance →* **0 % drop** | **15 % drop** | **40 % drop**

***Scenario #1:** 50% rows impacted by flicker*



***Scenario #2:** 100% rows impacted by flicker*

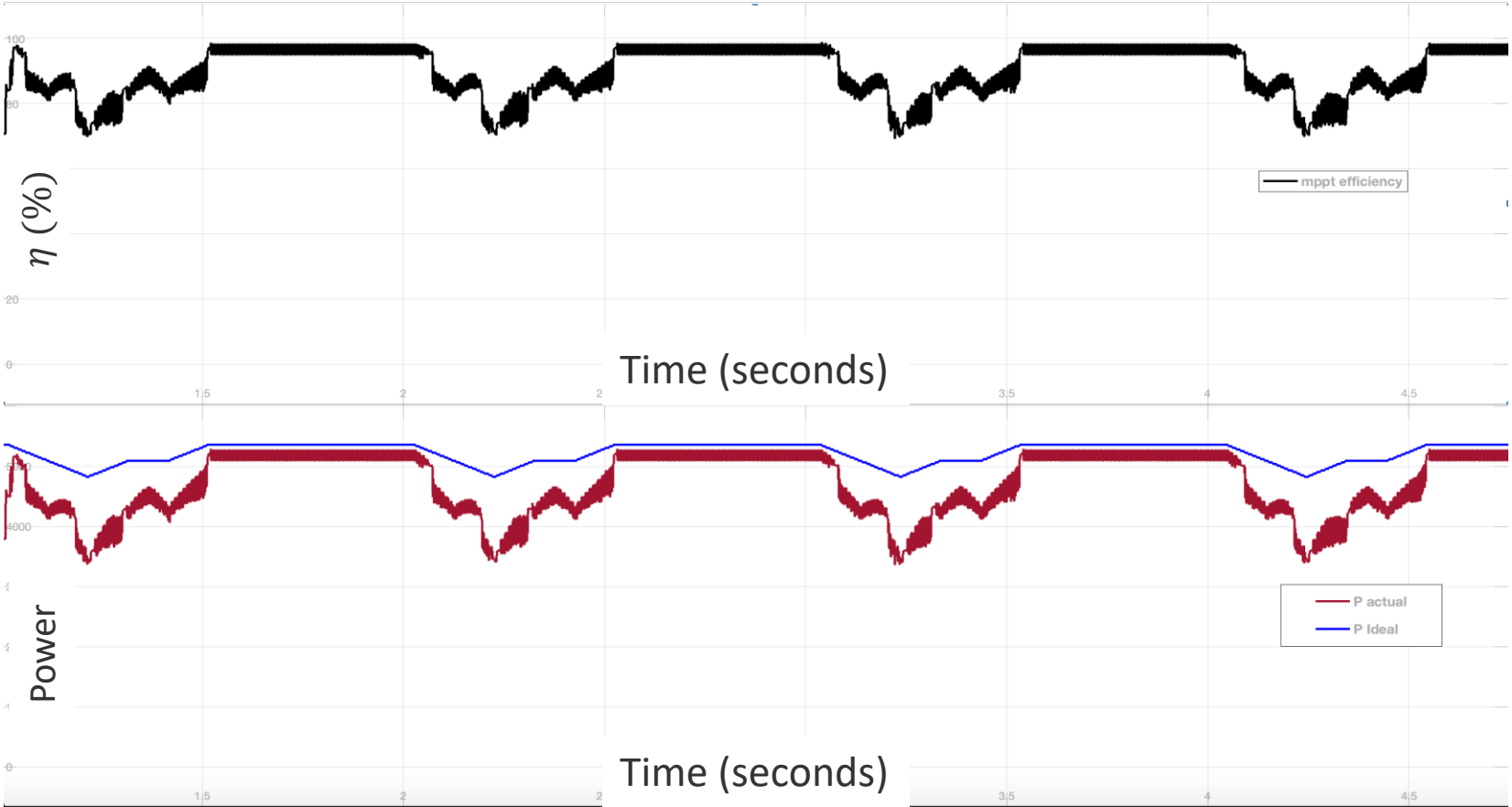
***8 PV modules per row**



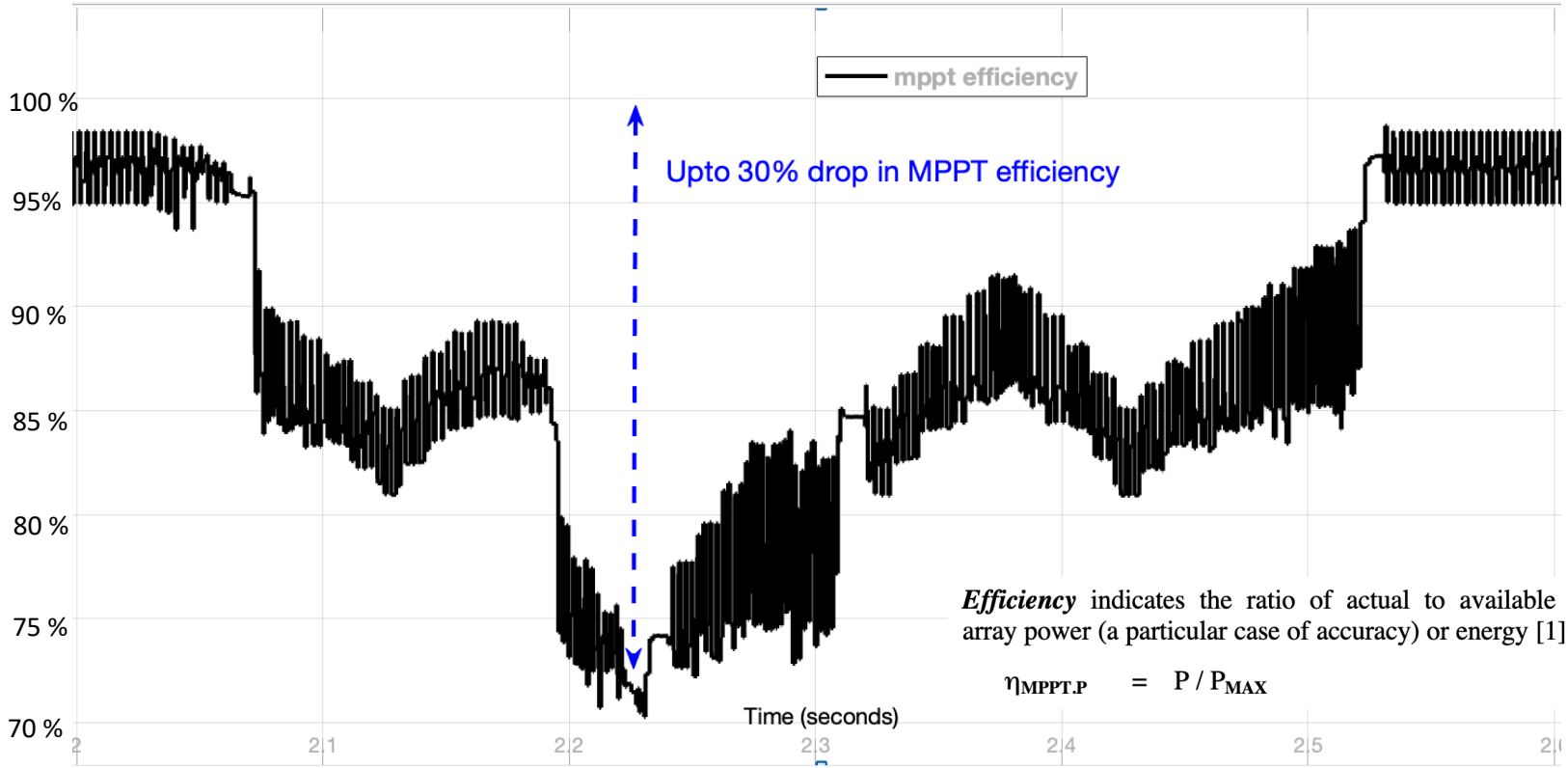
Results for: Scenario #1

50% of PV array impacted by flicker shading

MPPT Efficiency Under Shadow Flicker (Top) & P actual vs. P ideal (Bottom)



MPPT Efficiency (η) vs. Time



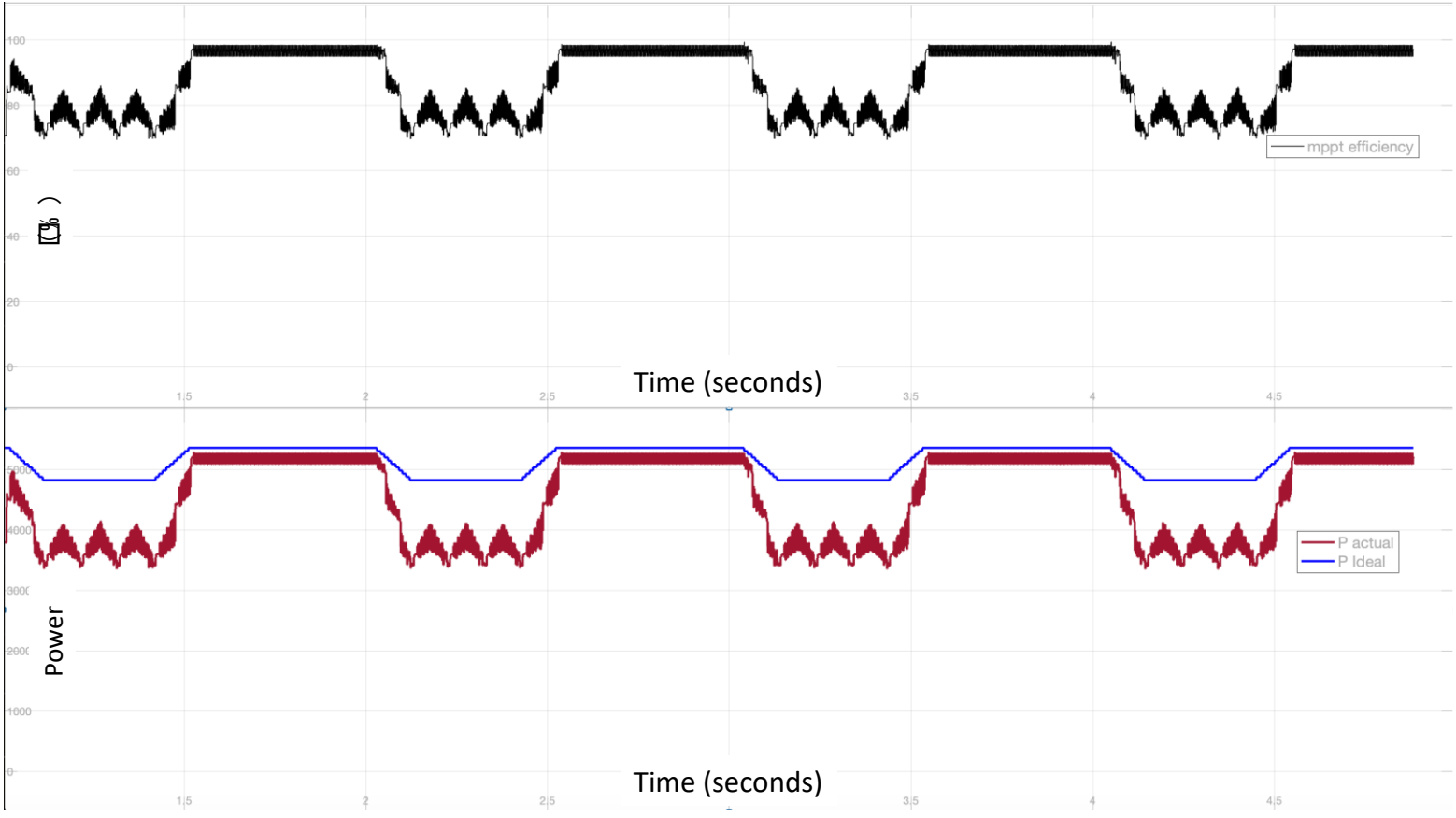
Efficiency indicates the ratio of actual to available PV array power (a particular case of accuracy) or energy [1]:

$$\eta_{MPPT.P} = P / P_{MAX}$$

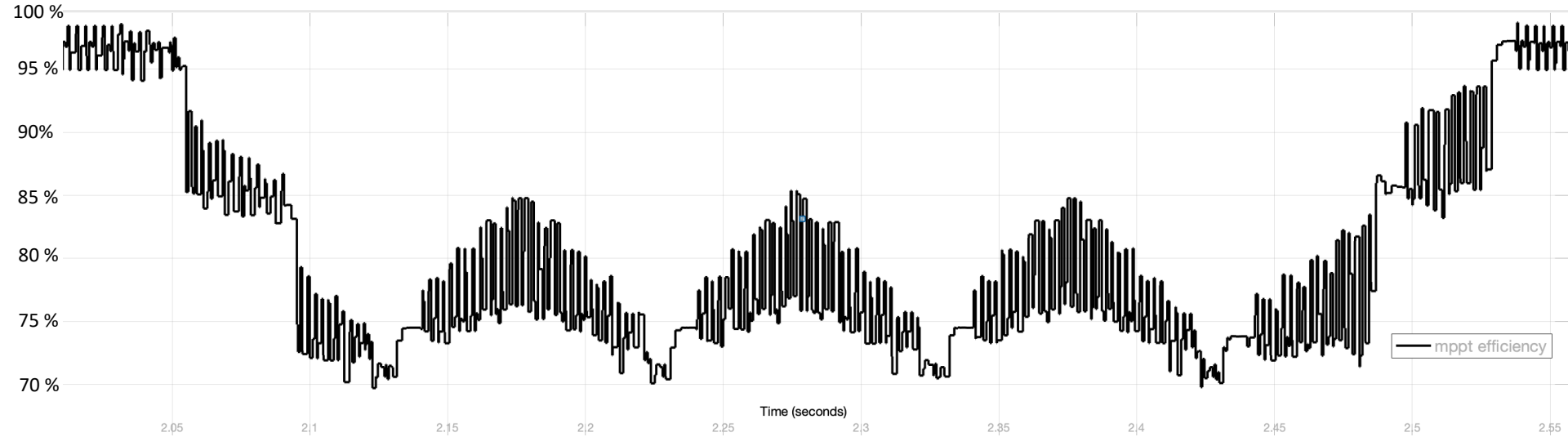
Results for: Scenario #2

100% of PV array impacted by flicker shading

MPPT Efficiency Under Shadow Flicker (Top) & P actual vs. P ideal (Bottom)



MPPT Efficiency (η) vs. Time



- Similar drop in MPPT efficiency (~70%) as seen in previous scenario
- However, average MPPT efficiency is below the average MPPT efficiency of previous scenario (50% of array shaded by flicker)

Impact of shadow flicker on bypass diodes (BPD)

- Another area of significance is BPD
- BPD's function is to eliminate the reverse bias hot-spot phenomena which can damage PV cells/modules and even cause fire if the light hitting the surface of the PV cells/module is not uniform
- Study done by NREL in 2013 looked at the thermal reliability of BPD; it was found that sustained, uneven shading can impose a strong thermal fatigue stress to the BPDs in a PV array and may cause permanent failures of the BPDs.

  Source: NREL 2013 (https://www.nrel.gov/docs/fy13osti/58225.pdf)
- Premature failure of BPDs is a fire hazard, and is also responsible for an accelerated degradation of a PV system

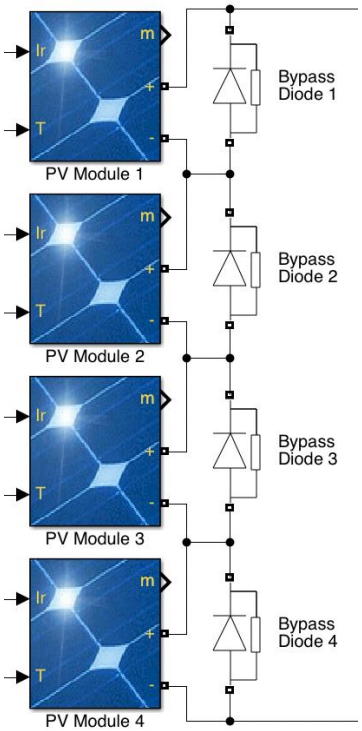


Figure. *BPD connected to each module to minimize energy loss from shading and prevent hot-spots. Hot spots are areas of concentrated heat.*

Next Steps

- Generate equation for power loss caused by flicker:

$$MPPT_{eff} = f(MPPT_{algorithm},\ Array_{\%\ shaded},\ Flicker_{intensity})$$

- Test MPPT performance for other MPPT algorithms; other most common algorithms include:
  - Incremental Conductance
  - Fractional Open Circuit Voltage
- Test grid-connected 3-phase circuits to assess impact of flicker on the grid
- Develop a model to examine the extent of thermal fatigue stress on BPD due to sustained flicker events, and impact on PV system degradation rate

Thank You!

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