Smart EV Battery Charging to Balance Intermittent Renewable Energy

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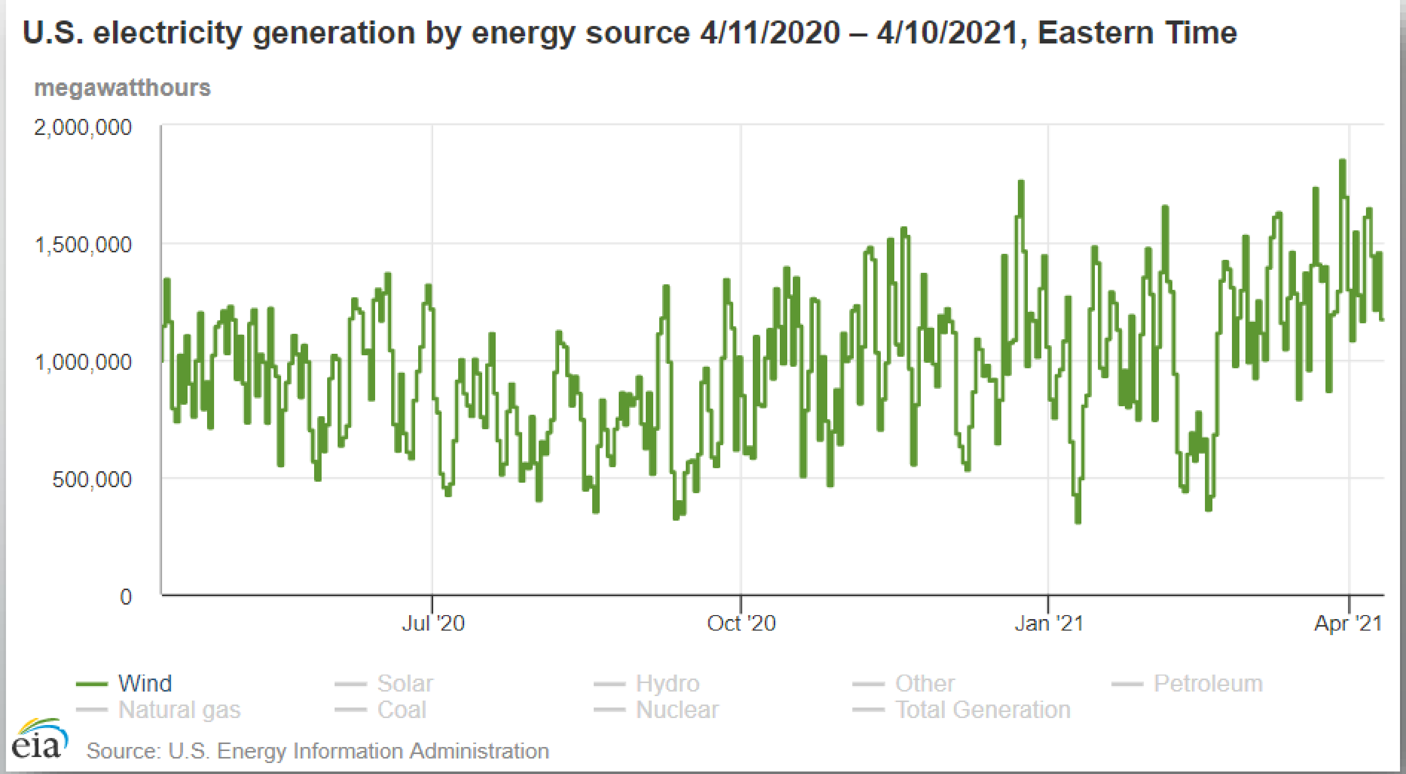
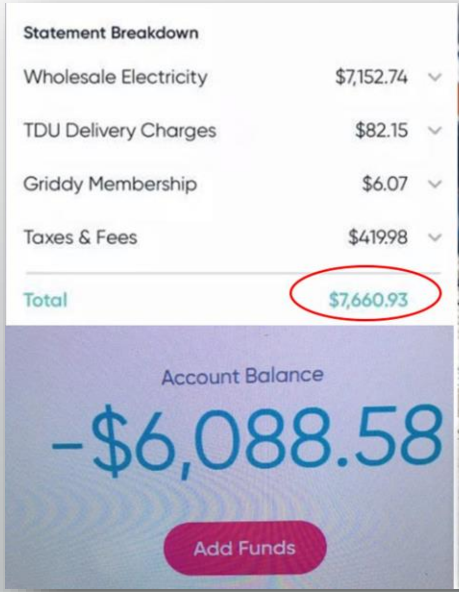
Background

- Instability in renewable energy generation
- 2 ways to increase consistency:
  - Energy storage
  - Smart loads



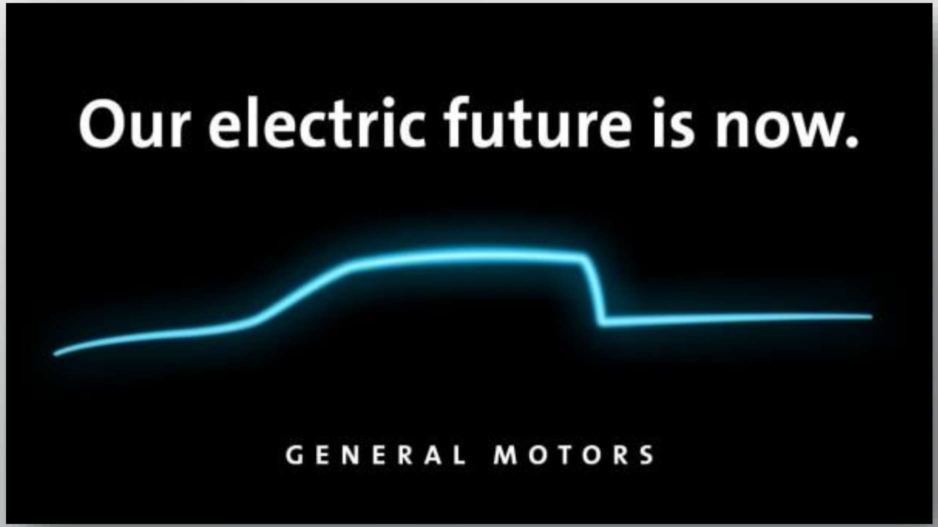
Background

- Importance of consistency
  - Supply-load balancing
  - Excess energy: wasted
  - Insufficient energy: more expensive (peaking) sources increase price
    - Worst case: blackouts and soaring energy bills



EV Batteries: Ideal Smart Load

- Prevalent
- Relatively large capacity
- Geographically distributed
- Likely connected to charger for extended period of time



Premise of MATLAB Simulation

- Question: Could large-scale smart EV battery charging “smooth out” intermittent wind generation?

- Factors explored:
  - Charging method (ASAP, above static/dynamic threshold)
  - 80% battery-charge opt-ins

- Outcomes examined:
  - Shape/standard deviation of supply power post-charging
  - Proportion of EV’s fully charged

Setup of Simulation

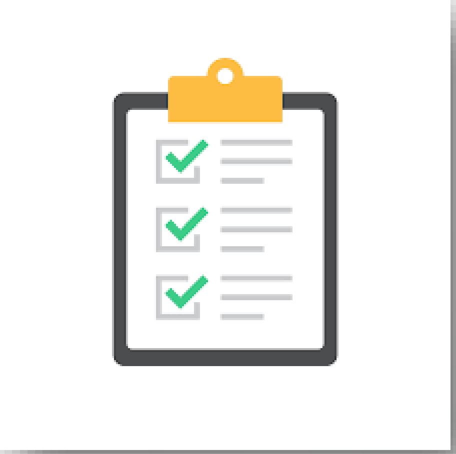
- Energy supply examined: Wind
  - Wind and solar are largest intermittent sources
  - Wind can provide power 24 hours a day

- Timescale examined: 1 year (10-hour charging periods)

- Time period simulated: 2050
  - Wind energy capacity estimates for 2050 allow for supply curve scaling
  - EVs account for most new sales in 2035+ → extremely prevalent by 2050

Major Simulation Assumptions

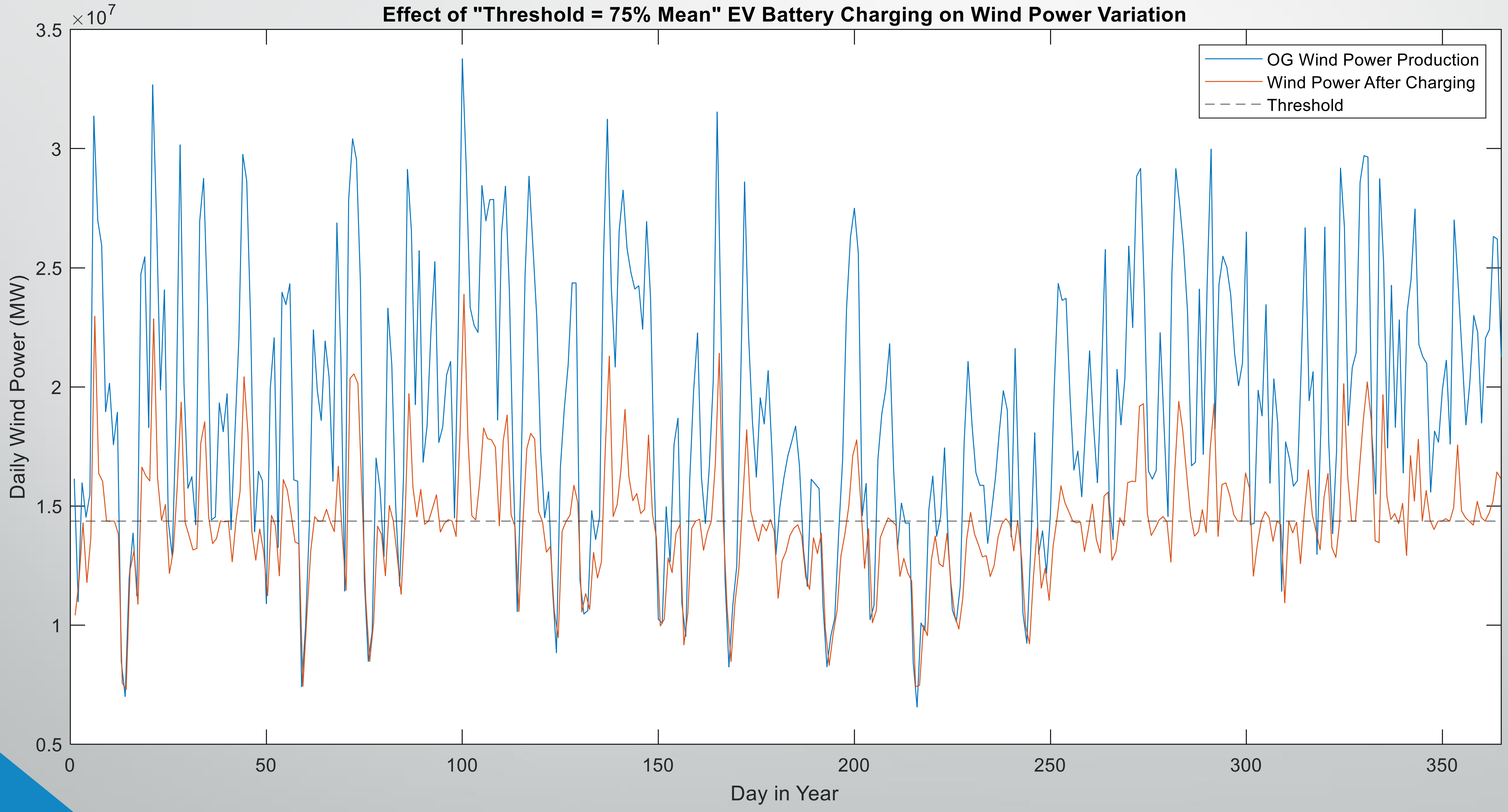
- Length of "plugged-in" period: 10 hours
- Average battery initial charge: 50%
- Average battery capacity: 100 kWh
- Average home charging rate: 11 kW
- Number of smart-charging EVs : 161.6 million
- Proportion of smart-charging EVs actively charging/period: 50%
- Proportion of EV customers opted-in to 80% charge: 40 – 75%



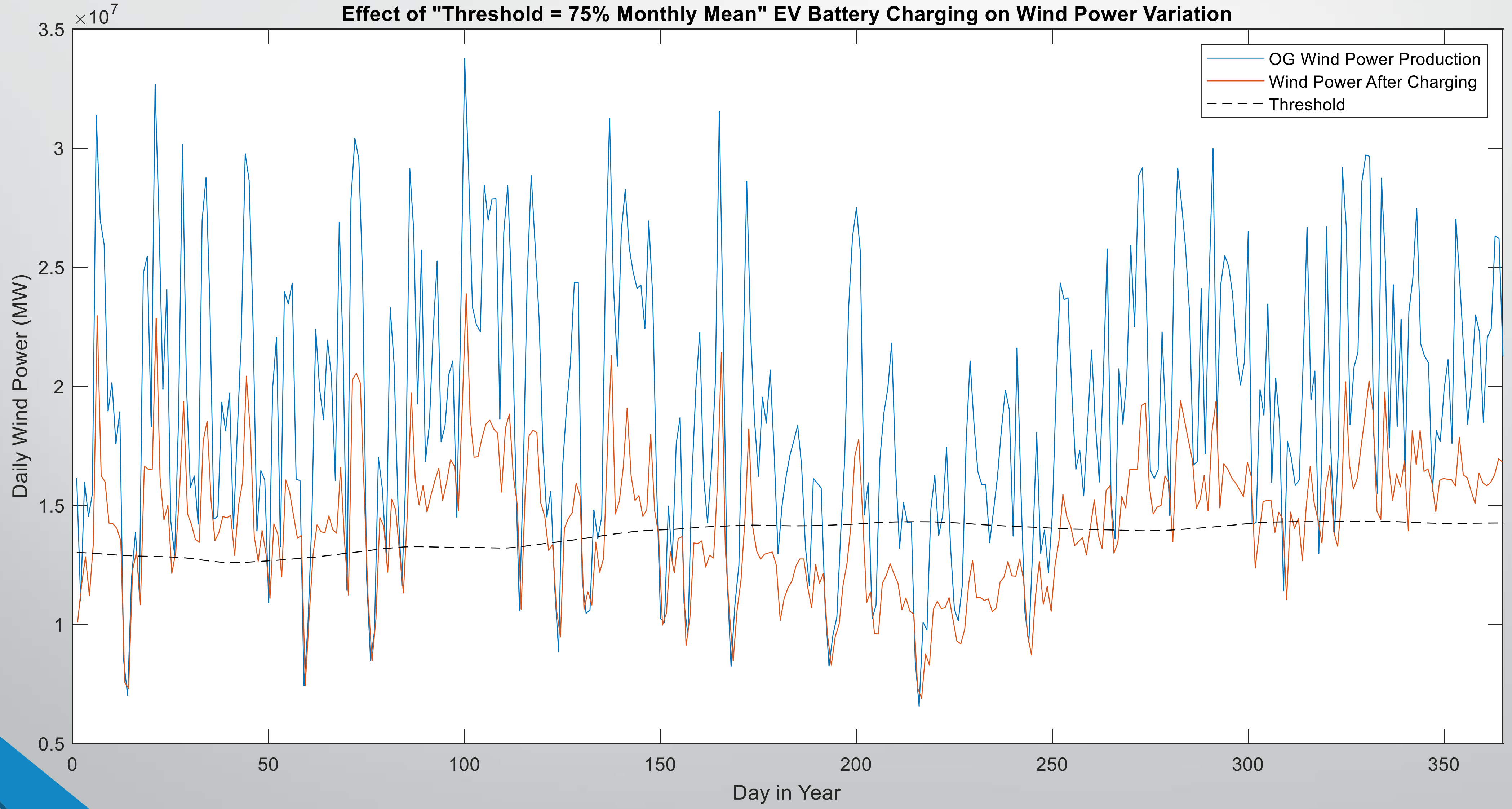
Basic MATLAB Simulation Process

- Hourly wind energy 1st directed to batteries that need 100% charge
- If 80%-opted in batteries have more than 80% charge, transfer charge to batteries that need 100% charge (as needed)
- Hourly wind energy then directed to batteries that opted-in to 80% charge
  - Will still charge to 100% if possible
- Iterates through 10-hour charging period
- Moves on to *next* 10-hour charging period (1 hour offset)

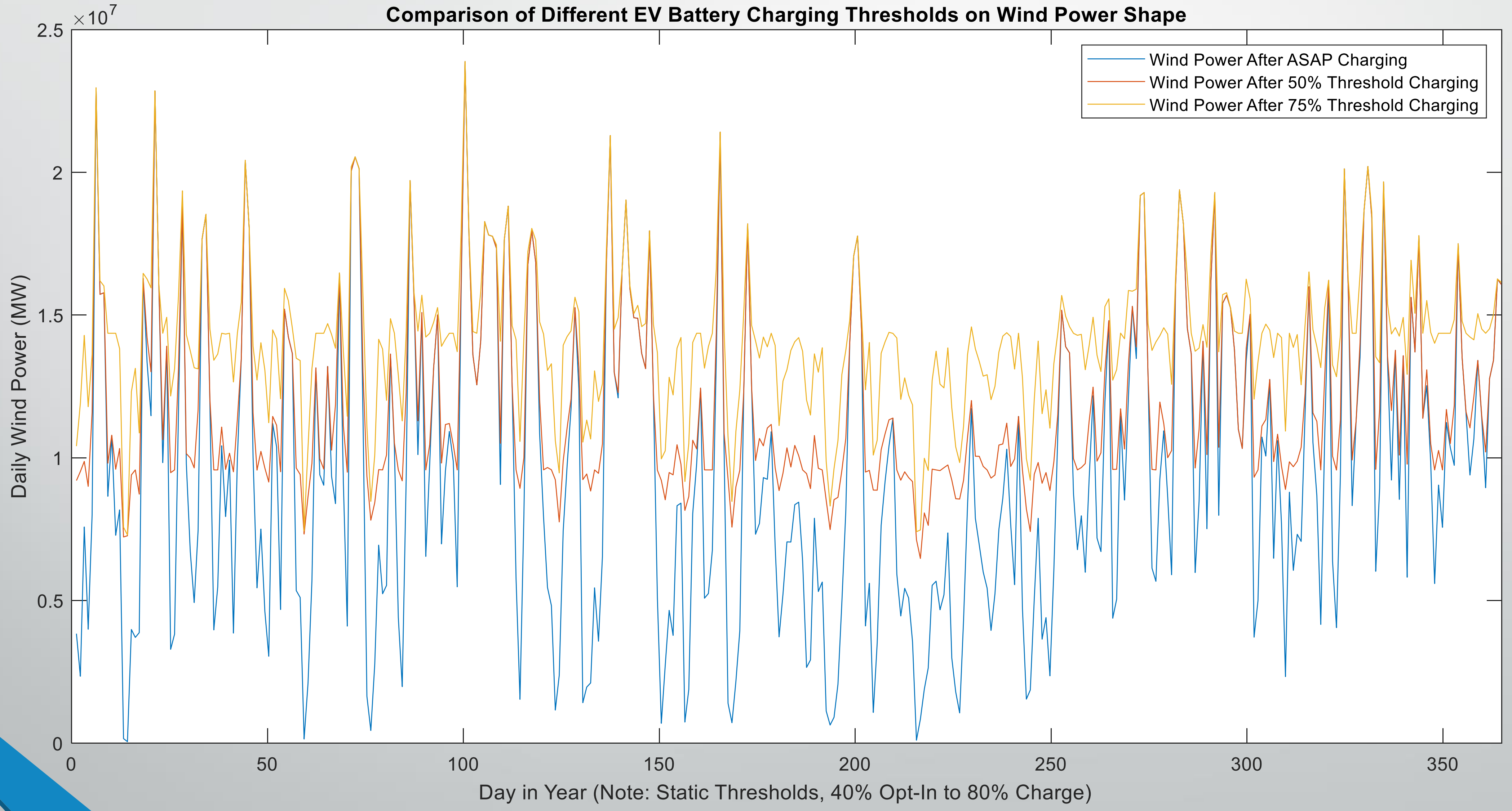
Example of Power Smoothing



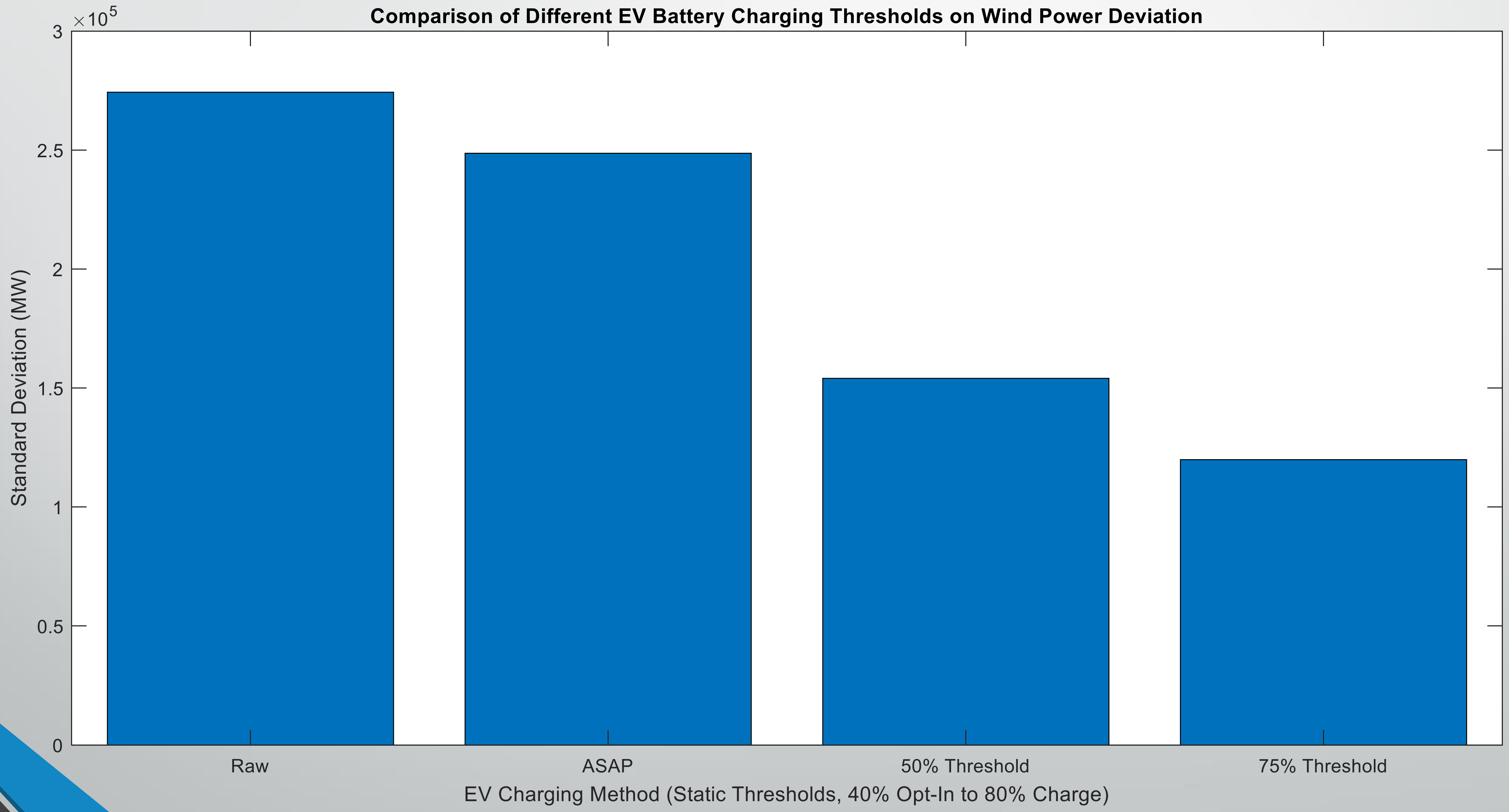
Example of Dynamic Threshold



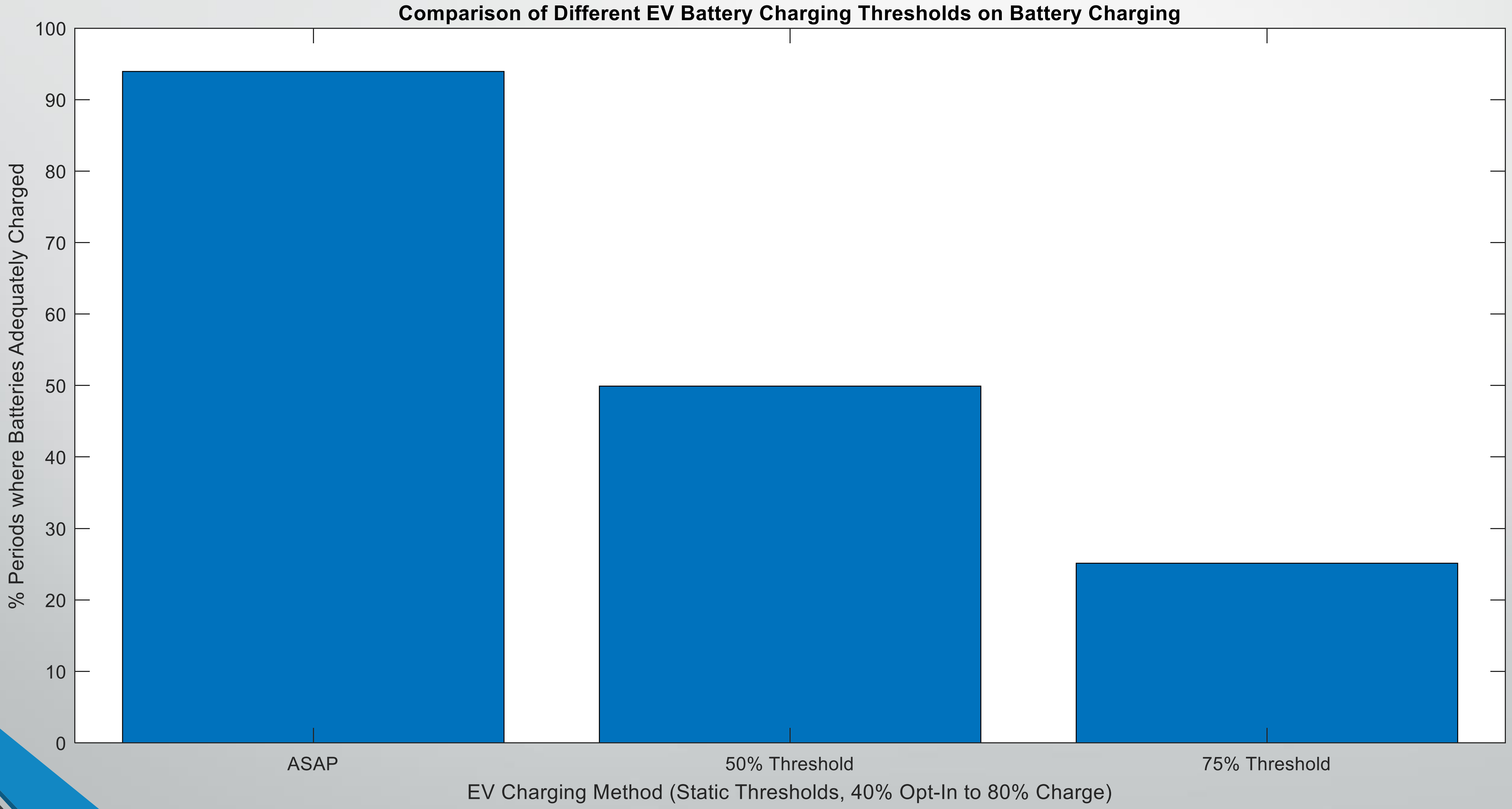
Threshold Comparison – Power Shape



Threshold Comparison – Power St. Dev.



Threshold Comparison – Charging Status



Full Simulation Numerical Results

Charging Power Threshold	Monthly Dynamic Threshold?	% Customers Opted-In to 80% Charge	Std. Dev. of Remaining Power (MW)	% Periods Where Charge Adequate
Raw Wind Power		N/A	274,301	N/A
0	No	40%	248,648	93.9%
50% Mean	No	40%	154,068	49.9%
50% Mean	Yes	40%	159,974	50.3%
75% Mean	No	40%	119,913	25.1%
75% Mean	Yes	40%	131,094	23.6%
50% Mean	No	75%	155,261	56.6%
50% Mean	Yes	75%	161,275	57.5%
75% Mean	No	75%	119,501	30.5%
75% Mean	Yes	75%	130,649	29.5%

Discussion of Trends

- Greater thresholds → lesser deviation, lesser achievable charging

- Greater 80% charge opt-ins → no impact on deviation, greater achievable charging

- Dynamic thresholds → greater deviation, no impact on charging status

Caveats

- Lower battery charging percentages OK
  - In practice, batteries wouldn't be charged *exclusively* by wind
  - BUT, simulation proves feasibility of EV batteries smoothing variable supply energy
- Actual charging behavior in 2050 unpredictable
  - Dominant charging mode could be level I/II home charging (this simulation)
  - OR could be level III highway chargers
- Personal vehicle ownership in 2050 unpredictable
  - Self-driving cars & increased urbanization could lead to rise of rideshare-style autonomous taxis

Conclusion

- Simulation demonstrated feasibility of using smart EV charging to reduce fluctuation in intermittent power supply

- Concurrent advancement of the “smart grid” with the advancement of renewable energy provides demand-side solutions to balancing increasing instability in supply and demand
  - Applies to other smart loads as well (ex. Nest Thermostat)

Questions?

References

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