BP-18 Solar Study

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BP-18 Solar Study Commitment Summary

Solar Technical Work. By January 2018, Bonneville will study and produce analysis on solar integration in Bonneville's Balancing Authority Area (BAA), though this is not a commitment to conduct a comprehensive integration study. The intent of Bonneville's analytical work will be to enhance Bonneville's current methodology and inform Bonneville and stakeholders prior to workshops leading to the BP-20 Initial Proposal. This analytical work will include:

a) A focus on the **unique characteristics of integrating solar energy generation** in Bonneville's BAA contrasted to that of wind energy in the Bonneville BAA.

b) The **creation of a robust synthetic solar generation data set** representative of a prospective geographically diverse build out of solar generation in Bonneville's BAA, forecasted based on the growth of **Bonneville's interconnection queue** through FY2025 as it exists on July 1, 2017 and through utilization of the **University of Oregon's Solar Radiation Monitoring Laboratory datasets**.

c) Analysis of the **impacts on balancing reserves** necessary to integrate solar energy in Bonneville's BAA with regards to **solar scheduling best practices and geographic diversity benefits** as shown in section 10(b) of this Attachment 1.

Bonneville will also hold stakeholder workshop(s) regarding solar generation prior to the BP-20 Initial Proposal to discuss (1) **potential actions** that can be taken by generators and **Bonneville to reduce the balancing reserve requirement**, (2) solar rate design*, (3) the impact of the variable cost methodology* and the **incremental standard deviation methodology** on balancing reserves held, and (4) the potential impact of **planned reserves held in shaped amounts**.

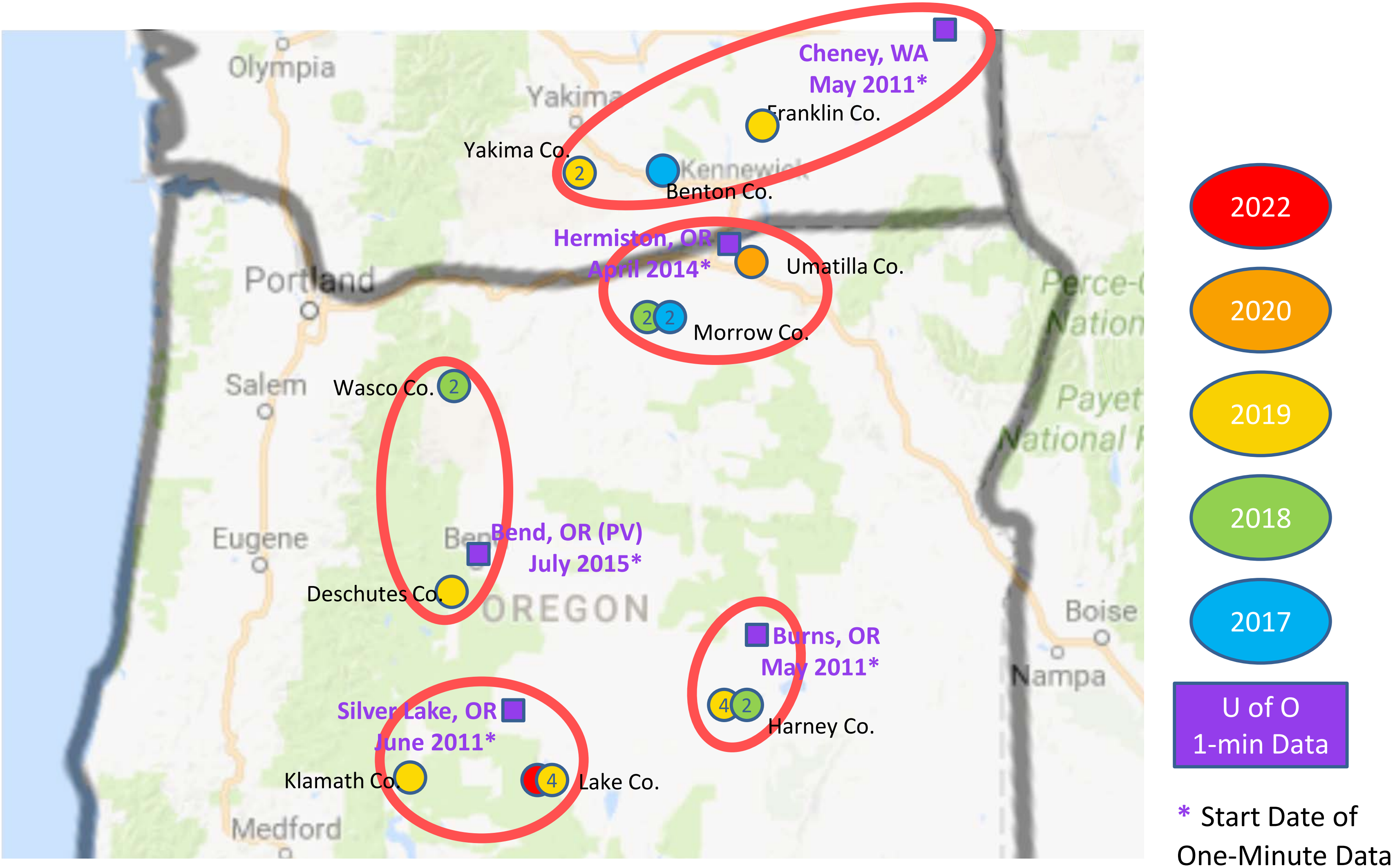
(Section 10 of "Rate Period Terms" Attachment 1 to the BP-18 Generation Inputs and Transmission Ancillary and Control Area Services Rates Settlement Agreement Page)

*These topics will be dealt with at a subsequent workshop

Solar Requests in Generation Interconnection Queue as of 7/1/2017

Request Number	State	County	Requested In-Service Date	Maximum Output	Generating Facility Type
G0517	OR	Morrow	7/01/2018	76	Solar
G0518	WA	Benton	11/13/2017	5	Solar
G0520	OR	Harney	6/01/2018	20	Solar
G0521	OR	Lake	1/31/2019	20	Solar
G0522	OR	Harney	12/31/2018	20	Solar
G0523	OR	Wasco	12/31/2018	13	Solar
G0524	OR	Wasco	12/31/2018	20	Solar
G0525	OR	Harney	4/30/2019	20	Solar
G0526	OR	Lake	4/01/2019	20	Solar
G0527	OR	Lake	4/01/2019	105	Solar
G0529	OR	Morrow	12/31/2017	50	Solar
G0532	OR	Morrow	6/30/2017	100	Solar
G0536	OR	Harney	4/01/2019	20	Solar
G0537	OR	Harney	4/01/2019	20	Solar
G0538	OR	Harney	4/01/2019	20	Solar
G0539	OR	Deschutes	4/01/2019	600	Solar
G0540	OR	Morrow	12/31/2018	10	Solar
G0545	OR	Klamath	10/01/2019	200	Solar
G0549	OR	Lake	12/01/2022	400	Solar
G0550	OR	Umatilla	12/01/2020	120	Solar
G0557	OR	Lake	12/01/2019	80	Solar
G0562	WA	Yakima	6/30/2019	80	Solar
G0563	WA	Yakima	6/30/2019	80	Solar
G0564	WA	Franklin	6/30/2019	80	Solar

Proposed Solar Plant and University of Oregon Data Locations

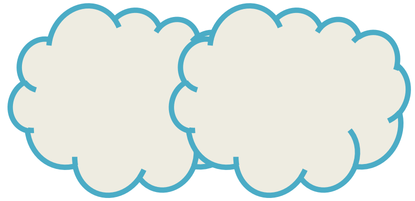


Data Locations

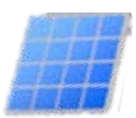
Data Location	Request Number	State	County	Requested In-Service Date	Maximum Output
Bend PV	G0539	OR	Deschutes	4/01/2019	600
	G0523	OR	Wasco	12/31/2018	13
	G0524	OR	Wasco	12/31/2018	20
Burns	G0520	OR	Harney	6/01/2018	20
	G0522	OR	Harney	12/31/2018	20
	G0536	OR	Harney	4/01/2019	20
	G0537	OR	Harney	4/01/2019	20
	G0538	OR	Harney	4/01/2019	20
	G0525	OR	Harney	4/30/2019	20
Cheney	G0518	WA	Benton	11/13/2017	5
	G0564	WA	Franklin	6/30/2019	80
	G0562	WA	Yakima	6/30/2019	80
	G0563	WA	Yakima	6/30/2019	80
Hermiston	G0532	OR	Morrow	6/30/2017	100
	G0529	OR	Morrow	12/31/2017	50
	G0517	OR	Morrow	7/01/2018	76
	G0540	OR	Morrow	12/31/2018	10
	G0550	OR	Umatilla	12/01/2020	120
Silver Lake	G0545	OR	Klamath	10/01/2019	200
	G0521	OR	Lake	1/31/2019	20
	G0526	OR	Lake	4/01/2019	20
	G0527	OR	Lake	4/01/2019	105
	G0557	OR	Lake	12/01/2019	80
	G0549	OR	Lake	12/01/2022	400

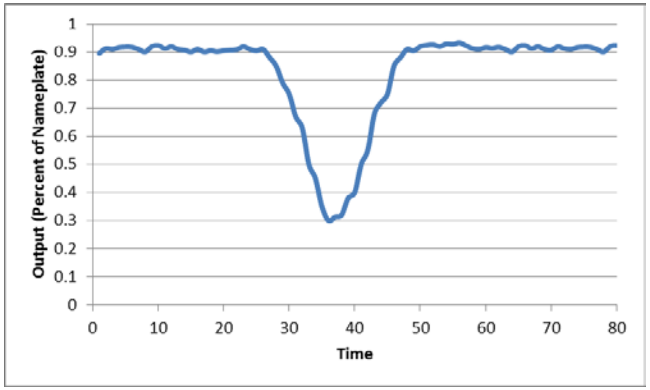
Note: As of 7/1/17, the Interconnection Queue had no solar plants with requested in-service dates past 2022.

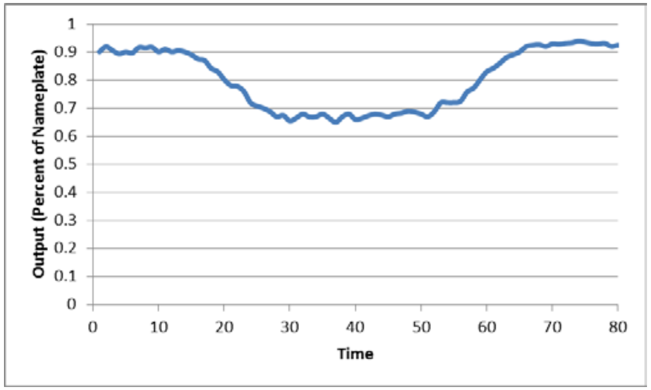
Need for Appropriate Scaling



VS.







Scaling Methodology Development

- University of Oregon data is "point source" - a single irradiance sensor at each location
- We want to represent various sizes of solar farms
- Variability of the signal decreases as size of the plant increases, so we must pay attention to how we scale the data up from the single sensors to the representative plant data

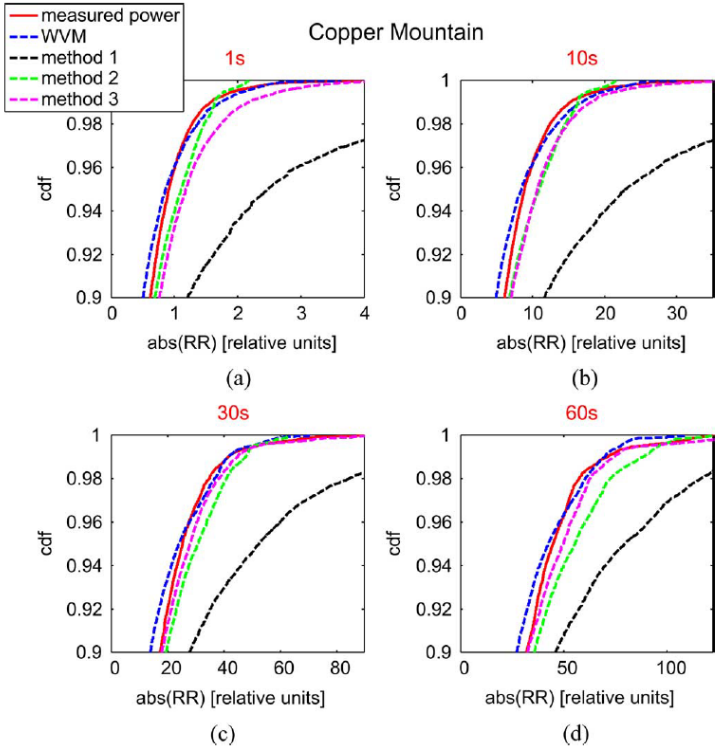


Fig. 9. Extreme (>90th percentile) ramp rate cumulative distribution functions at CM on October 1, 2011 at (a) 1 s, (b) 10 s, (c) 30 s, and (d) 1 min for measured power output (solid red), and for different methods of simulating PV power plant output: WVM (dashed blue), Method 1: linearly scaling from a point sensor (dashed black), Method 2: a moving average of 115 s corresponding to $t_{avg} = Ar^{1/2}/V$ (dashed green line), and Method 3: averaging all 15 reference cells (dashed magenta line).

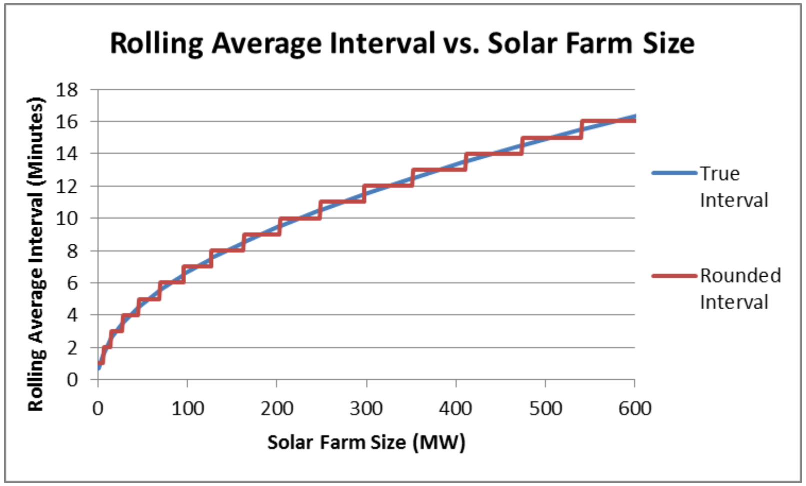
Adapted from "A Wavelet-Based Variability Model (WVM for Solar PV Power Plants" by Matthew Lave, Jan Kleissl, and Joshua Stein, 2013, IEEE Transactions on Sustainable Energy, Volume 4, No. 2

Lave et al. Rolling Average

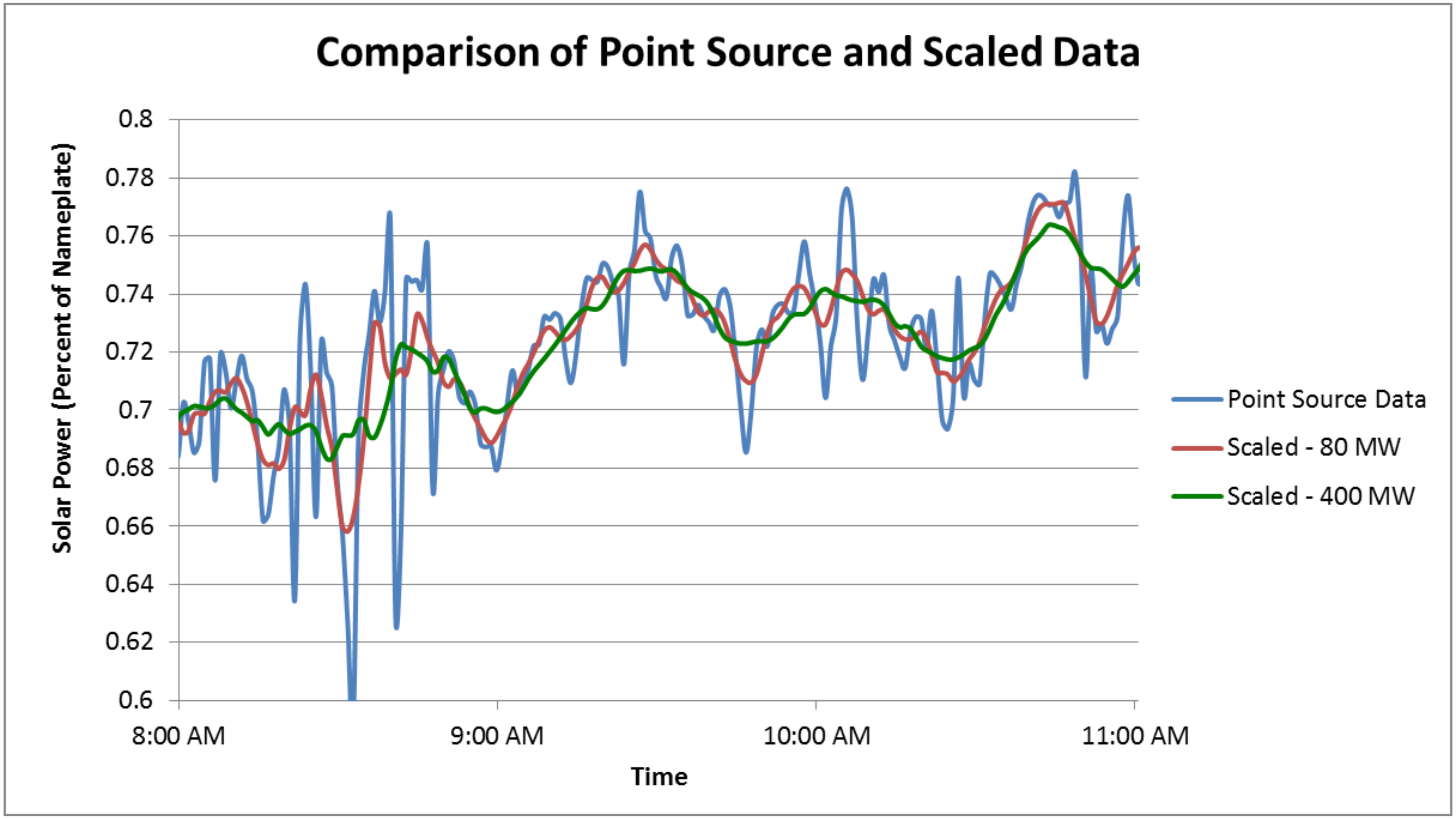
- $MovingAvg(t) = average\left(data\left[t - \left(\frac{T}{2} - 1\right) : t + \frac{T}{2}\right]\right)$, where T is the length in seconds of your rolling average interval.
  - Ex: A 2 minute rolling average has an interval size $T = 120s$, and $MovingAvg(t) = average(data[t - 59: t + 60])$

- Equation to translate from desired plant size to interval length →

- Algorithm to translate second-based calculation to minute-based calculation (see appendix)



Scaling Comparison

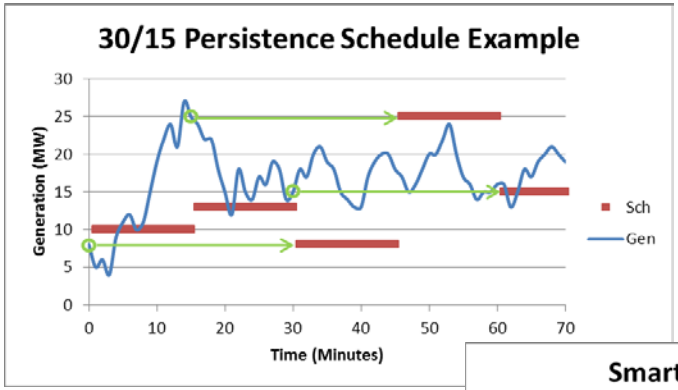


Balancing Reserve Study Methodology

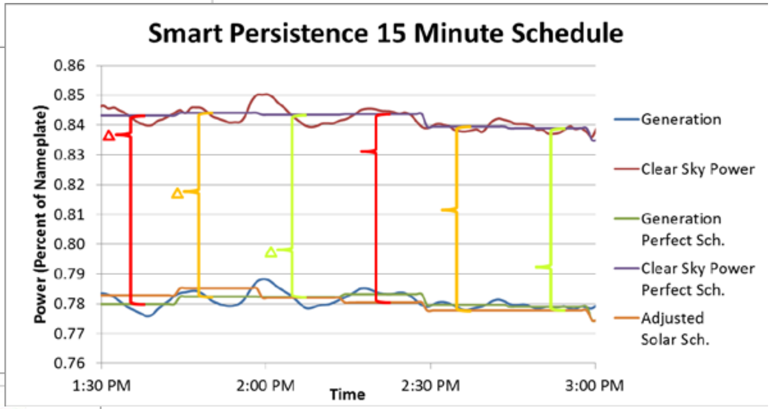
- 2 years of data (July 2015 – July 2017)
  - Limited to 2 years due to length of University of Oregon solar data at identified sites
- Load and non-solar generation held at post-BP-18 level
- Per the BPA balancing reserve forecast methodology, load and generation are analyzed as a whole for diversity and ISD is used to separate out the solar requirement

Scheduling Paradigms

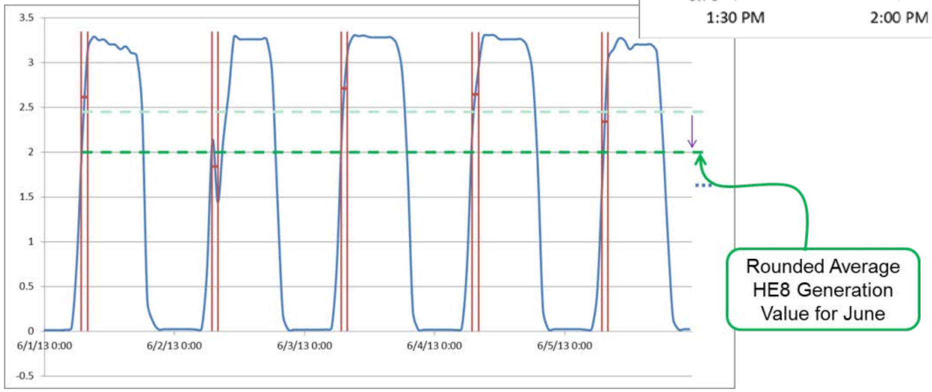
- Persistence
  - 30/60
  - 30/15



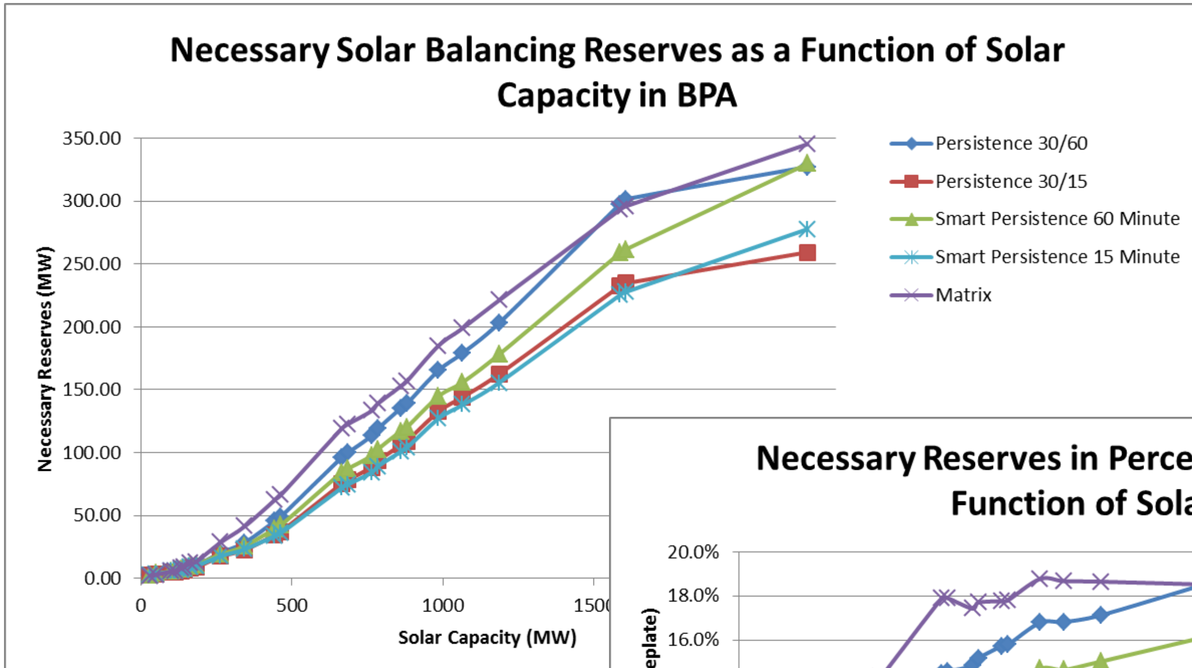
- Smart Persistence
  - 60 Minute
  - 15 Minute

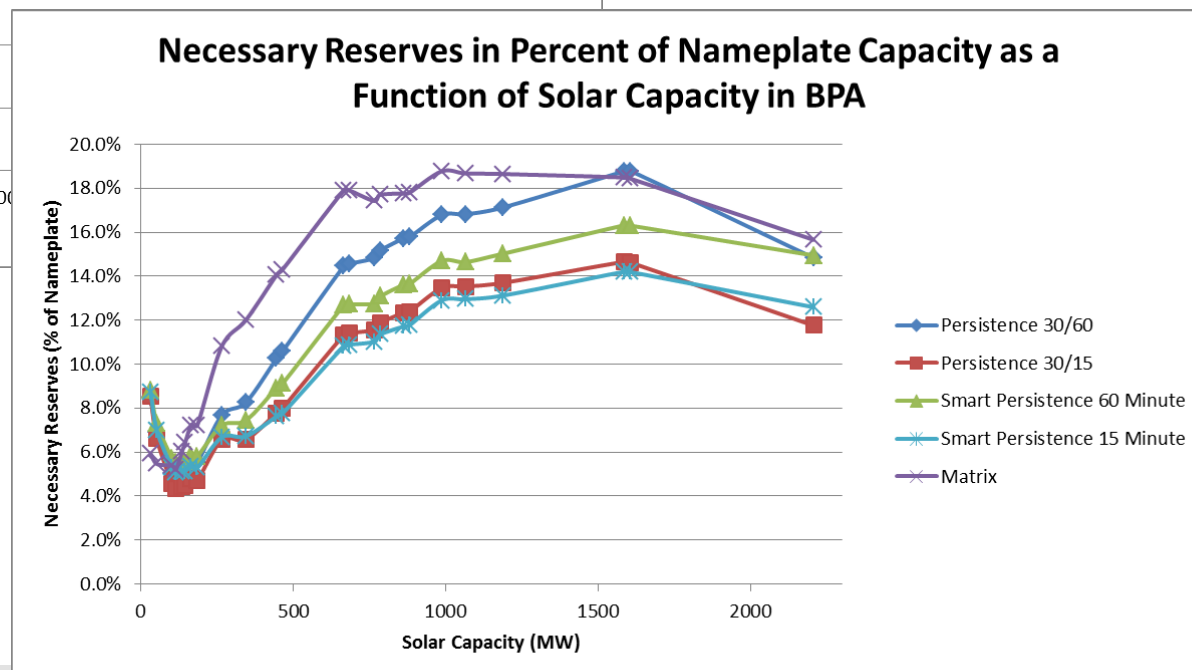


- Matrix

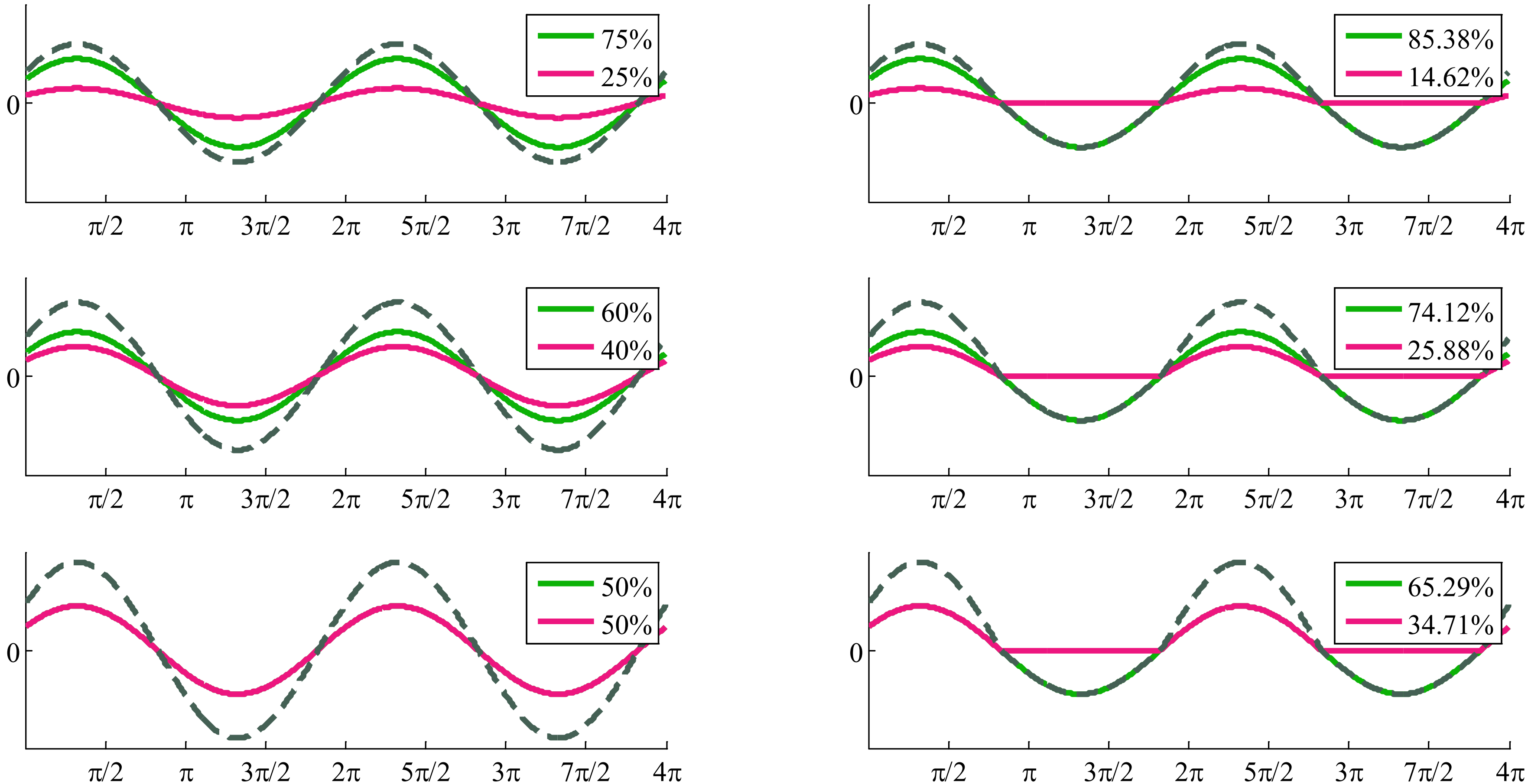


Solar Balancing Reserve Forecast

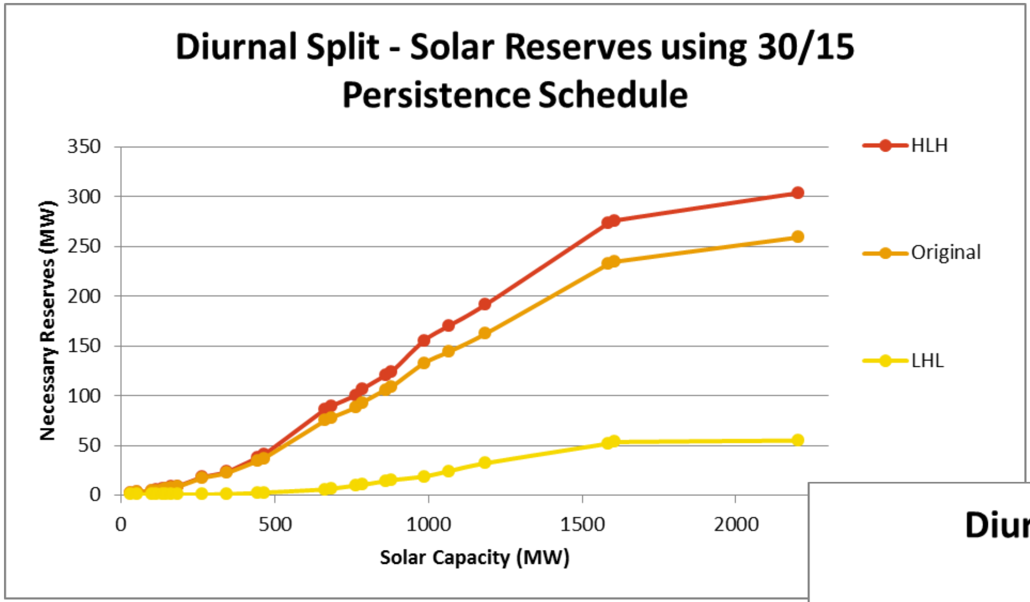


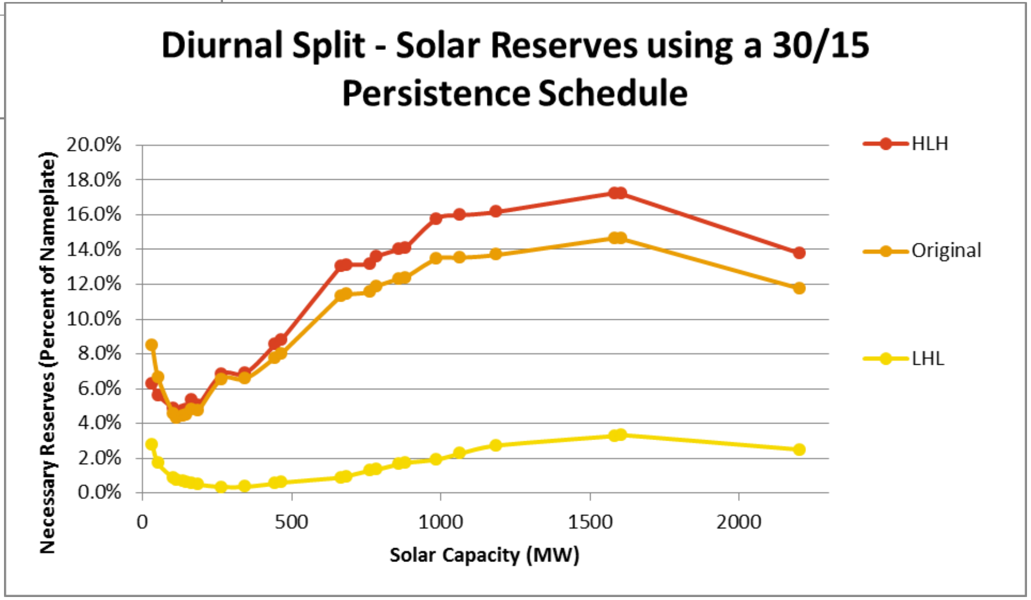


Incremental Standard Deviation

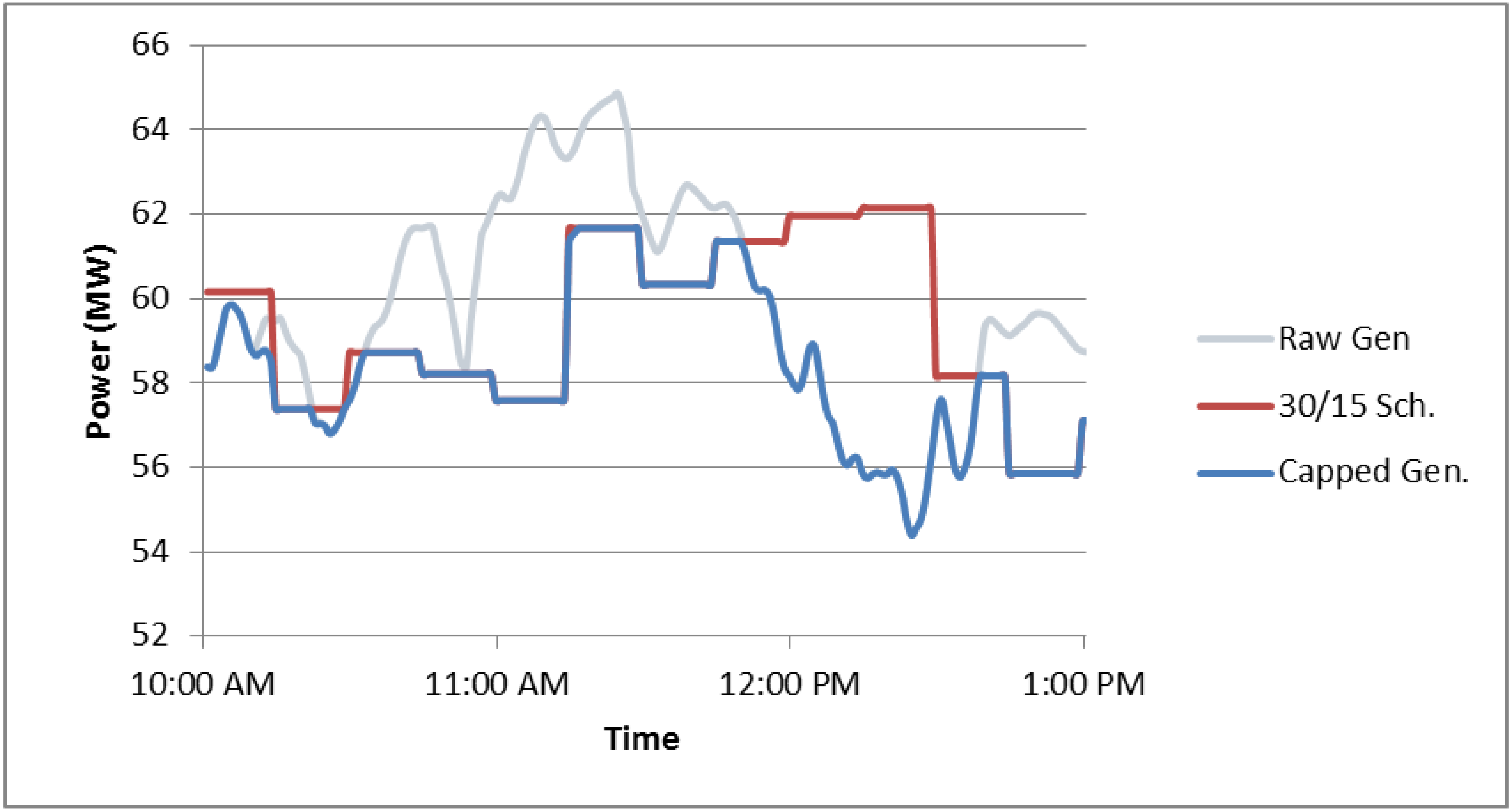


Impact of Shaped Reserves

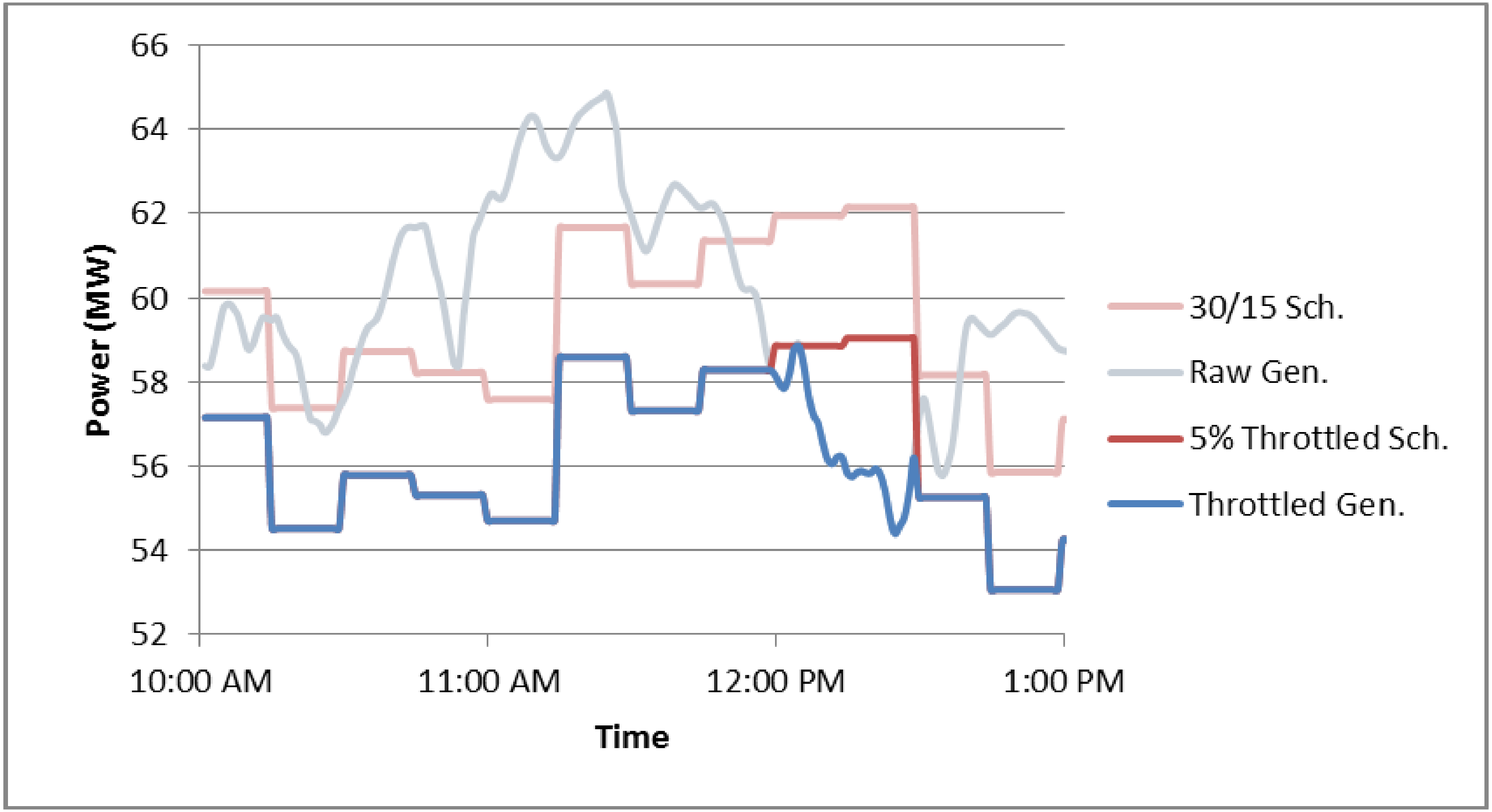




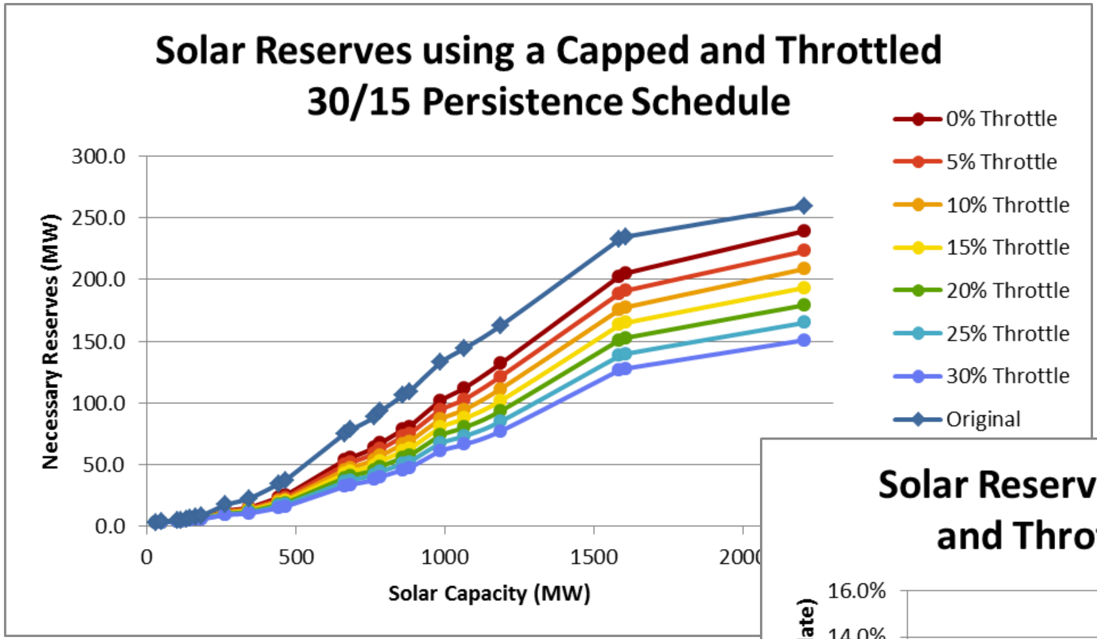
Potential Reserve Reduction Techniques
Capping

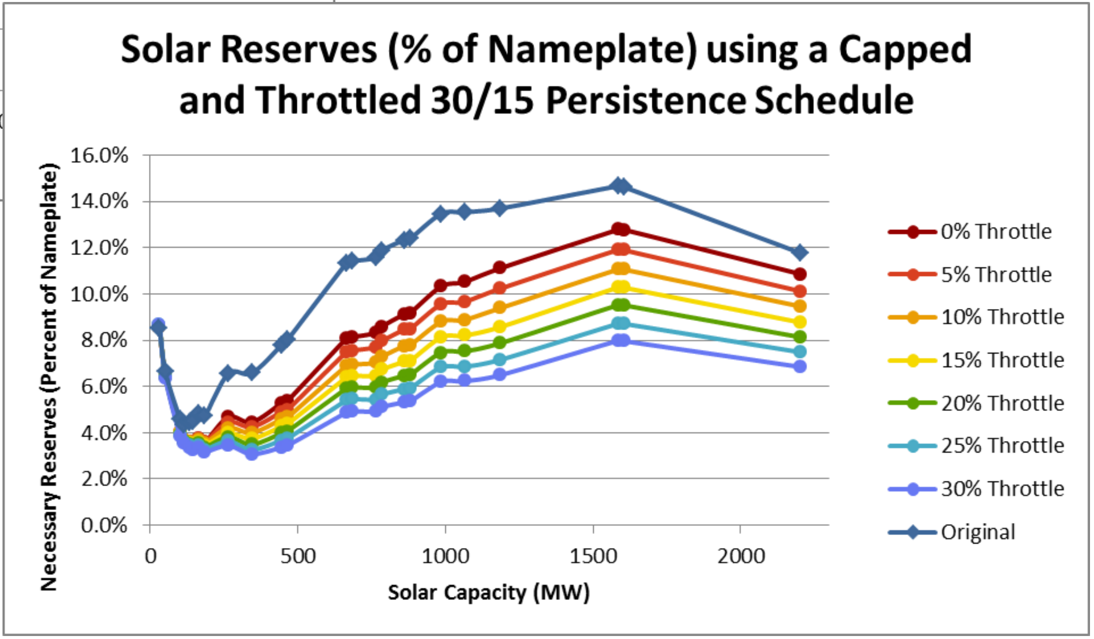


Potential Reserve Reduction Techniques Throttling

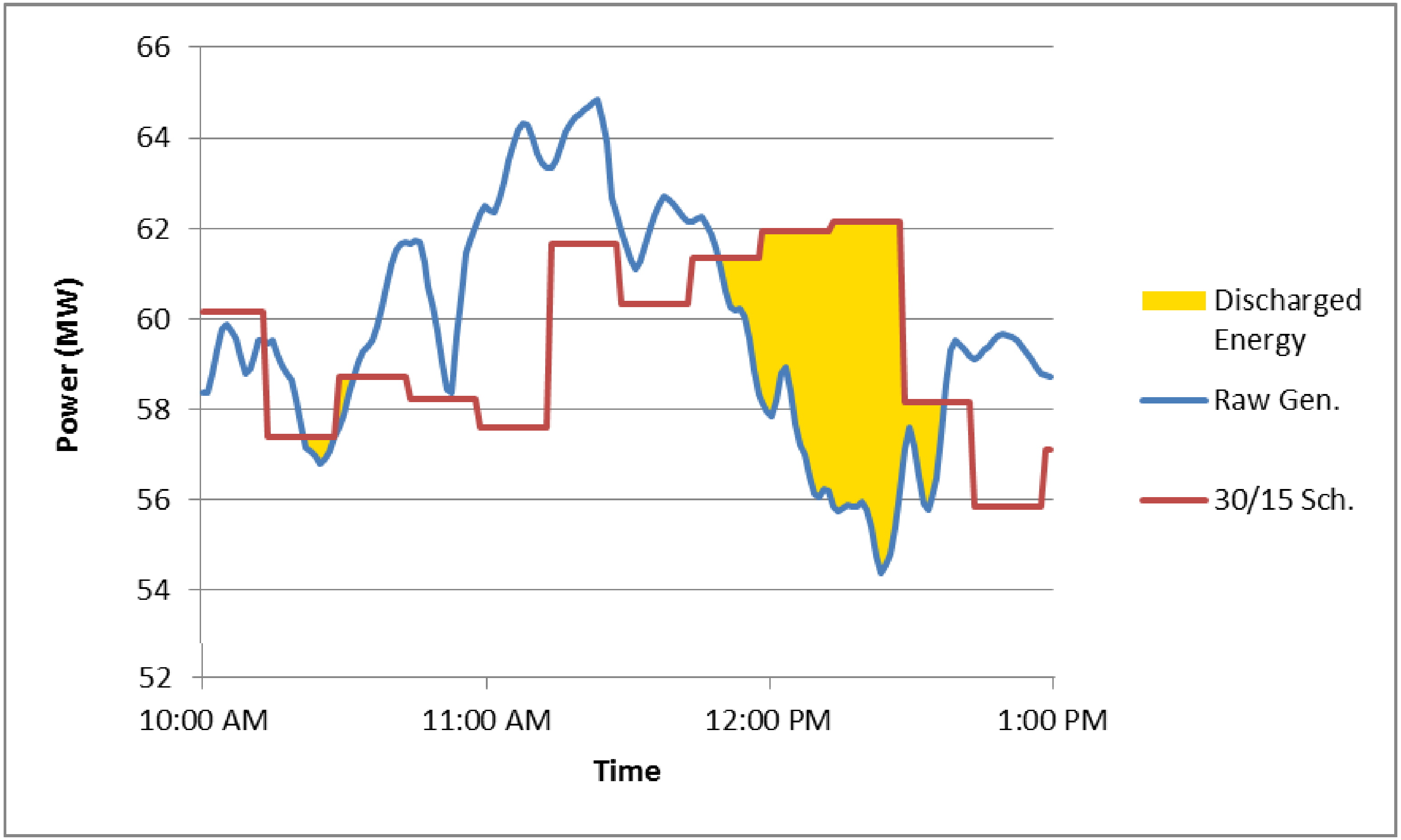


Potential Reserve Reduction Techniques





Storage



66
64
62
60
58
56
54
52
Power (MW)
10:00 AM
11:00 AM
12:00 PM
1:00 PM
Time
Discharged Energy
Raw Gen.
30/15 Sch.

Appendix

Weighted Minute Rolling Average

- Ex: Under previous definition, minute 3 under a 4 minute rolling average would have:
- T = 240s
- $MovingAvg(t) = average(data[t - 119{:}t + 120])$
- Define: $$\begin{array}{l} minute\ 1 : t = [1{:}60] \\ minute\ 2 : t = [61{:}120] \\ minute\ 3 : t = [121{:}180] \\ minute\ 4 : t = [181{:}240] \\ \vdots \end{array}$$

	Minute 1 Contribution	Minute 2 Contribution	Minute 3 Contribution	Minute 4 Contribution	Minute 5 Contribution
MovingAverage(121) = avg(data[2 : 241])	59	60	60	60	1
MovingAverage(122) = avg(data[3 : 242])	58	60	60	60	2
MovingAverage(123) = avg(data[4 : 243])	57	60	60	60	3
⋮	⋮	⋮	⋮	⋮	⋮
MovingAverage(178) = avg(data[59 : 298])	2	60	60	60	58
MovingAverage(179) = avg(data[60 : 299])	1	60	60	60	59
MovingAverage(180) = avg(data[61 : 300])	0	60	60	60	60
Total Contribution of Minute X to Minute 3:	1770	3600	3600	3600	1830

$$\text{Block average of minute 3} = \text{avg}([\text{MovingAverage}(121), \text{MovingAverage}(122), \ldots \text{MovingAverage}(180)])$$