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NREL Variability Analysis for the Western Interconnect

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WECC WebEx

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- Study Data
- Methodology
- Analysis
- Allocation of reserve requirements

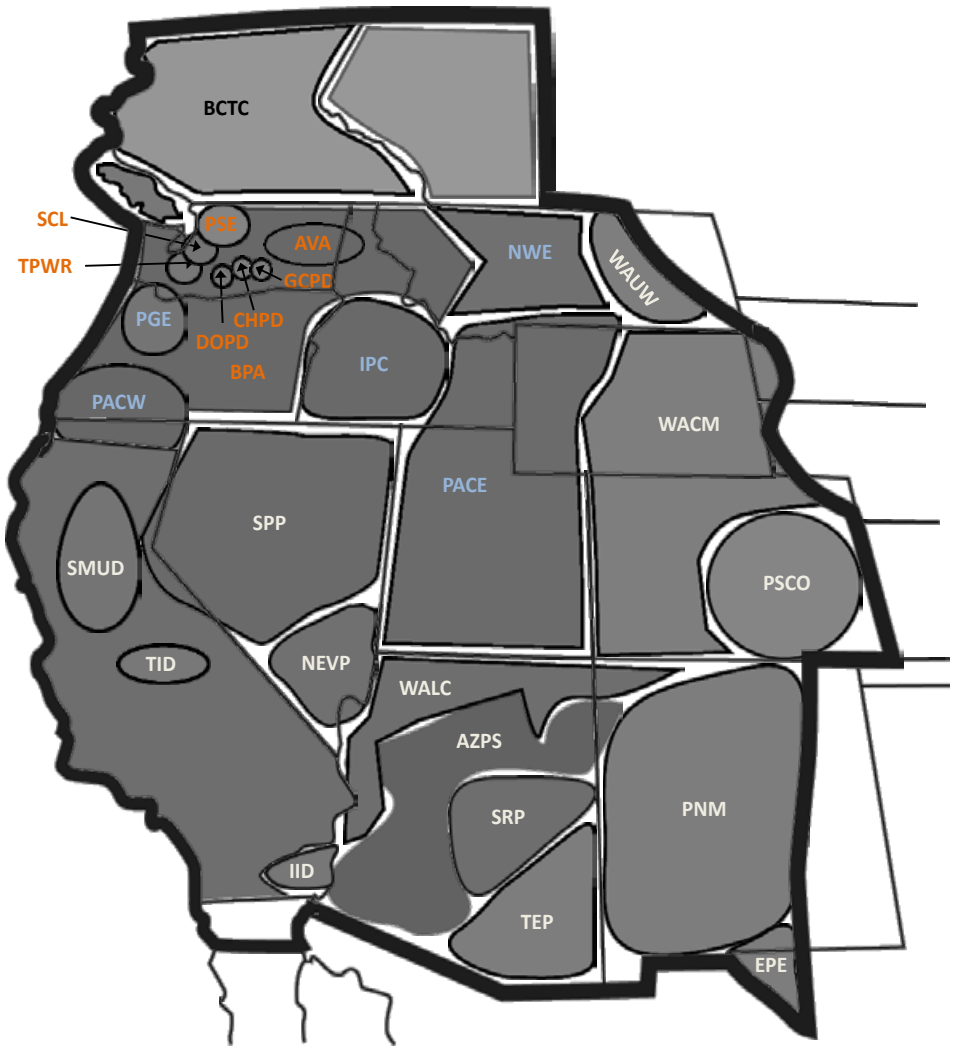
Overview

- Investigate the effects of several Energy Imbalance Markets implementations in the Western Interconnect (WI):
  - Operating reserves;
  - Ramping demand;
  - Alternative Schedu.ing
- Analysis based on aggregation of variability and uncertainty:
  - Uses available load, wind and solar data.
- Calculate the reserve requirements:
  - Estimating within the hour and hourly requirements based on historical data.
- Compared to NREL draft report, this analysis has approximately 1/3 VG.

Study Data

Model Area

- Based on TEPPC PC 0.
- Areas of the WI not already in a market structure (CAISO, Alberta).
- LADWP not included.
- Analysis at BAA granularity.
- Generation only BAAs not considered.
- 28 load and generation BAAs retained – The study 'Footprint.'
- Regions are:
  - Columbia Grid – Orange;
  - NTTG – Blue;
  - West Connect – White.



Load Data

- 2020 loads provided by WECC;
- Load shape is based on 2006 load;
- 193,700 MW in full Western Interconnect (non-coincident).
- 116,700 MW in analysis footprint (non-coincident);
- One hour load provided, 10-minute synthesized.

Wind Data

- NREL WWSIS wind dataset for 2006;
- 10-minute resolution;
- Sites identified by TEPPC 2020 PC 0;
- 29,085 MW in Western Interconnect;
- Approximately 8% of WI 2020 load;
- 18,272-MW nameplate modeled in analysis – footprint.

Solar Data

- NREL WECC Solar dataset for 2006;
- 10-minute resolution;
- Sites identified by TEPPC 2020 PC 0;
- 14,300 MW in WI;
- Approximately 3% of WI 2020 load;
- 4,568 MW nameplate in analysis footprint.

Reserve Calculations

Reserve Calculations

- Developed for the EWITS study;*
- Statistical approach based on 10-minute time series wind, solar and load;
- Method that can estimate adequate reserves to cover the short term and hour-ahead forecast error based on historical data;
- Predicts requirements based on current hour load and wind, solar production;
- Statistically combine with load regulation requirements;
- Provide 8760 vector of requirements for the production simulations.

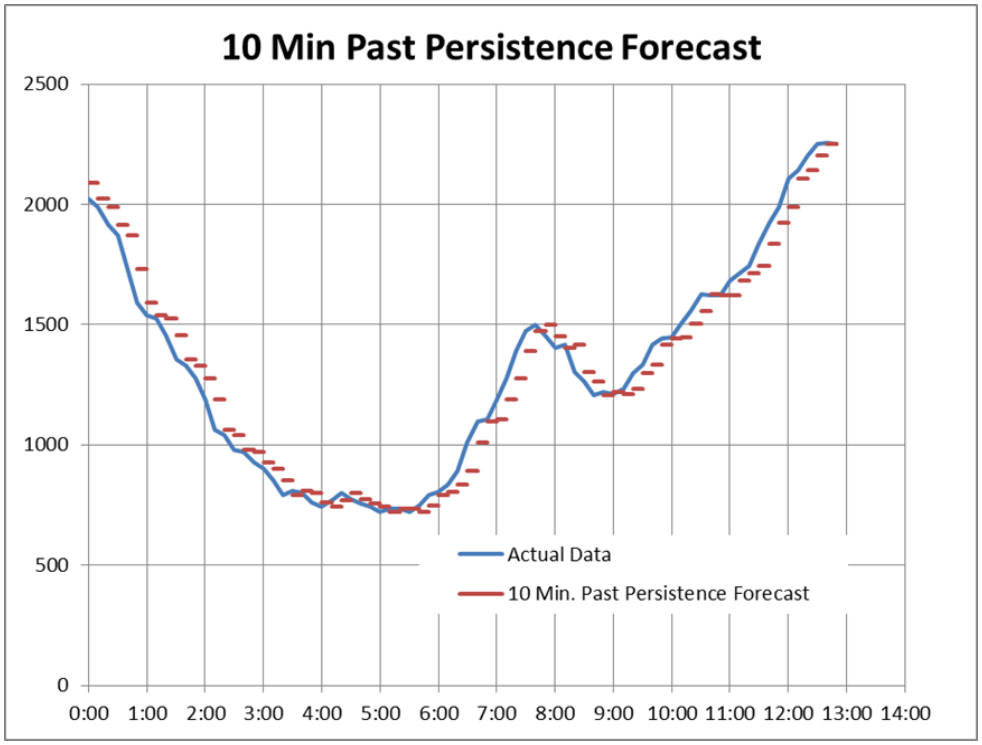
*For in-depth discussion see section 5 of the EWITS final report: http://www.nrel.gov/wind/systemsintegration/pdfs/2010/ewits_final_report.pdf

Reserve Definitions

- Regulation – Fast changes:
  - Due to variability and short-term forecast errors;
  - Faster than re-dispatch period;
  - AGC resources required.
- Spinning – larger, slower, less frequent variations:
  - Due to longer term forecast errors;
  - AGC not required;
  - 10-minute response.
- Non-spinning/supplemental:
  - Large, infrequent, slow moving events such as unforecasted ramps;
  - 30-minute response.

Short-Term Forecast Error - Regulation

- Based on persistence forecas;t
- Wind data is 10 minute, 10-minute delay for forecast;
- Forecast error is calculated as difference from actual to forecast.

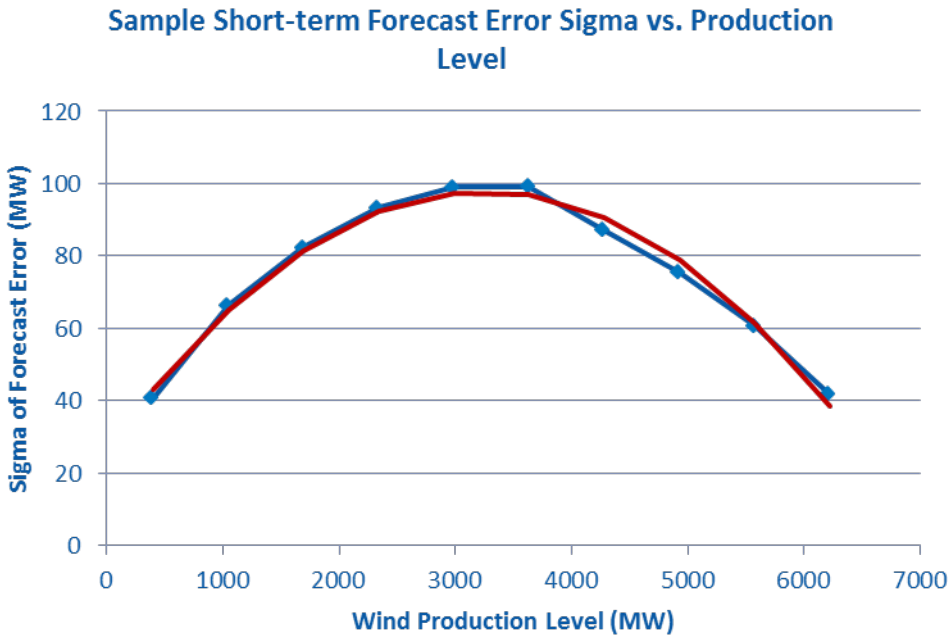


Short-term Calculation

- Measure as standard deviation of the forecast error;
- Forecast error varies with production level;
- Empirical expected error as a function of production is quadratic:
  - Low variability at low and high wind (cut-in and rated);
  - High variability in mid range at steep part of power curve;
  - Solar follows same pattern, more or less.
- Predicts the expected variability for the hour based on the intra-hour statistics, current production;
- Assumes fast dispatch, 10 minutes in this case:
  - Implication is that economic movement happen at 10-minute updates.

Calculation of Short-term Forecast Error

- Calculate and sort error by production level;
- Divide production into deciles;
- Calculate error sigma in each decile;
- Blue line is calculated from data;
- Red line is curve fit;
- Equation of the curve shown below.



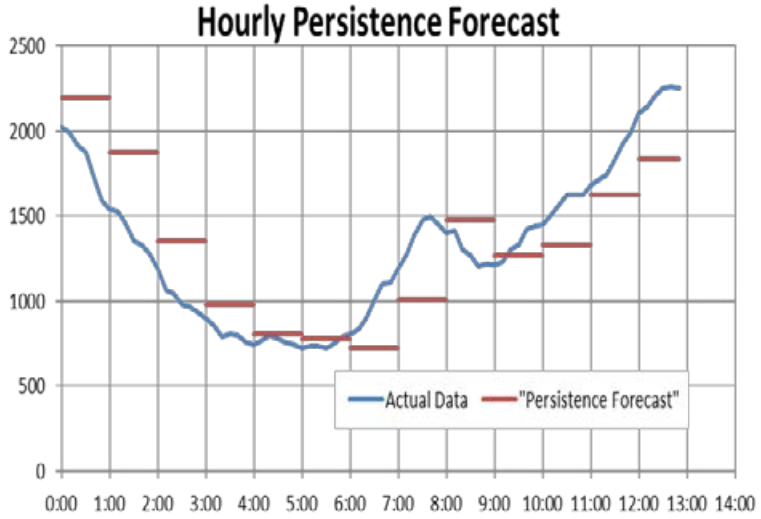
$$\sigma_{ST}\,(Hourly\ Wind) = -6.72E-06 \cdot (Hourly\ Wind)^2 + 0.0437 \cdot (Hourly\ Wind) + 26.74$$

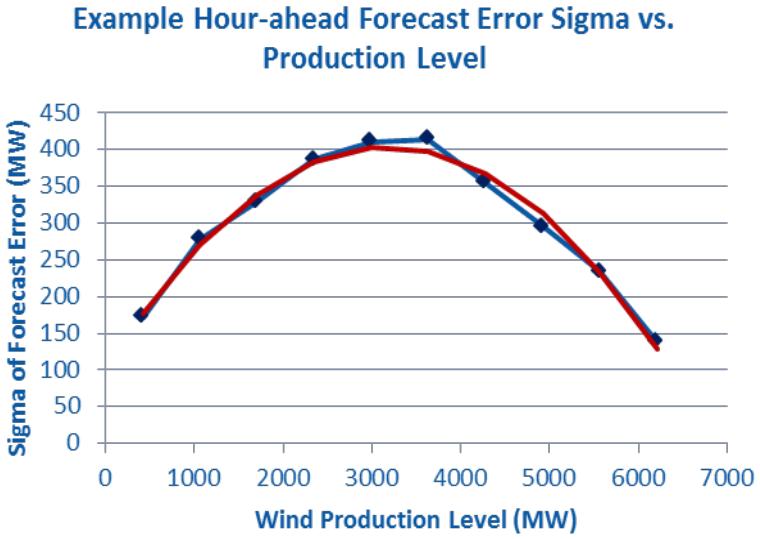
Calculating the Regulation Requirement

- Combine load, wind and solar components statistically assuming no correlation in this time frame
- $$Regulation\ Requirement\ (With\ Wind\ and\ Solar) = 3 \cdot \sqrt{(\sigma_{Load})^2 + (\sigma_{STWind}\ (Hourly\ Wind))^2 + (\sigma_{STSolar}(Hourly\ Solar))^2}$$
- σ_{Load} calculated as fixed % of hourly load based on BA size
- $\sigma_{STWind}\ (Hourly\ Wind)$ calculated from previous slide
- $\sigma_{STSolar}\ (Hourly\ Solar)$ calculated from solar version
- This is 3 sigma to cover 99.7% of all short term forecast errors
- Assumed equal up and down
- Calculated for each hour of the study year

Hour-ahead Forecast Errors

- Repeat the short term forecast procedure with hour-ahead forecasting;
- Again, same procedure for wind and solar;
- Load following not included.





$$\sigma_{Hour-ahead}(Hourly\ Wind) = -2.985E-05 \cdot (Hourly\ Wind)^2 + 0.1895 \cdot (Hourly\ Wind) + 103.2$$

Spin and Non-spin Calculation

- One sigma allocated to **Spinning** category

$$Spinning\ Requirement\ (Hour-ahead\ wind\ forecast\ error)$$
$$1 \cdot \sigma_{hour-ahead}(Previous\ Hour\ Wind)$$

  - Covers 68%* of all movements less than 1 hour
  - With regulation, covers approximately 98% of 30 minute movements

- Two sigma allocated to **Non-spin** category

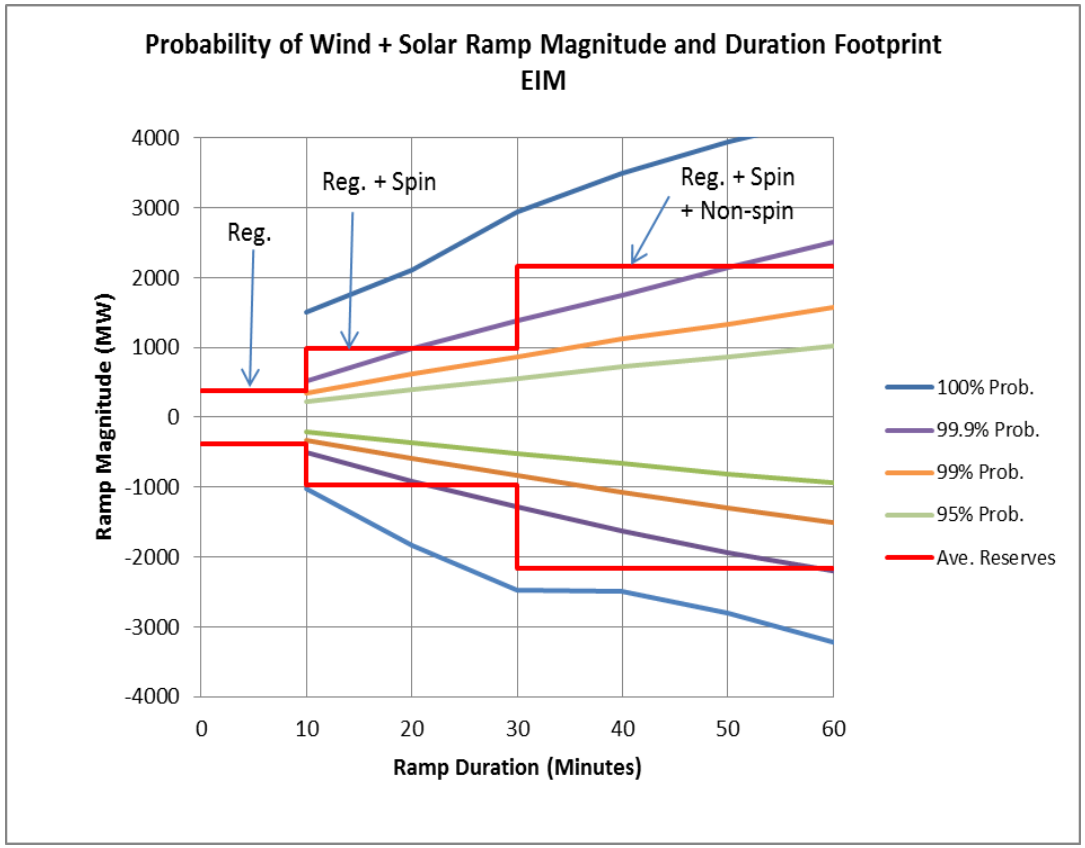
$$Non-spin\ Requirement\ (Hour-ahead\ wind\ forecast\ error) =$$
$$2 \cdot \sigma_{hour-ahead}(Previous\ Hour\ Wind)$$

  - With spin, covers 99.7%* of all movements less than 1 hour

*assuming movements are normally distributed which is slightly optimistic

Verification of Reserve Coverage

- Shows coverage of VG intra-hour movements;
- Actual ramp data from footprint EIM;
- Red line – Actual average reserve calcs from footprint EIM;
- Probability lines are z% of all ramps at x minutes are less than y MW.



Reserves Provided to E3 for Phase 2 Study

- NREL provided reserve calculations to E3 for phase 2 study;
- Slight variation in calculation of regulation component – load not included in E3 Flex;
- Does not include contingency reserves;
- Areas are slightly different from each other.

NREL	E3	Response	Notes
Regulation	Flex	AGC	E3 flex reserve does not contain load
Spin	Spin	<10 minutes	
Non-spin	Supplemental	<30 minutes	Terminology change

Analysis

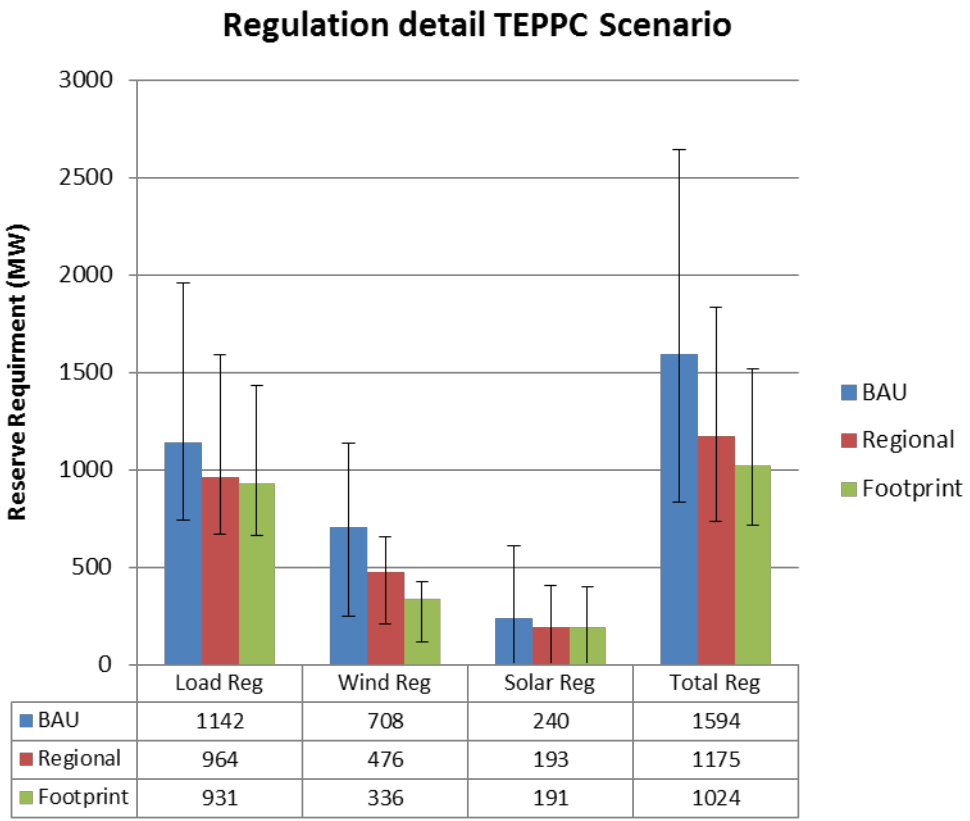
Cases

- Complete analysis includes:
  - Footprint EIM
    - All 28 BAAs participating.
  - ‘Regional’ EIM implementations
    - Columbia Grid;
    - Northern Tier Transmission Group;
    - WestConnect.
  - EIM implementations without BPA and/or WAPA participation.
  - Comparison to the Business-As-Usual (BAU) case – No EIM in place;
  - Selected results.

Footprint EIM Regulation

- Detail of the individual regulation components;
- Bars are average values, whiskers are min and max;
- 3 regional results in smaller reductions compared to footprint.

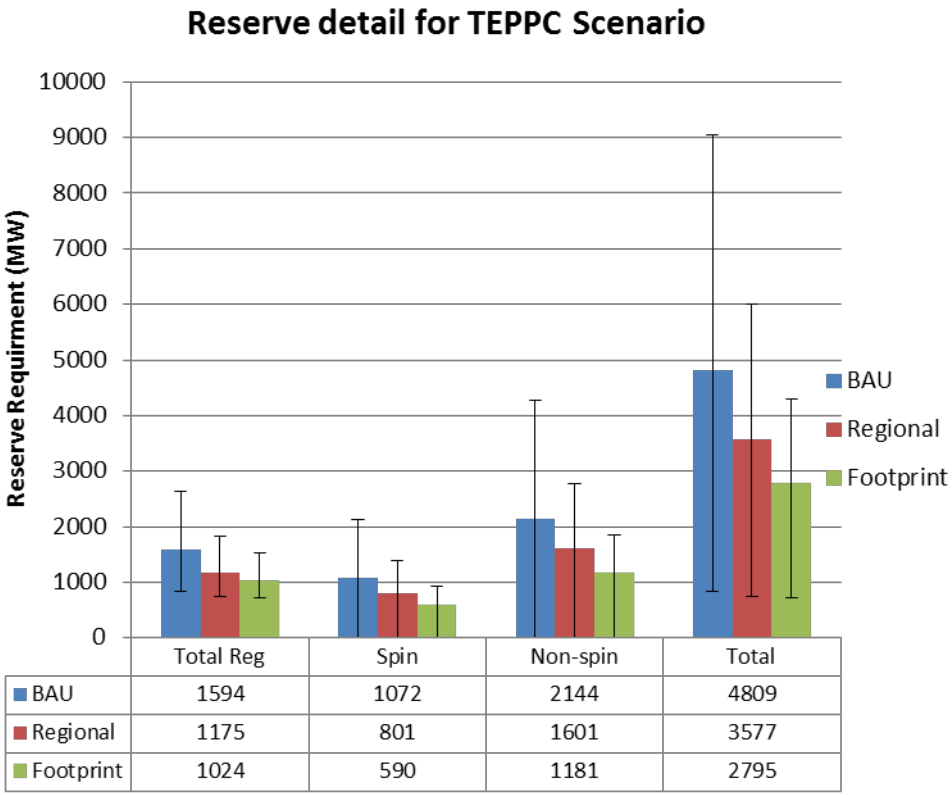
	Reduction over BAU			
	Footprint		Regional	
	MW	% Reduct.	MW	% Reduct.
Load Reg	211	18%	178	16%
Wind Reg	372	53%	231	33%
Solar Reg	49	21%	46	19%
Total Reg	570	36%	419	26%



Reserve Details for Footprint and Regional EIM

- **Up to 42% (2000 MW) reduction in total reserve requirement for footprint EIM;**
- **26% for regional EIMs.**

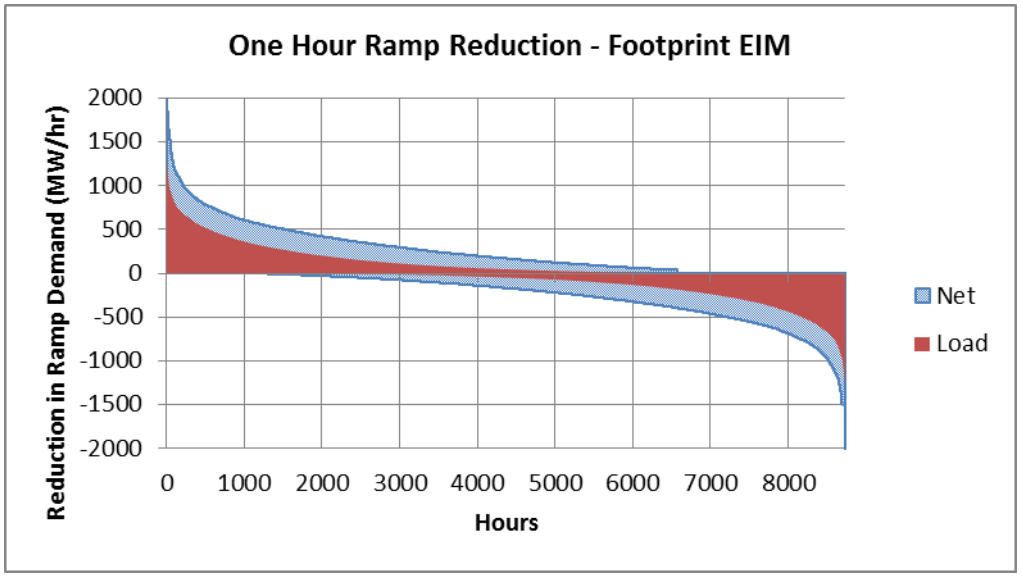
	Reduction over BAU			
	Footprint		Regional	
	MW	% Reduct.	MW	% Reduct.
Total Reg	570	36%	419	26%
Spin	481	45%	271	25%
Non-spin	963	45%	542	25%
Total	2014	42%	1233	26%

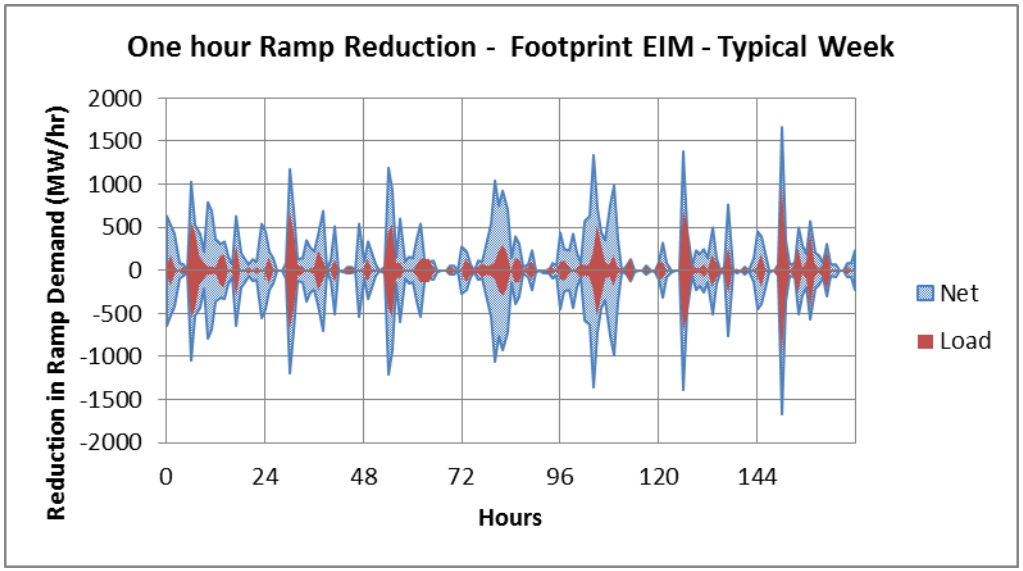


	Total Reg	Spin	Non-spin	Total
BAU	1594	1072	2144	4809
Regional	1175	801	1601	3577
Footprint	1024	590	1181	2795

Ramp Demand Reduction – Footprint EIM

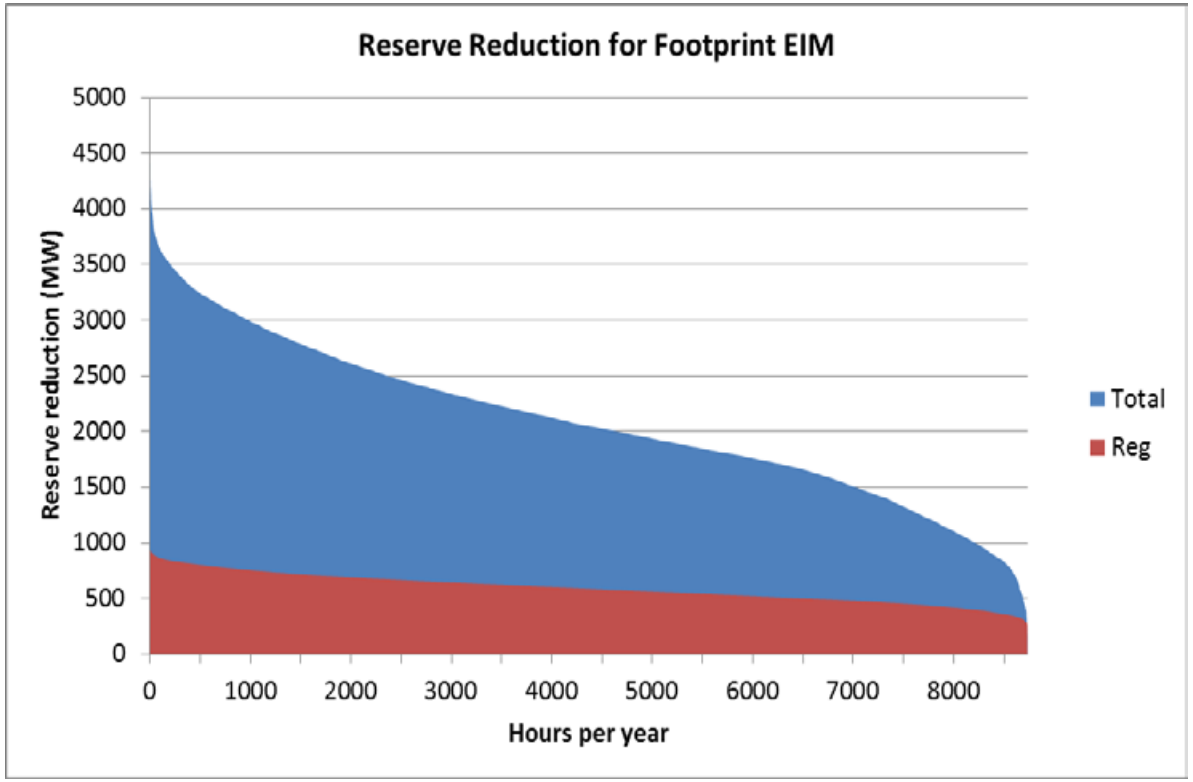
- Based on hourly ramps;
- Shows ramp reduction from EIM over BAU;
- Duration plot shows hours per year for reduction level;
- Reduction in net ramp is greater than 1000 MW for 251 hours per year and averages about 260 MW.





Reserve Reduction Duration – Footprint EIM

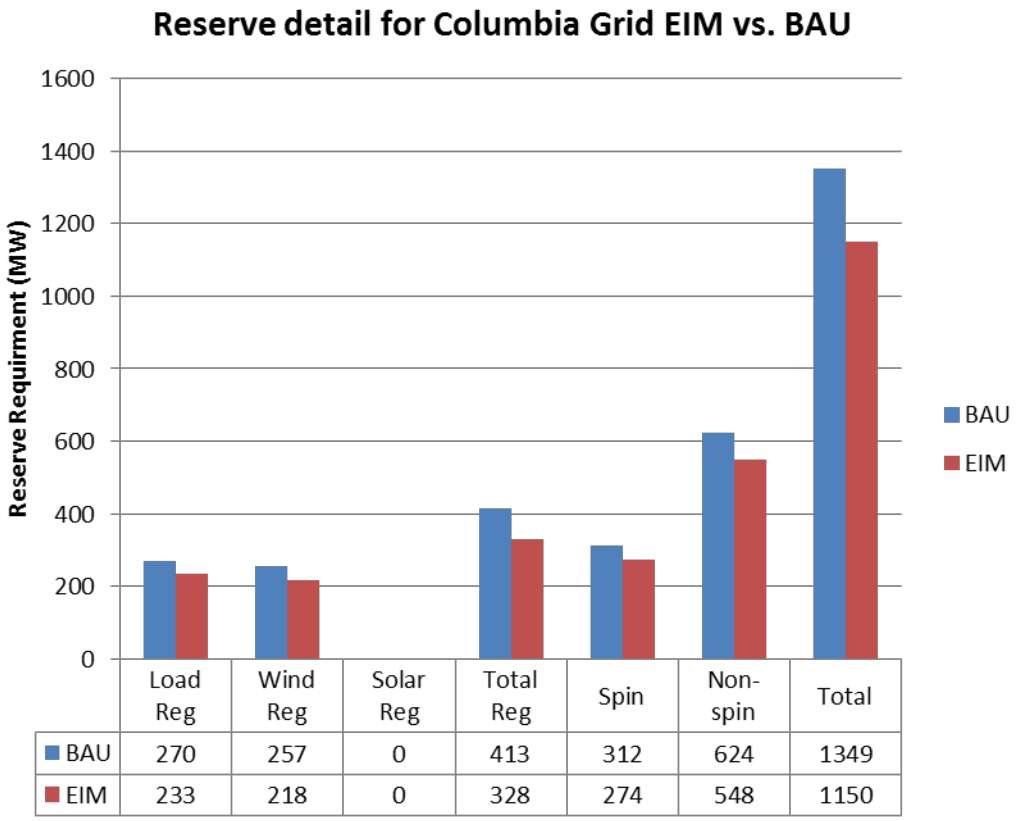
- Average reductions:
  - 590-MW Regulation;
  - 2092-MW Total Reserves.



Regional EIM – Columbia Grid (CG)

- Average reserves for a CG EIM;
- BPA dominates the wind so saving less than other regions;
- 8070 MW Wind.

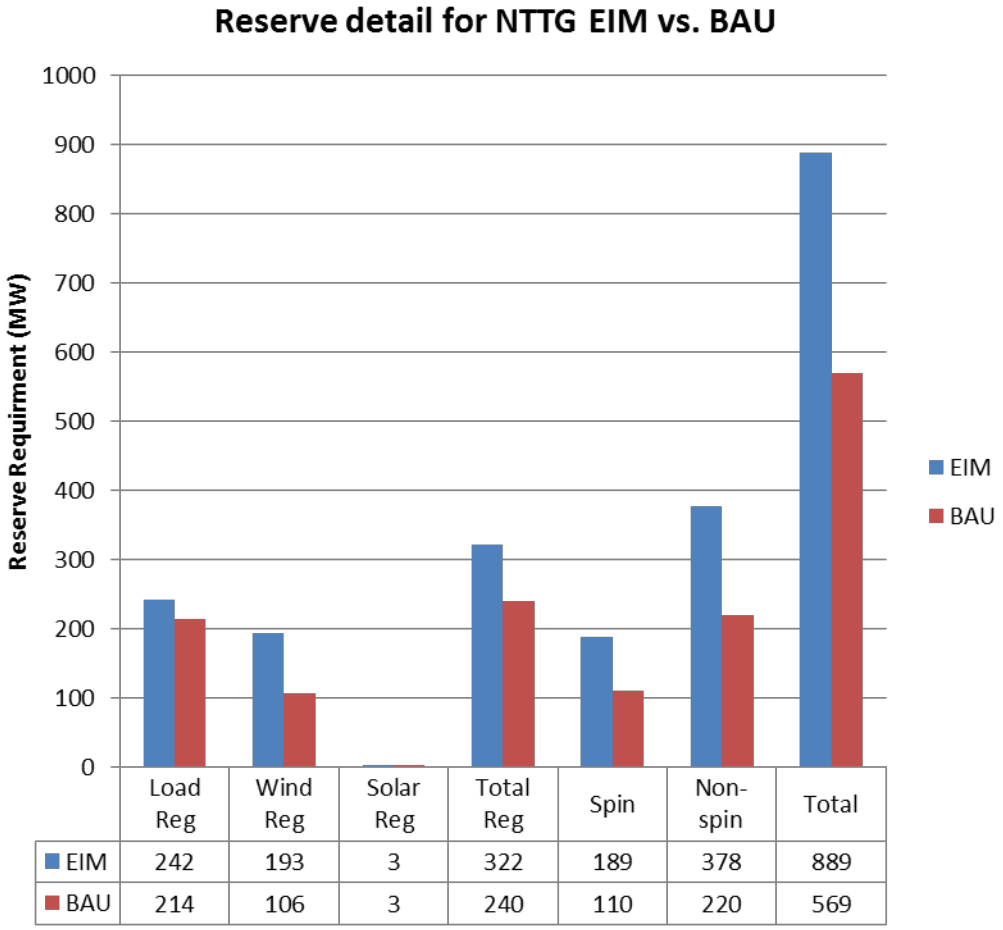
	Reserve Reduction	
	MW	% Reduc.
Load Reg	37	14%
Wind Reg	39	15%
Solar Reg	0	0%
Total Reg	85	21%
Spin	38	12%
Non-spin	76	12%
Total	199	15%



Regional EIM – NTTG

- Average reserves;
- Very small solar;
- Wind dominates savings;
- ~4200 MW wind and 20 MW solar.

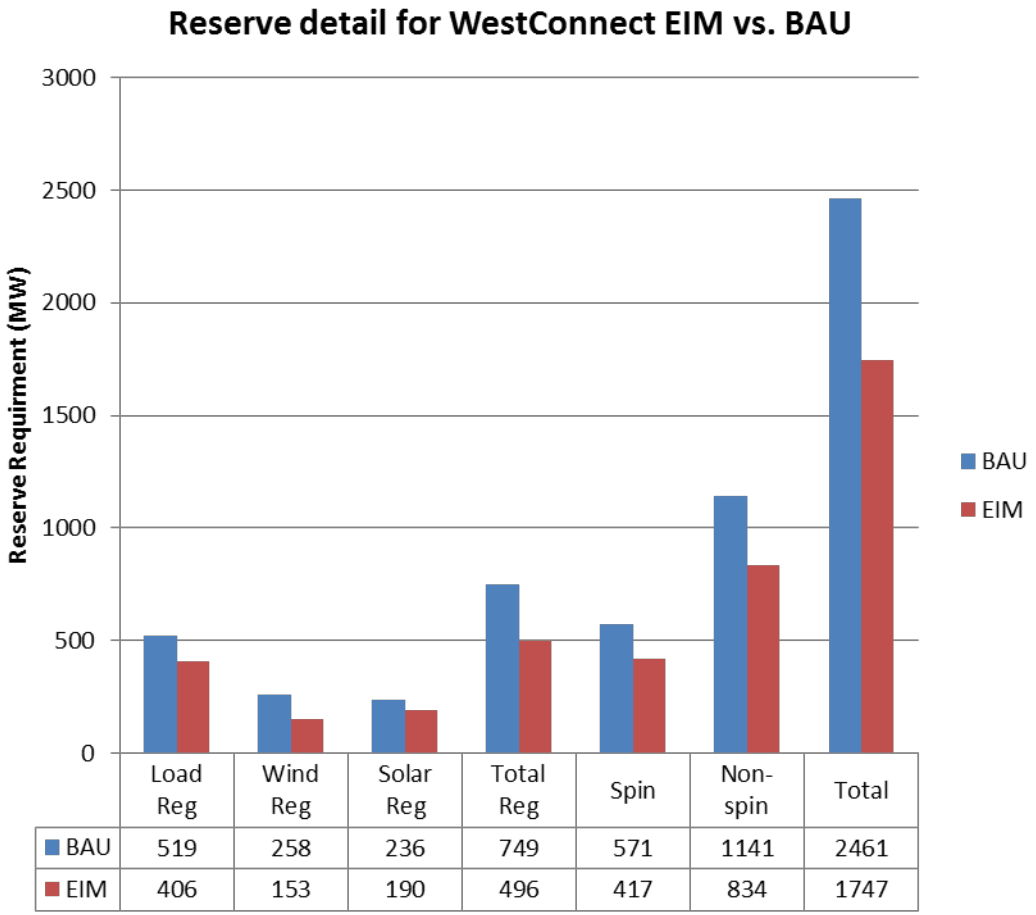
	Reserve Reduction	
	MW	% Reduc.
Load Reg	28	12%
Wind Reg	87	45%
Solar Reg	0	0%
Total Reg	82	25%
Spin	79	42%
Non-spin	158	42%
Total	319	36%



Regional EIM – WestConnect (WC)

- Average reserves;
- Substantial saving from wind and solar;
- ~5700 MW Wind and 4550 MW solar.

	Reserve Reduction	
	MW	% Reduc.
Load Reg	113	22%
Wind Reg	105	41%
Solar Reg	46	20%
Total Reg	253	34%
Spin	154	27%
Non-spin	307	27%
Total	714	29%



Conclusions

- Method for calculating additional reserve requirements due to wind and solar production;
- EIM results in substantial reduction in reserves requirements and ramping demand;
- Reduced participation reduces benefits for all but reduces the benefits to non-participants the most;
- Full participation leads to maximum benefit across the Western Interconnection, up to 42% of total reserve requirement;
- Regional EIM implementations have smaller but substantial benefits.