



Wind Integration Study External Stakeholder Meeting

May 18, 2011

Introduction

- Evolution of PGE Wind Integration Study
 - Phase 1 to Phase 2
- Currently, PGE receives integration services from third parties for Klondike II (PPA), Vancycle Ridge (PPA), and PGE's Biglow Canyon Wind Farm.
 - We do not currently self-integrate.
- As demand increases for a finite supply of BPA's hydro capacity, BPA prices are expected to rise sharply.
- Our objective is to determine PGE's costs to self-integrate wind energy.
- Preliminary results will be provided in today's meeting.

Technical Review Committee

- J. Charles Smith, Executive Director
 - Utility Wind Integration Group (UWIG)
- Michael Milligan, Ph.D.
 - National Renewable Energy Laboratory (NREL)
- Brendan Kirby, P.E.
 - Consultant with NREL
- Michael Goggin, Manager of Transmission Policy
 - American Wind Energy Association (AWEA)

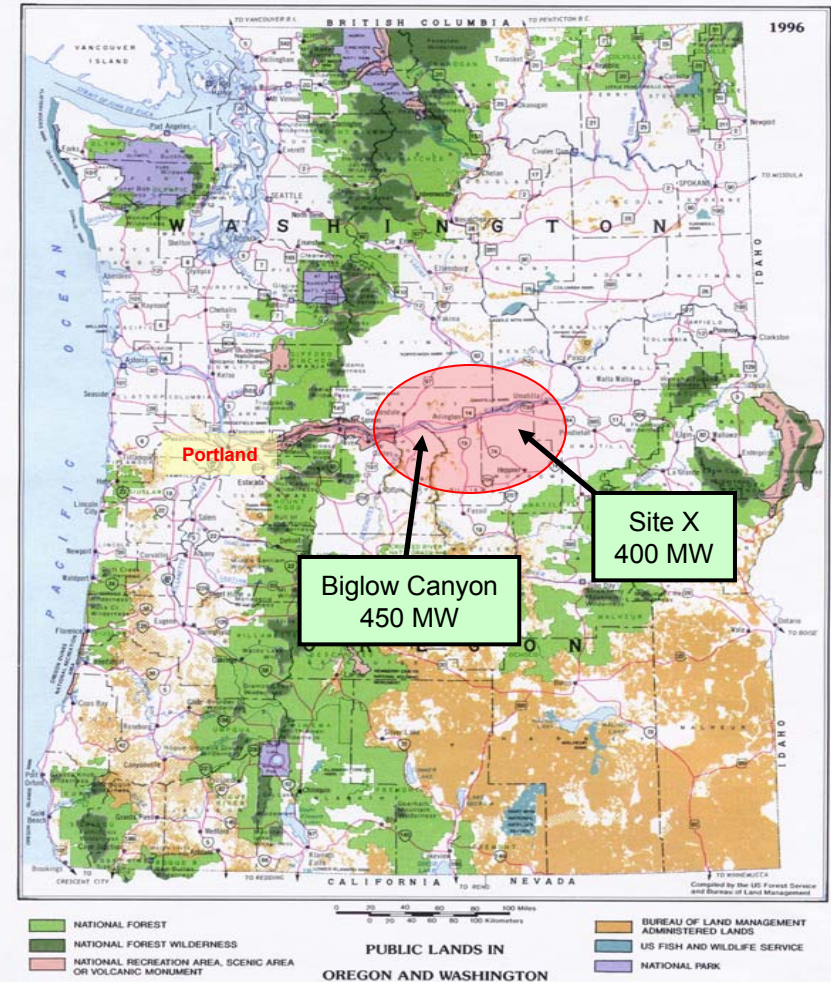
External Consultants

- Bob Zavadil, E.E., Executive VP of Power Systems Consulting
 - EnerNex Corporation
- Tom Mousseau, M.Ed., Principal Consultant
 - EnerNex Corporation
- Jennifer A. Hodgdon, Ph.D.
 - Poplar ProductivityWare
- Jeffrey T. Linderoth, Ph.D, Associate Professor
 - Department of Industrial & Systems Engineering
 - College of Engineering, University of Wisconsin-Madison

Phase 2 Project Scope and Timeline

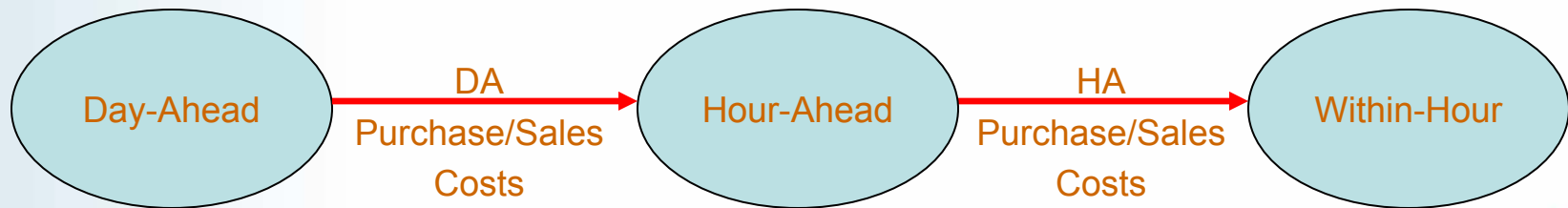
- Determine costs of integrating wind generation into PGE system
 - Uses only current PGE generating resources (no future balancing resources)
 - Diminished Hydro Generation Capacity
 - Physical and Administrative constraints placed on balancing resources
 - Target year: 2014
 - Assumes 850 MW of wind integrated into PGE system
 - Used 2005 as the year for hydro flows, wind data, and load forecast errors

- Projected completion of Wind Study
 - Mid-Year 2011
 - Produce written report with help of EnerNex



Wind Integration Model: Stages

- One-year analysis consists of 52 one-week runs.
- Model is currently defined at a one-hour scheduling interval level.
- The model is run in three stages corresponding to:
 - Day-Ahead (DA)
 - Hour-Ahead (HA)
 - Within Hour (WH)
- Total system operating costs at the third stage are used in assessing the costs of wind integration.



Resource Assumptions

- Plants Providing Ancillary Services:
 - PGE's 2014 Share of the Mid-C.
 - Two-Thirds of Pelton and Round Butte
 - Beaver: Combined Cycle and Simple Cycle.
- Plants Not Providing Ancillary Services
 - Port Westward*
 - Coyote**
 - Boardman**
 - Colstrip**
- PGE resources are used to integrate 850 MW of wind in 2014
 - Includes self-integration of 450 MW of Biglow Canyon instead of integrating through BPA, as is current practice

* Not designed to provide Dynamic Capacity

** Due to PGEM interpretation of BPA Dynamic Transfer Business Practice limitations

PGE's Plant Portfolio: Phase 1 vs. Phase 2 Study

- 850 MW in Wind Generation

	Operational Reserve	Mid-C	Round Butte **	Pelton **	Boardman	Colstrip	Port Westward	Duct Burner	Coyote	BV-SC	BV-CC	DSG
Energy		√ X	√ X	√ X	√ X	√ X	√ X	√	√ X	√ X	√	
Capacity	Load Following	√ X	√ X	√ X	X	X	X	√	X	√ X	√	
	Regulation	√ X	√ X	√ X						√ X		
	Spinning Reserve	√ X	√ X	√ X	X	X	X	√	X	√ X	√	
	Non-Spinning Reserve	√ X	√ X	√ X	X	X	X	√	X	√ X*	√	√ X

Hydro	Coal	Natural Gas	Diesel
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X Phase 1 Study √ Phase 2 Study

* Beaver has to be spinning to provide both spinning and non-spinning contingency reserve

** Pelton/Round Butte dispatched at 100% in Phase 1 WIS



PGE's Plant Portfolio: Phase 2 Study

- 850 MW in Wind Generation

	Operational Reserve	Mid-C	Round Butte **	Pelton **	Boardman	Colstrip	Port Westward	Duct Burner	Coyote	BV-SC	BV-CC	DSG
Energy		√	√	√	√	√	√	√	√	√	√	
Capacity	Load Following	√	√	√				√		√	√	
	Regulation	√	√	√						√		
	Spinning Reserve	√	√	√				√		√	√	
	Non-Spinning Reserve	√	√	√				√		√*	√	√

Hydro	Coal	Natural Gas	Diesel
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√ Phase 2 Study



* Beaver has to be spinning to provide both spinning and non-spinning contingency reserve

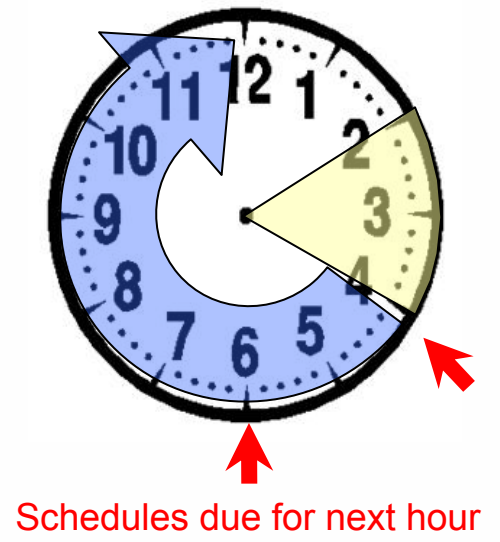
** Pelton/Round Butte dispatched at 100% in Phase 1 WIS

Reserve Components

- Regulation
 - Regulation of Load and Regulation of wind are not correlated.
- Load following load only
 - Baseline for Load
- Load following with perfect short term wind forecast
 - Assess the incremental load following for wind.
- Load following with persistence uncertainty
 - Assess the incremental load following for persistence forecast.
 - No explicit reserves held out for Day-Ahead Uncertainty (Load or Wind)

Pre-Model Run: TRC Input

- Hour-Ahead Forecast



- Within-Hour Reserves

- For Within-Hour execution, no regulation or load following is used for wind generation of 5 MWa or less; or for wind generation of 845 MWa or greater

Wind Integration Cost Break-Out

Identification	Description
RUN 1	PGE integrates Regulation, Load Following, Hour Ahead and Day Ahead Uncertainty
RUN 3	PGE doesn't Integrate Hour Ahead- Uncertainty
RUN 4	PGE doesn't Integrate Load Following
RUN 5	PGE doesn't Integrate Regulation
RUN 6	PGE doesn't Integrate Day Ahead Uncertainty
RUN 7	PGE doesn't Integrate Load Following, Regulation, Hour-Ahead and Day-Ahead Uncertainty

Wind Integration Cost Break-Out (Preliminary)

The result on row A below may not equal B+C+D+E

Identifier	Cost Saving For PGE	Run Delta Measures:	Cost/ MWh
A	RUN 7 – RUN 1	Cost of Wind Integration Cost for Day-Ahead Uncertainty, Hour- Ahead Uncertainty, Load Following and Regulation	\$14.46
B	RUN 6 – RUN 1	Cost for Day-Ahead Uncertainty	\$3.25
C	RUN 3 – RUN 1	Cost for Hour-Ahead Uncertainty	\$5.60
D	RUN 4 – RUN 1	Cost for Load Following	\$1.79
E	RUN 5 – RUN 1	Cost for Regulation	\$5.30



Validating Results

■ Cost Drivers

- PGE Portfolio and Unit Dispatch
 - Limited Balancing Resources
 - High Penetration of Wind on PGE System
- Lack of Geographic Diversity (Not quantified)
- Bilateral vs. Organized Market

■ Collaborative Discussion with TRC

- Regulation Due to Wind

PGE's Plant Portfolio 2011 Study

- 850 MW in Wind Generation

	Operational Reserve	Mid-C	Round Butte	Pelton	Boardman	Colstrip	Port Westward	Duct Burner	Coyote	BV-SC	BV-CC	DSG
Energy		√	√	√	√	√	√	√	√	√	√	
Capacity	Load Following	√	√	√				√		√	√	
	Regulation	√	√	√						√		
	Spinning Reserve	√	√	√				√		√	√	
	Non-Spinning Reserve	√	√	√				√		√*	√	√

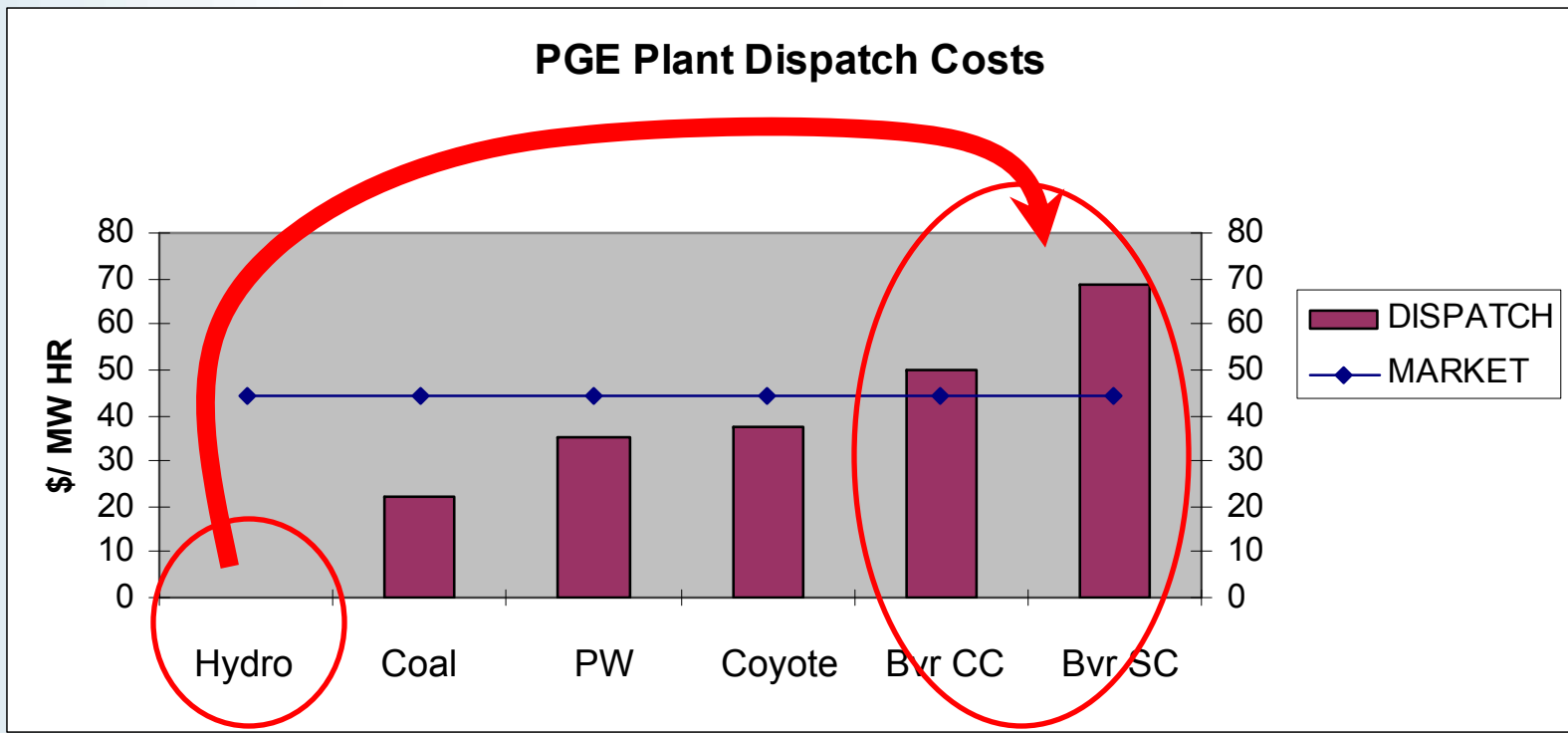
Hydro	Coal	Natural Gas	Diesel
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* Beaver has to be spinning to provide both spinning and non-spinning contingency reserve

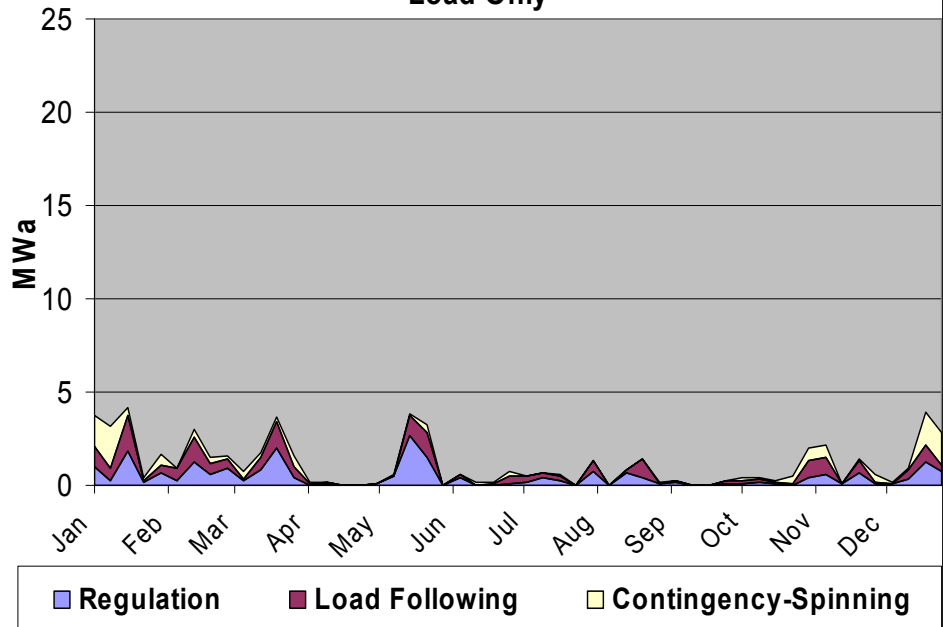
PGE Plant Dispatch

PGE Plant Dispatch at
Feb 2011 PIRA Gas Price

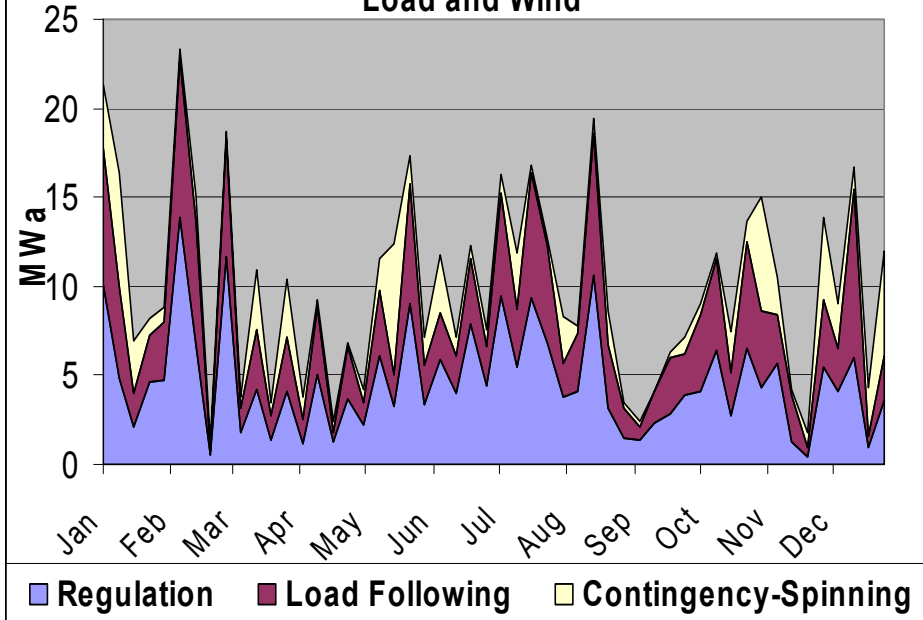


Beaver Simple Cycle Dispatch

Beaver Simple Cycle Ancillary Service Load Only



Beaver Simple Cycle Ancillary Service Load and Wind

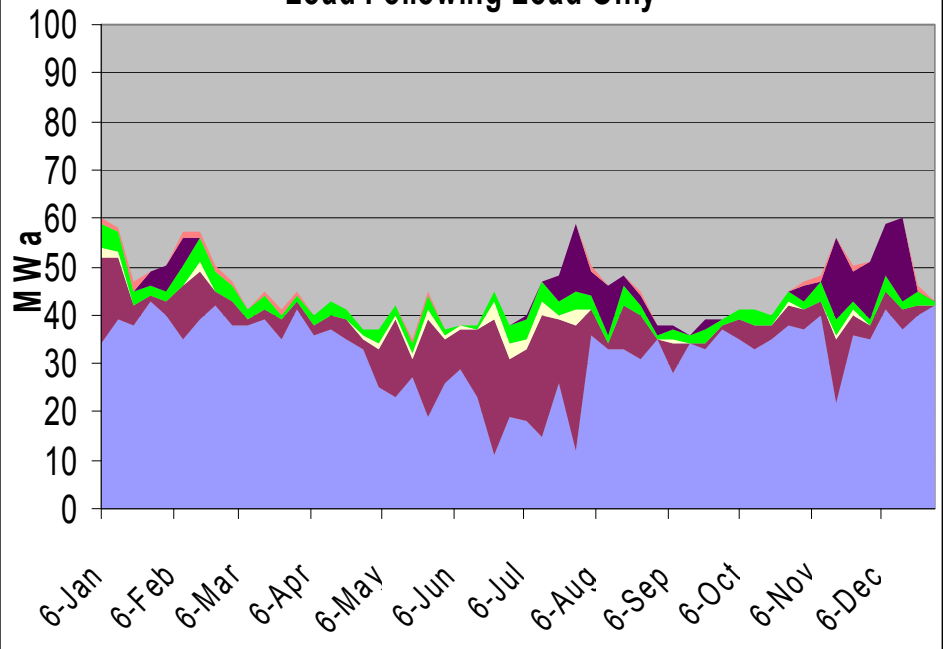


Projected 2014 Beaver dispatch for Capacity prior to new capacity actions



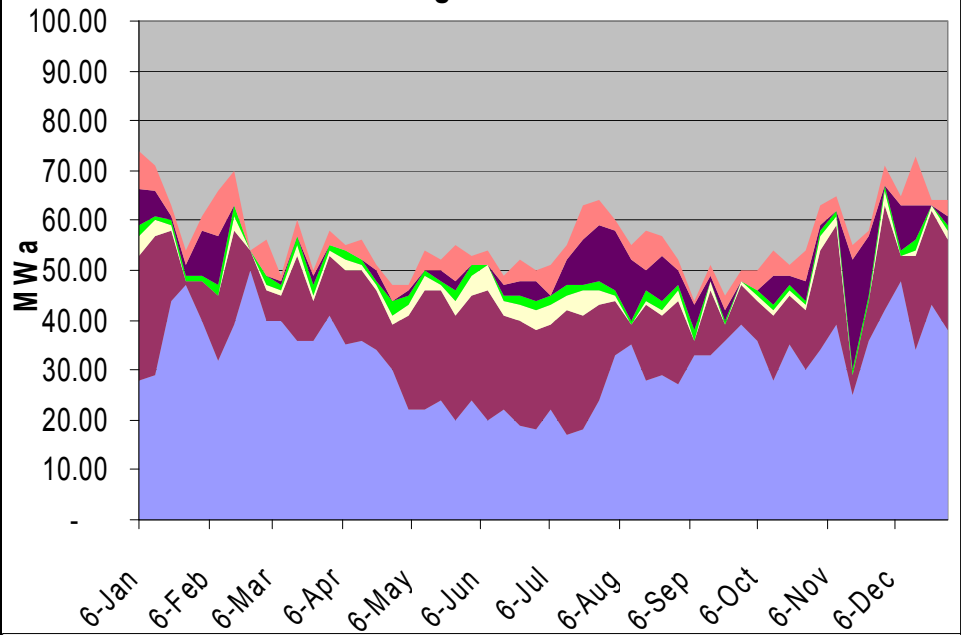
Load Following

Load Following Load Only



Mid-C	Round Butte	Pelton
PW Duct Firing	Beaver CC	Beaver SC

Load Following for Load and Wind

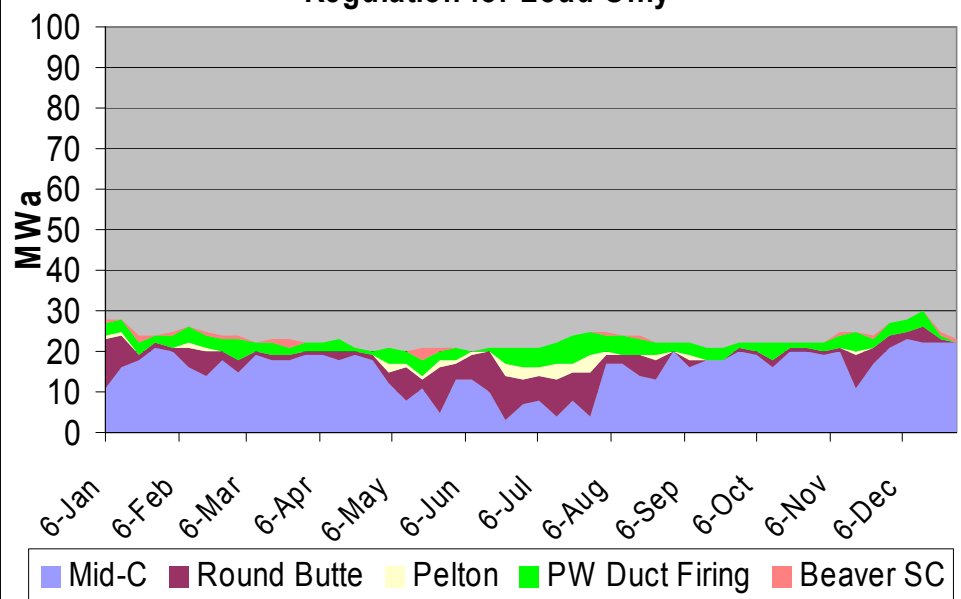


Mid-C	Round Butte	Pelton
PW Duct Firing	Beaver CC	Beaver SC

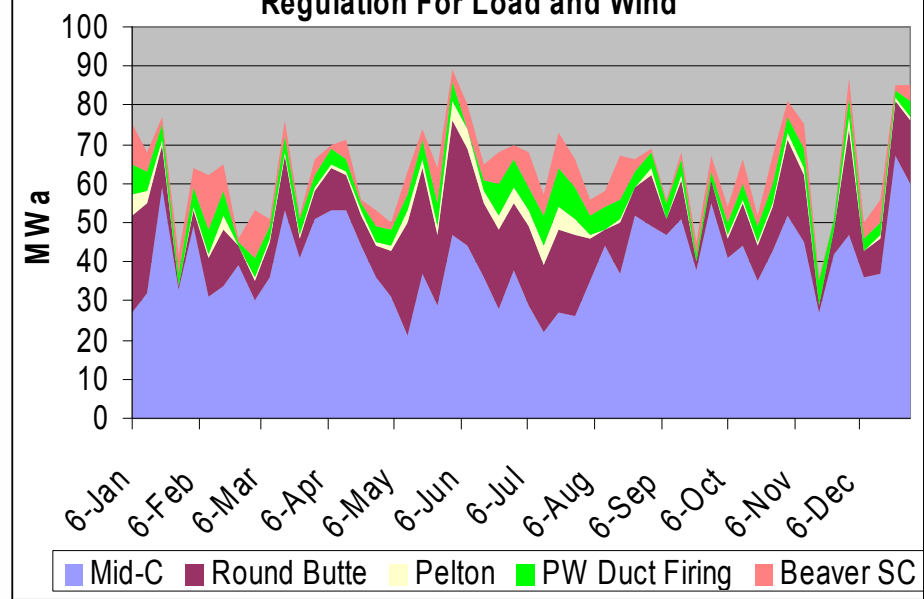


Regulation

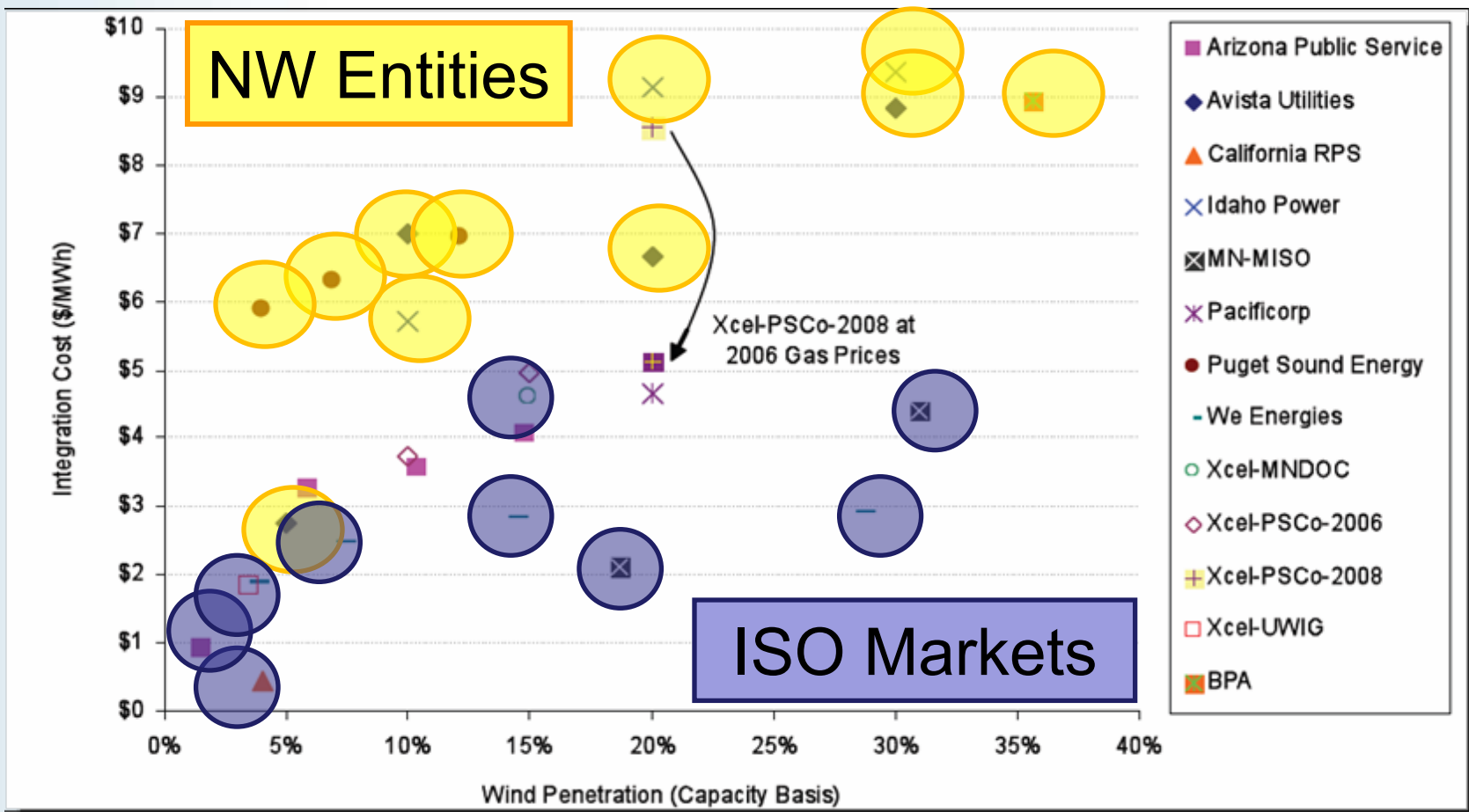
Regulation for Load Only



Regulation For Load and Wind



Bilateral vs. Organized Markets



Validating Results

■ Cost Drivers

- PGE Portfolio and Unit Dispatch
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■ Collaborative Discussion with TRC

- Regulation Due to Wind

Post-Model Run: TRC Input

Incremental Regulation due to Wind Generation

- TRC concerned about cost of Regulation
- Asked to review PGE's Regulation calculation and wind data
- Two Major Observations:
 - NREL Data Mesoscale (Known 3-Day seams anomaly)
 - Variability of wind data
 - Standard deviations of the deviations between the 10 minute average reading and the trend
- EnerNex is reviewing NREL wind data post power curve conversion
- TRC members researching 3Tier wind modeling methodology

Next Steps for PGE Variable Energy Resources (VER) Integration Study

- Close the loop with TRC on Regulation
- Re-run model (if necessary)
- Prepare Phase 2 Final Report
- Final Phase 2 presentation in June or July
 - Respond to Stakeholder Comments
 - Review/Discuss Phase 2 Final Report
- Begin internal discussions for future phases of VER Integration Study
 - Addition of flexible resources
 - Future Renewable Energy Standard (RES) Requirements
 - Additional sensitivity analyses
 - Natural gas prices and constraints
 - Estimate cost of transmission constraints and if necessary, model transmission constraints
 - Short-term market impact
 - Intra-hour scheduling impact
 - Water years

Comment Period

- Stakeholder comment period based upon today's presentation
 - Comments due by COB of June 1, 2011
 - Send comments to Brian Kuehne (brian.kuehne@pgn.com)

Appendix



Overview

- Reserved capacity/energy constraints in PGE dispatch model
 - Regulation
 - Load Following
- Load Following constraint is broken into two components
 - Reserves required for intra-hourly movement (perfect forecast of load net wind)
 - Reserves required to account for short-term (Hour-Ahead) forecast errors

Approach

- Load and wind “decomposition”
 - Real-time variations are covered by regulation
 - Load following tracks short-term estimates of net load trend
 - Existing PGE practice establishes benchmarks for “load only” case (1% regulation, LF allocation)

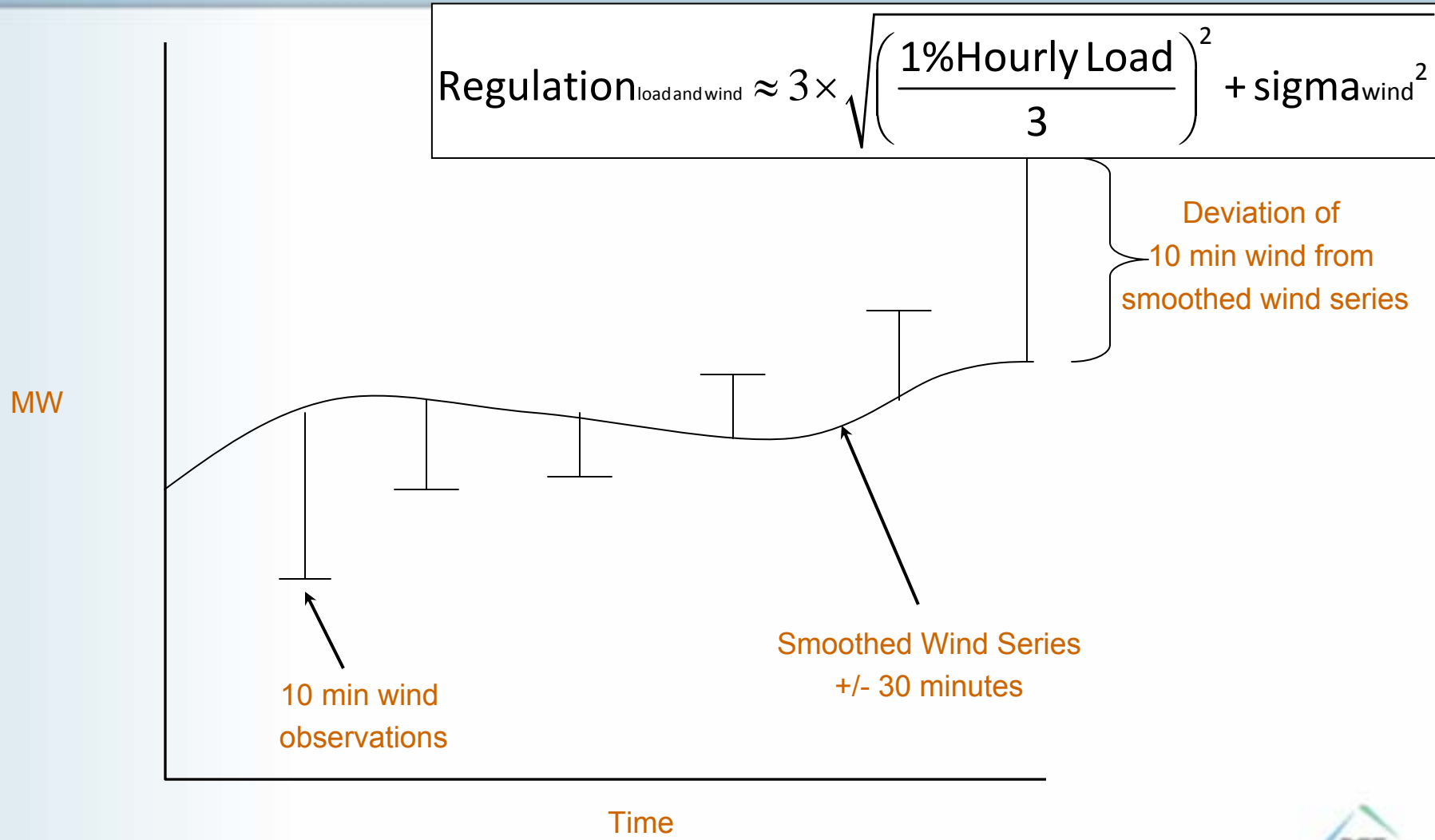
Regulation vs. Load Following

- Regulation for wind must cover fast variations and other deviations from wind trend
- LF resources will follow deviations of load net wind from hourly avg. of load net wind

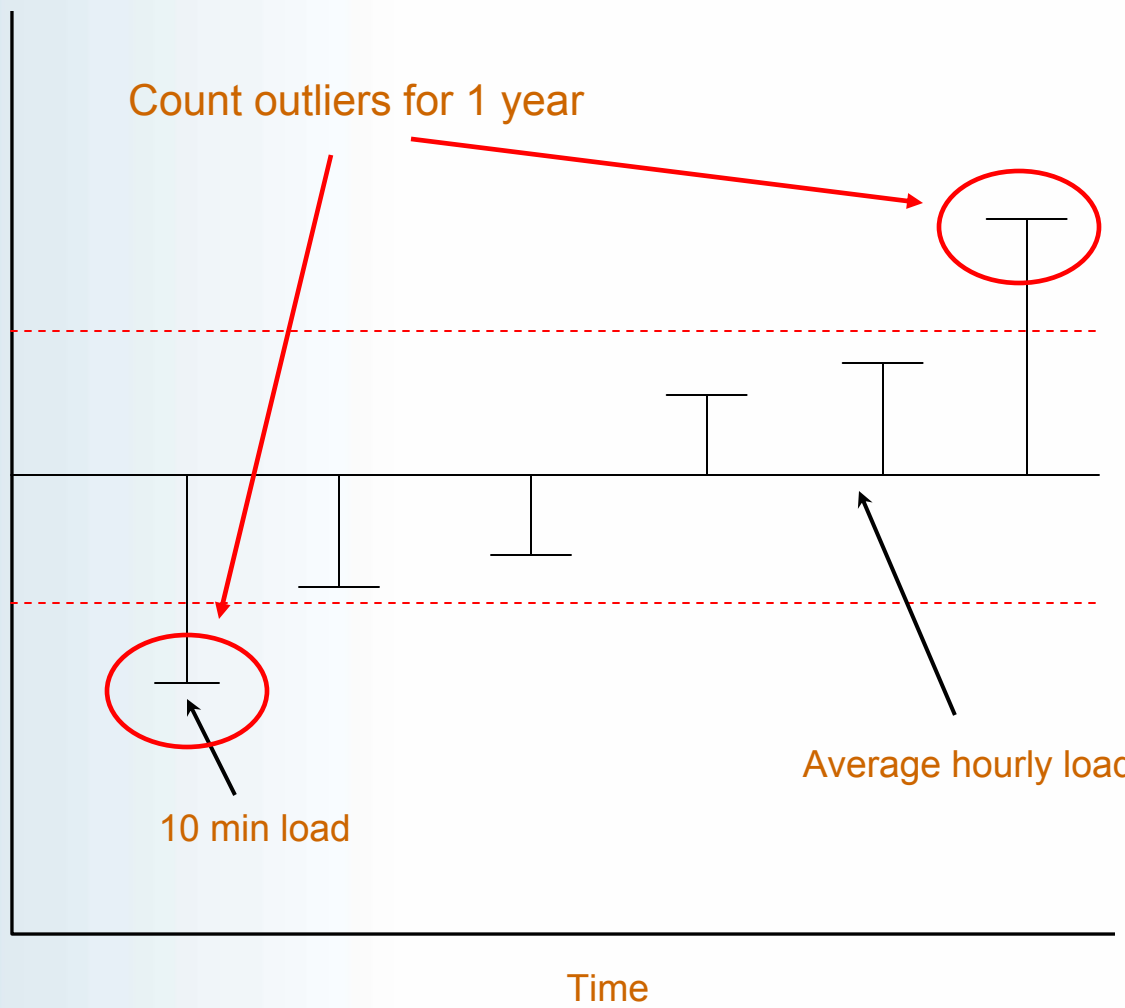
Regulation

- How is the “trend” for wind uncovered?
 - Smoothing: +/-30 min rolling average of 10-minute values
 - Smoothed values correspond to “perfect” ST forecasts of the underlying wind trend
- Regulation deviations
 - 10-minute value minus wind trend (smoothed series)
 - Standard Deviation - Function of wind production level (“quadratic” approximations)

Regulation Wind



Load Following Baseline

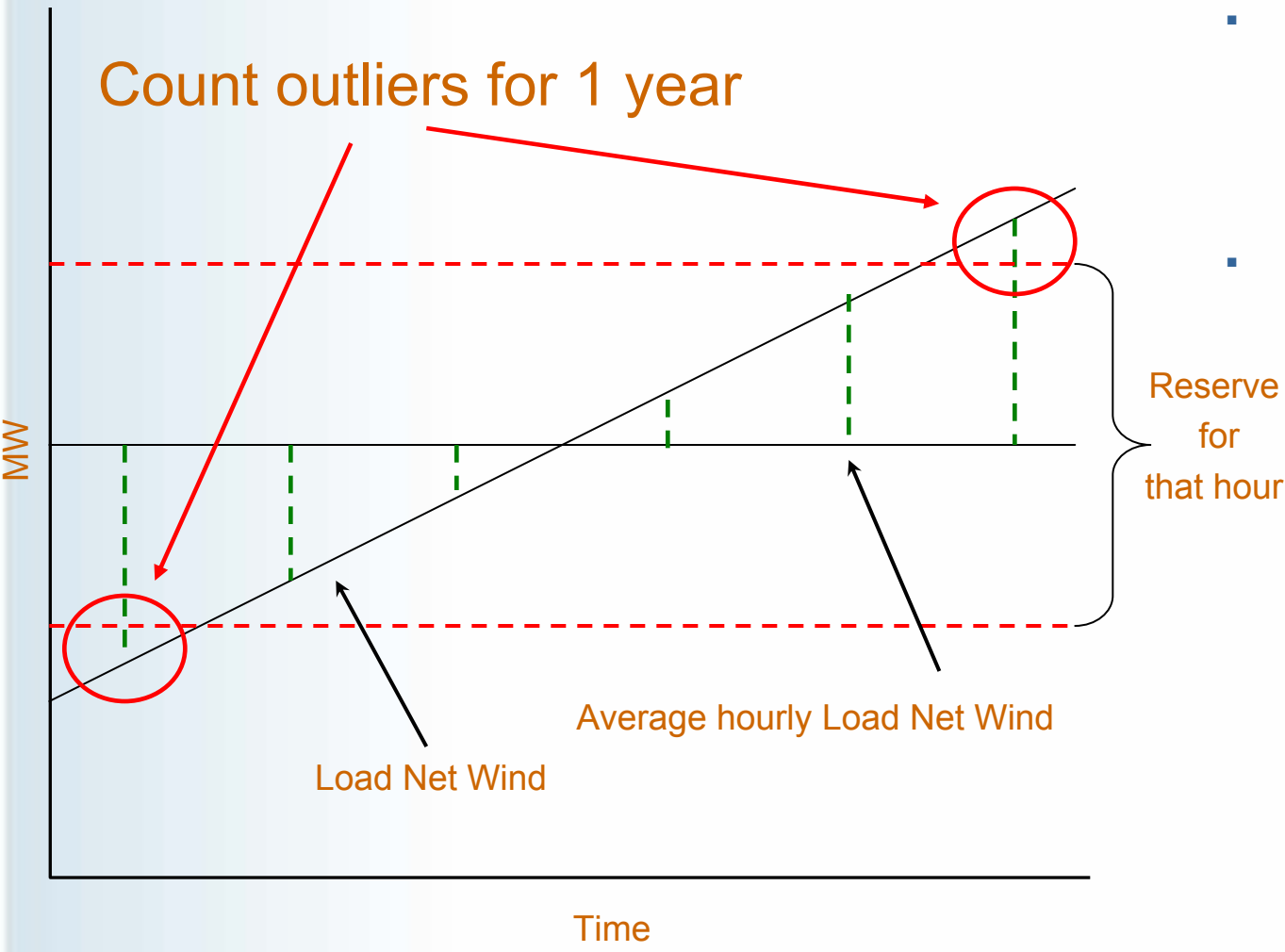


- Test “Load Only” case for calibration (Load Following)
 - Basic data is 10-minute average load data
 - Count number of intervals where the magnitude deviation of 10-minute load exceeds LF Reserves allocated for hour



Load Net Wind Following: Step 1

Count outliers for 1 year



- **First step: Assume no additional LF reserve**
 - Count intervals where 10-min. net load deviations (from hourly average) exceed hourly LF reserve

- **Second step: Augment hourly LF**
 - Use quadratic approximation for wind trend deviations (as a function of wind generation)
 - Add additional reserves (by adjusting multiplier on quadratic equation for wind trend deviations) until # of violations for “perfect in-hour forecast” case equals load only case



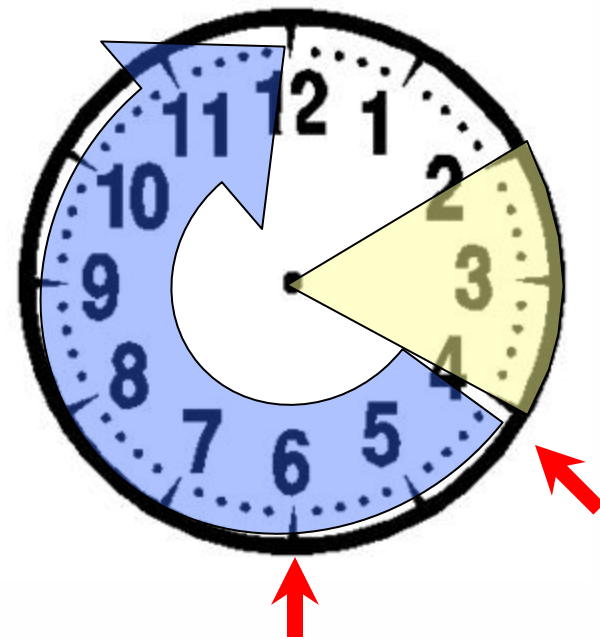
Hour-Ahead and Within-Hour Forecast Development

Hour Ahead Forecast

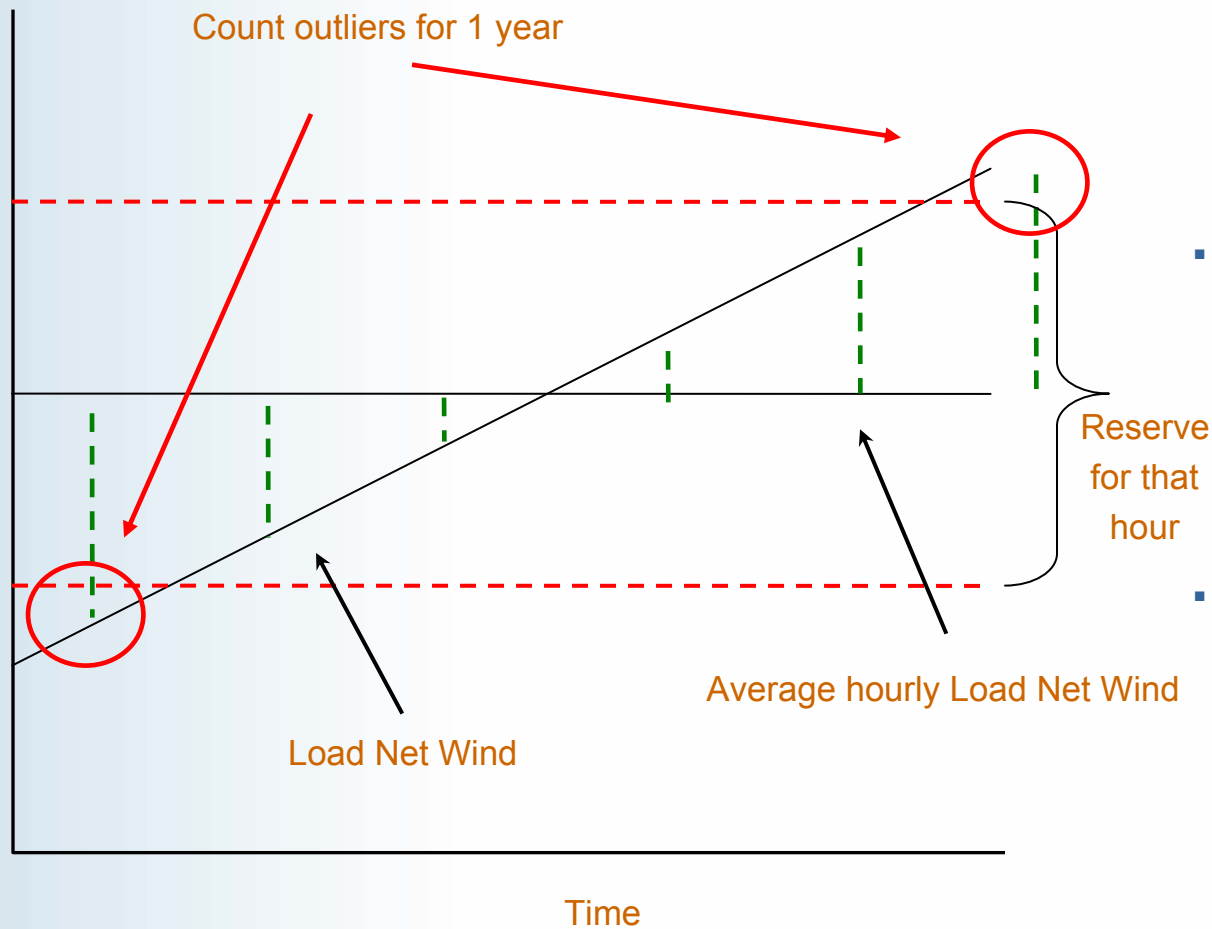
- NREL WWD Actual generation estimate composed of 10 minute data
- Used single data point at 00:20 to determine HA Forecast for hour 1:00
- Simulates realistic Operations for 30 minute scheduling window
 - Does not simulate 30 minute persistence

Within-Hour Forecast

- Computed from NREL WWD Actual Forecast 10 minute data



Load Following for Wind forecast error: Step 2



- Calculate the expected hour-ahead forecast error per PGE specified approach
 - Average of defined intervals from previous hour
 - Again, expected error a function of production level (another quadratic approximation)
- Adjust the wind each hour by the amount of the forecast error; recalculate load net wind
 - Count # of violations (load net wind minus hourly average) and compare to # of violations for perfect forecast case
 - If greater, more LF reserve needed
- Augment LF reserves for HA uncertainty
 - use quadratic approximation for wind forecast error
 - Add reserves (by adjusting multiplier on quadratic equation for HA forecast error) until # of violations = load only = perfect wind forecast



Wind Integration Cost Break-Out

Model Stage Scenarios	Day Ahead	Hour Ahead	Within Hour	Included Costs
RUN 1	PGE Integrates All			
Reserves	LF(W,L), RM(W,L)	LF(W,L), RM(W,L), UN(W,L)	LF(W,L), RM(W,L)	RM(L,W), LF(L,W), DA-UN(L,W), HA-UN(L,W)
Input	Pre-schedule Load and Wind Forecast	Hour Ahead Load and Wind Forecast	“Actual” load and wind	
RUN 2	PGE Integrates DA-UN (No Reserves for LF(W),RM(W),HA-UN(W))			
Reserves	LF(L), RM(L)	LF(L), RM(L), UN(L)	LF(L), RM(L)	RM(L), LF(L), DA-UN(L,W)
Input	Pre-schedule Load and Wind	Hour Ahead Load and Wind	Actual Load and Hour-Ahead wind	
RUN 3	PGE Doesn't Integrate HA-UN(W)			
Reserves	LF(W,L), RM(W,L)	LF(W,L), RM(W,L), UN(L)	LF(W,L), RM(W,L)	RM(L,W), LF(L,W), DA-UN(L,W), HA-UN(L)
Input	Pre-schedule Load and Wind	Hour Ahead Load and Wind	Actual Load and Hour-Ahead wind	



Wind Integration Cost Break-Out

Model Stage Scenarios	Day Ahead	Hour Ahead	Within Hour	Included Costs
RUN 4	PGE Doesn't Integrate LF(W)			
Reserves	LF(L), RM(L,W),	LF(L), RM(W,L), UN(W,L)	LF(L), RM(W,L)	RM(L,W), LF(L), DA-UN(L,W), HA-UN(L,W)
Input	Pre-schedule Load and Wind	Hour Ahead Load and Wind	Actual Load and Wind	
RUN 5	PGE Doesn't Integrate RM(W)			
Reserves	LF(L,W), RM(L)	LF(W,L), RM(L), UN(W,L)	LF(W,L), RM(L)	RM(L), LF(L,W), DA-UN(L,W), HA-UN(L,W)
Input	Pre-schedule Load and Wind	Hour Ahead Load and Wind	Actual Load and Wind	
RUN 6	PGE Does Not Integrate DA-UN(W)			
Reserves	LF(L,W), RM(L,W)	LF(L,W), RM(L,W), UN(L,W)	LF(L,W), RM(L,W)	RM(L,W), LF(L,W), HA-UN(L,W)
Input	Pre-Schedule Load and Hour-Ahead Wind	Hour-Ahead Load and Wind	Actual Load and Wind	
RUN 7	PGE Does Not Integrate LF(W),RM(W),HA-UN(W) and DA-UN(W)			
Reserves	LF(L), RM(L)	LF(L), RM(L), UN(L)	LF(L), RM(L)	RM(L), LF(L), DA-UN(L),HA-UN(L)
Input	Pre-Schedule Load and Actual-Wind	Hour-Ahead Load and Actual Wind	Actual Load and Wind	