



# Idaho Power Wind Integration Study

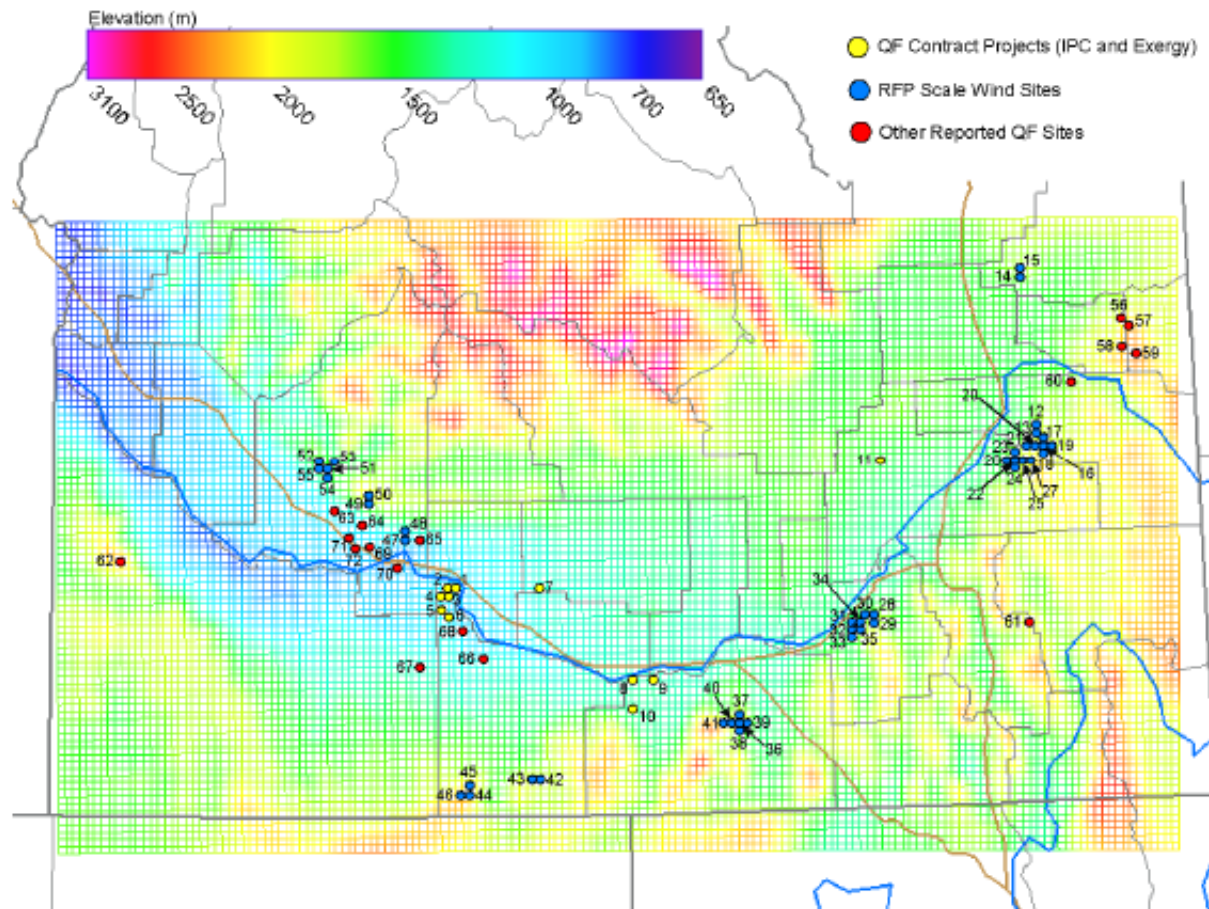
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# Overview of Study Design

- EnerNex → Consultant
- Simulations for three calendar years
  - 1998 → high-type hydrology
  - 2000 → medium-type hydrology
  - 2005 → low-type hydrology
- Synthetic wind time series
  - Four penetration levels
    - 300 MW (10% of system peak load)
    - 600 MW (20% of system peak load)
    - 900 MW (30% of system peak load)
    - 1200 MW (40% of system peak load)

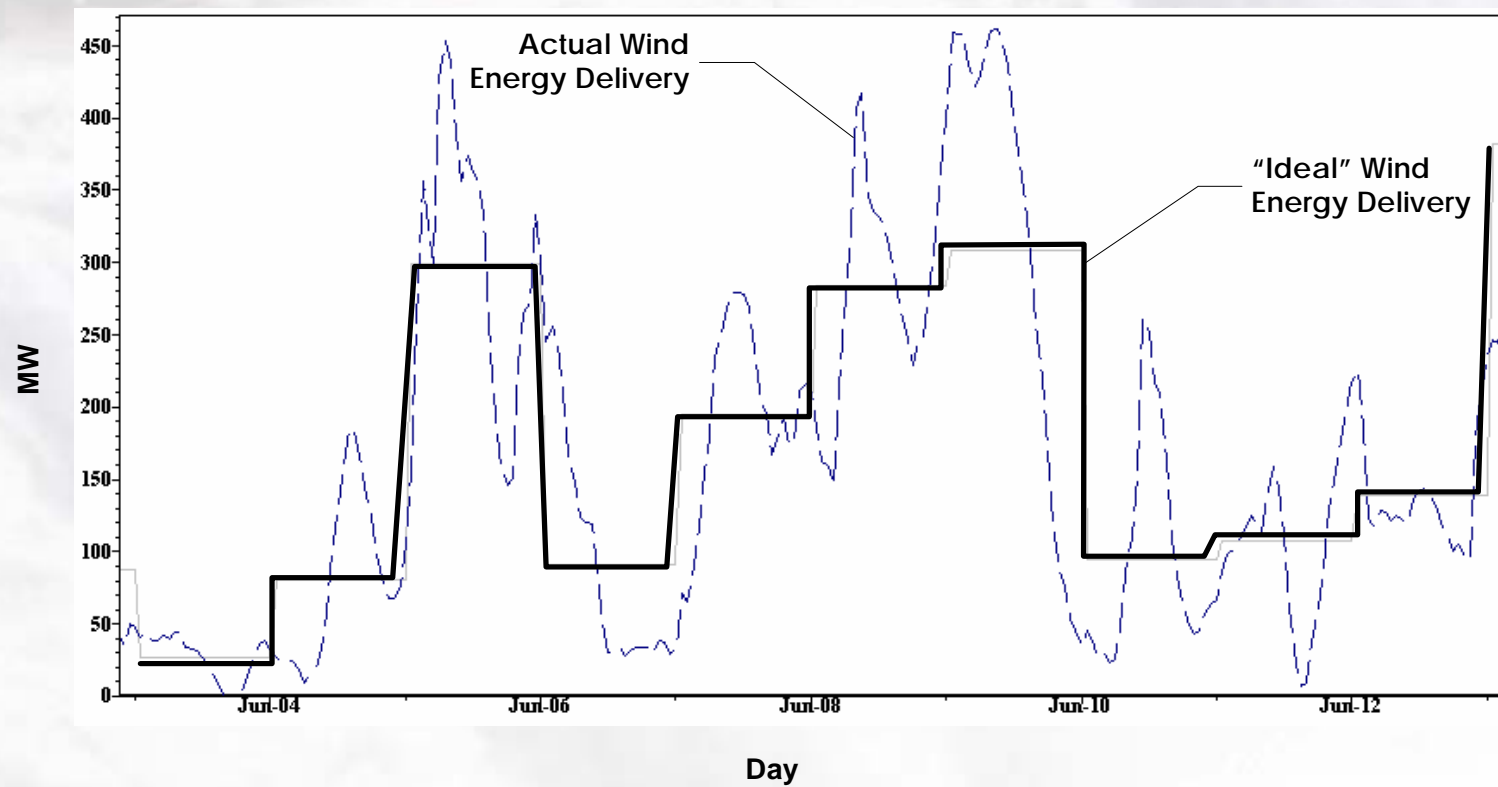
### Grid 3 (Idaho) with Detailed Data Extraction Points



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## Illustration of actual and flat (“ideal”) energy wind deliveries



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# Electric Utility Operation

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# Basics of Electric Utility Operation

- About Idaho Power
- Load/resource balance
- NERC compliance standards
- NW wholesale electricity market
- Operating reserves

# Overview of Idaho Power's System

- Generation mix under normal streamflow conditions
  - 55% hydroelectric
  - 45% thermal
- Generating resources
  - 17 hydroelectric projects → 1,706 MW nameplate
  - Interests in 3 coal-fired projects → 1,110 MW nameplate
  - 2 simple cycle combustion turbines → 263 MW nameplate
  - 1 diesel-powered generator → 5 MW
- CSPP → 104 aMW purchased in 2006

# Overview of Idaho Power's System

<b>Year</b>	<b>Total Nameplate Generation (MW)</b>	<b>Peak Firm Load (MW)</b>	<b>Average Firm Load (MW)</b>	<b>Customers</b>
1990	2,635	2,052	1,205	290,492
1991	2,635	1,972	1,206	296,584
1992	2,694	2,164	1,281	306,292
1993	2,644	1,935	1,274	316,564
1994	2,661	2,245	1,375	329,094
1995	2,703	2,224	1,324	339,450
1996	2,703	2,437	1,438	351,261
1997	2,728	2,352	1,457	361,838
1998	2,738	2,535	1,491	372,464
1999	2,738	2,675	1,552	383,354
2000	2,738	2,765	1,653	393,095
2001	2,851	2,500	1,576	403,061
2002	2,912	2,963	1,622	414,062
2003	2,912	2,944	1,657	425,599
2004	2,912	2,843	1,671	438,912
2005	3,085	2,961	1,660	456,104

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# Hells Canyon Complex

- Brownlee Reservoir
  - 585 MW nameplate over five generating units
  - Usable storage → 975,000 acre-feet or 101 feet
  - Plant hydraulic capacity → 35,000 cfs
- Oxbow Reservoir
  - 190 MW nameplate over four generating units
  - Usable storage → 5,000 acre-feet or 5 feet
  - Plant hydraulic capacity → 28,000 cfs
- Hells Canyon Reservoir
  - 392 MW nameplate over three generating units
  - Usable storage → 12,000 acre-feet or 5 feet
  - Plant hydraulic capacity → 30,500 cfs

## Hells Canyon Complex

- Total complex in normal water year
  - Nearly 70% of annual hydroelectric generation
  - Nearly 40% of total energy generation
  - Annual generation 5.8 million MWh (667 aMW)
- Provides the major portion of peaking and load-following capability
- Decision support system (DSS) software modeling of operations at complex
  - *Vista* DSS – Synexus Global (Ontario, Canada)

## Load/Resource Balance

- NERC Standard BAL-001-0 – Real Power Balancing Control Performance
  - Purpose: “To maintain Interconnection steady-state frequency within defined limits by balancing real power demand and supply in real-time.”<sup>1</sup>
  - Balancing Authority Area Control Error (ACE)
  - $ACE = (NI_A - NI_S) - 10\beta(F_A - F_S) - I_{ME}$  ← see report p. 14
    - “Instantaneous difference between actual and scheduled interchange, taking into account the effects of Interconnection frequency ...” (Hirst and Kirby, June 2003)<sup>2</sup>
    - “... measures how well the system operator maintains the necessary generation-load balance.” (Hirst and Kirby, June 2003)<sup>2</sup>

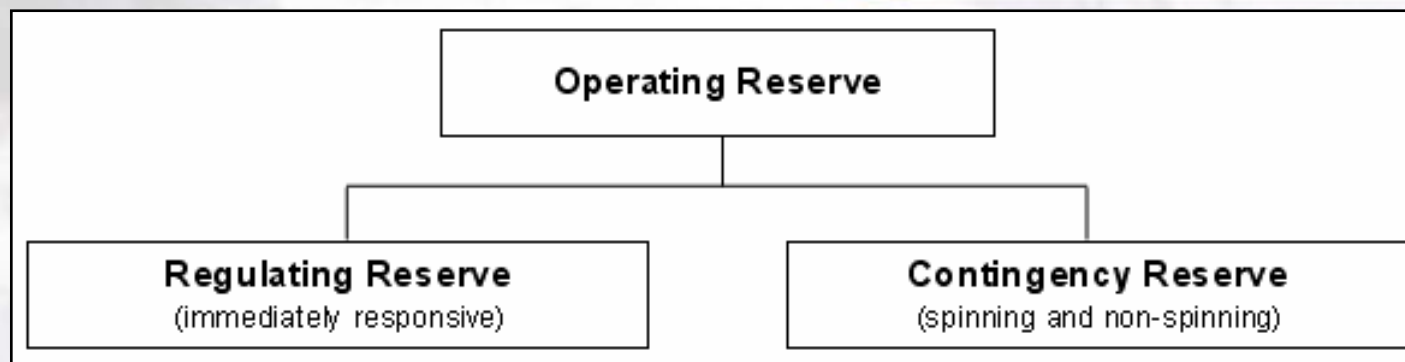
<sup>1</sup>NERC Reliability Standards, BAL-001-0, *Real Power Balancing Control Performance*.

<sup>2</sup>*Allocating Costs of Ancillary Services: Contingency Reserves and Regulation*, Eric Hirst and Brendan Kirby, ORNL/TM-2003/152, June 2003.

# NW Wholesale Electricity Market

- Market to NW → Mid-Columbia (Mid-C) hub
- Market to E → Palo Verde (PV) hub (assumed trading hub for study)
- Liquid markets – study assumed no limit to liquidity
- Study focus → real-time market
  - Heavy load (HL) → 6:00 a.m.–10:00 p.m. (Monday – Saturday)
  - Light load (LL) → 12:00 a.m.–6:00 a.m. AND 10:00 p.m.–12:00 a.m. (Monday – Saturday) AND all day Sunday
- Hourly markets
- Market activity for a given hour typically ceases as much as 50 minutes prior to start of hour
- Load/resource balance
  - Load = system demand + committed sales
  - Resource = system generation + committed purchases

# Operating Reserves



## **Regulating reserve**

- from online generating units set to AGC that can immediately respond to minute-to-minute fluctuations in system load/wind, and to correct for unintended fluctuations in generator output
- CPS compliance
- Brownlee & Oxbow

## **Contingency reserve**

- Unloaded generating capacity capable of responding to a major generator or transmission outage
- DCS compliance (Disturbance Control Standard)
- Brownlee, Oxbow, & Hells Canyon

# Estimation of Reserve Requirements

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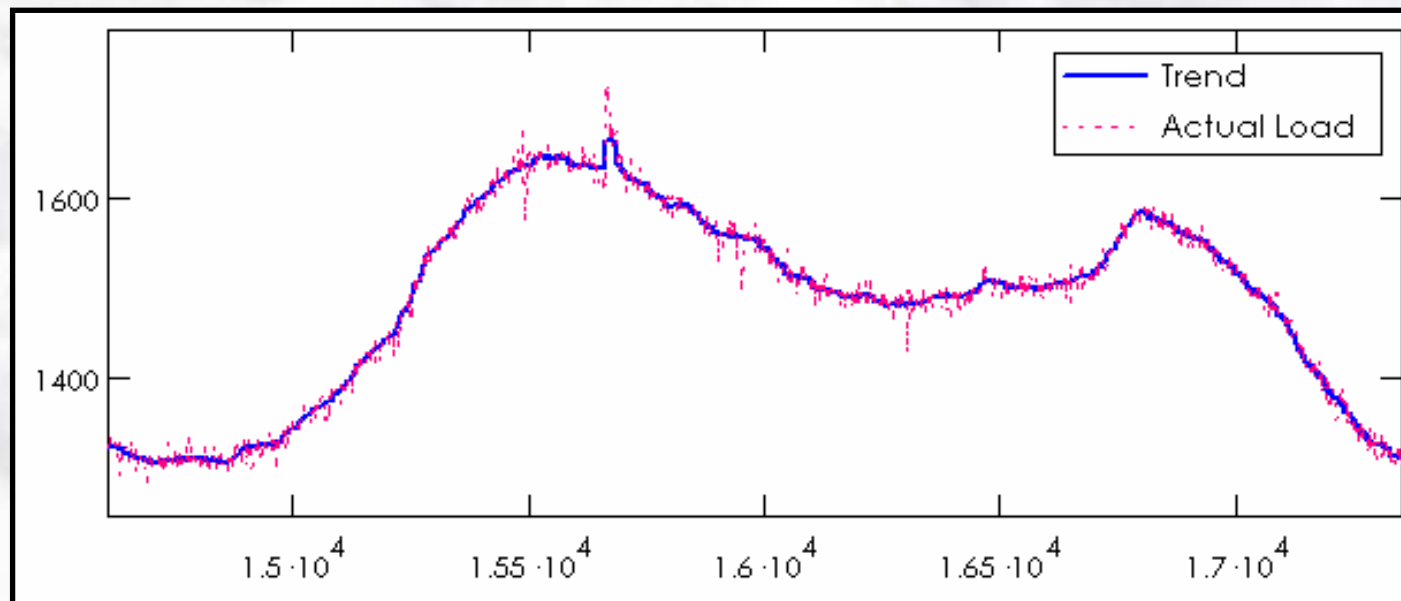
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# Regulating Reserves

- Real-time operations scheduling is binding
  - Market unavailable for intra-hour load/resource balancing
- System of generating resources must have flexibility during course of given hour to manage:
  - Variability in load and wind
  - Differences between forecast and actual load and wind
- Essential for maintaining CPS compliance

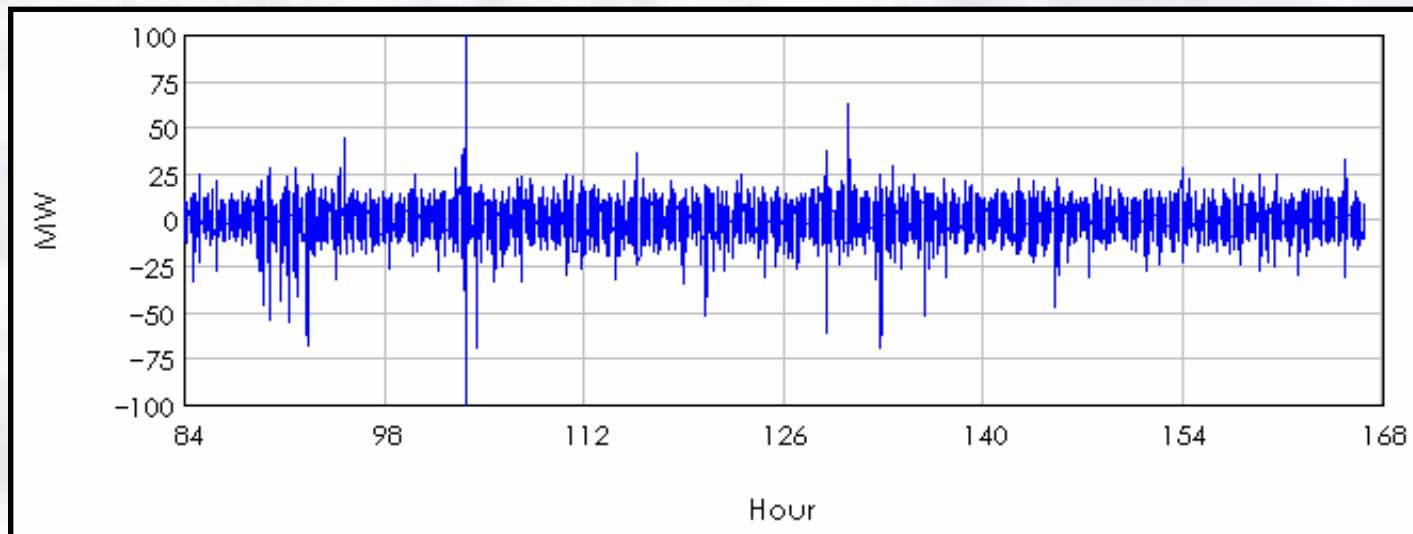
# Fast Fluctuations

- Load alone (MW load vs. time)



# Fast Fluctuations

- Load alone (MW deviation vs. time)

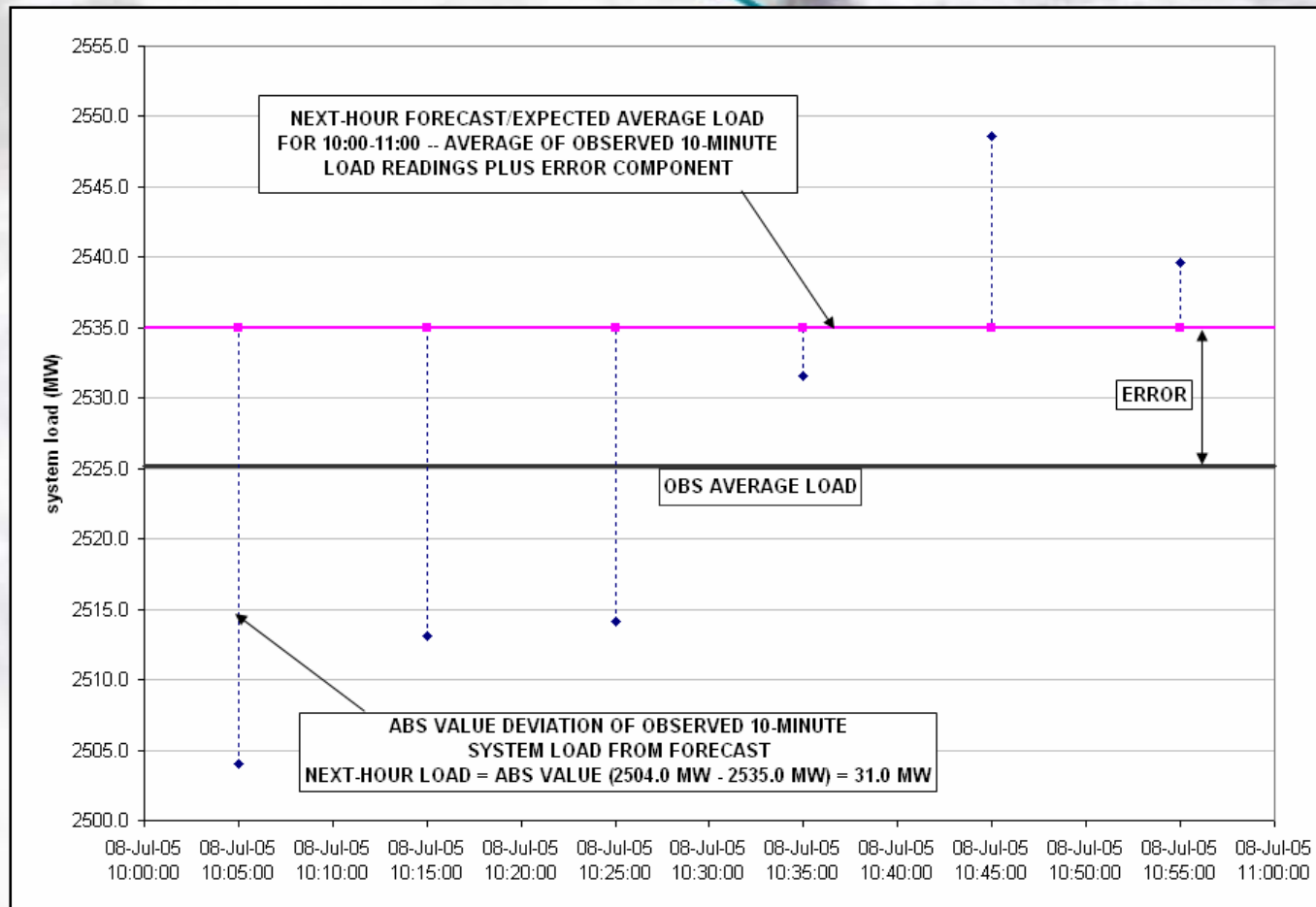


- 28.6 MW of bi-directional reserve to adequately cover deviations

# Fast Fluctuations

Case	Bi-directional Reserve	Increase Due to Wind
	(MW)	(MW)
Load only	28.6	--
300 MW Wind	32.3	<b>3.7</b>
600 MW Wind	35.6	<b>7.0</b>
900 MW Wind	38.6	<b>10.0</b>
1200 MW Wind	41.5	<b>12.9</b>

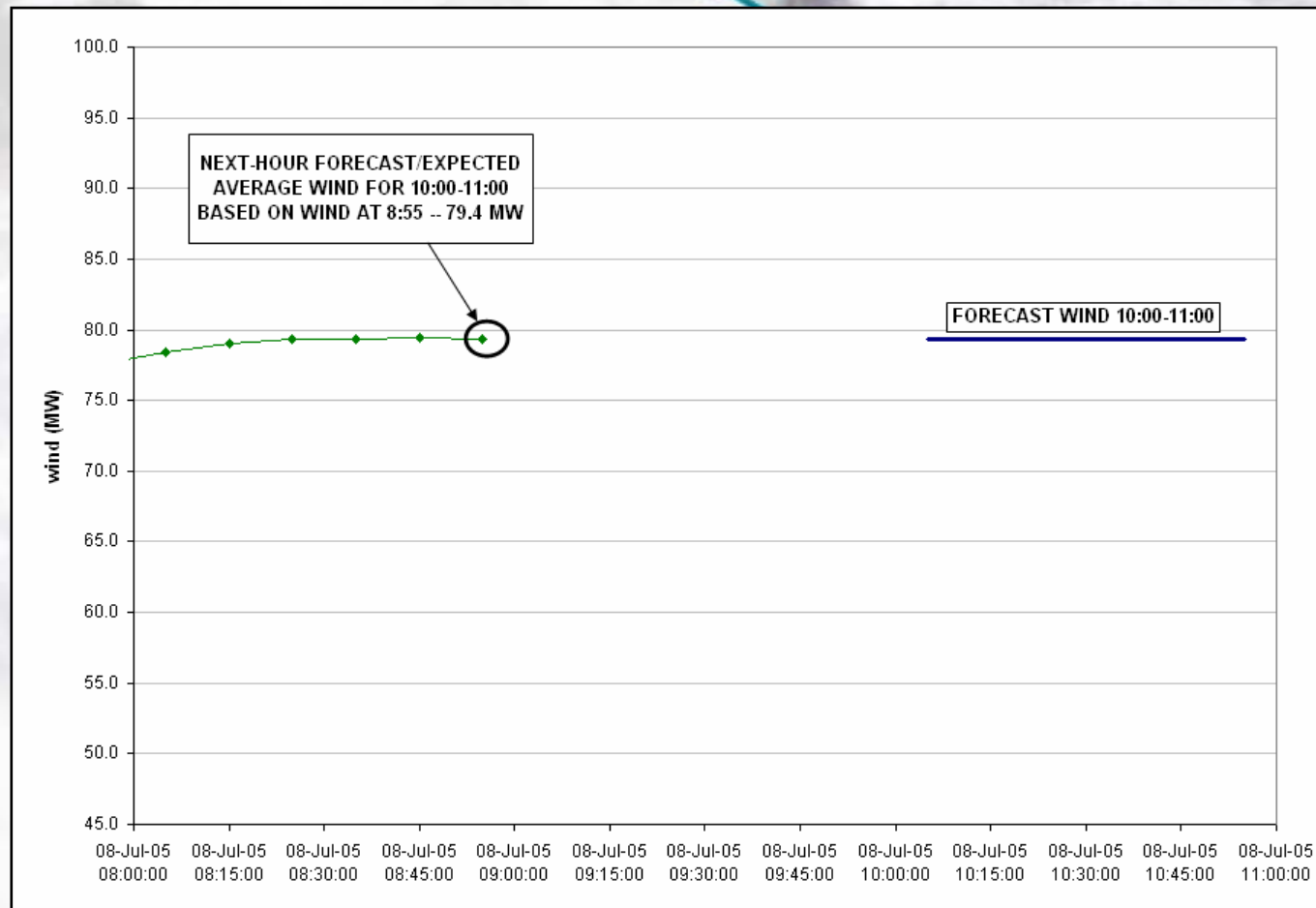
# 10-Minute Load Data



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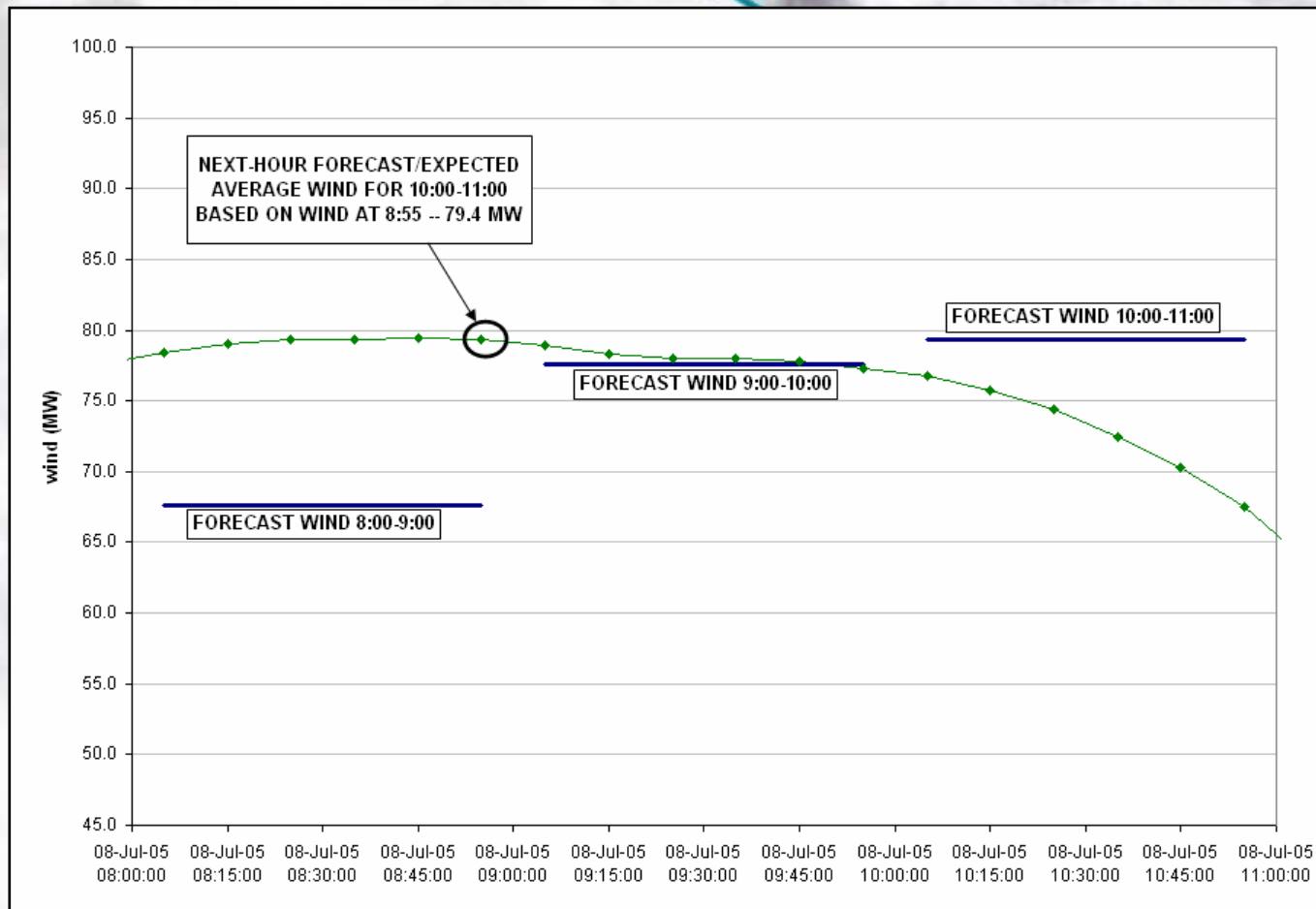
# 10-Minute Wind Data



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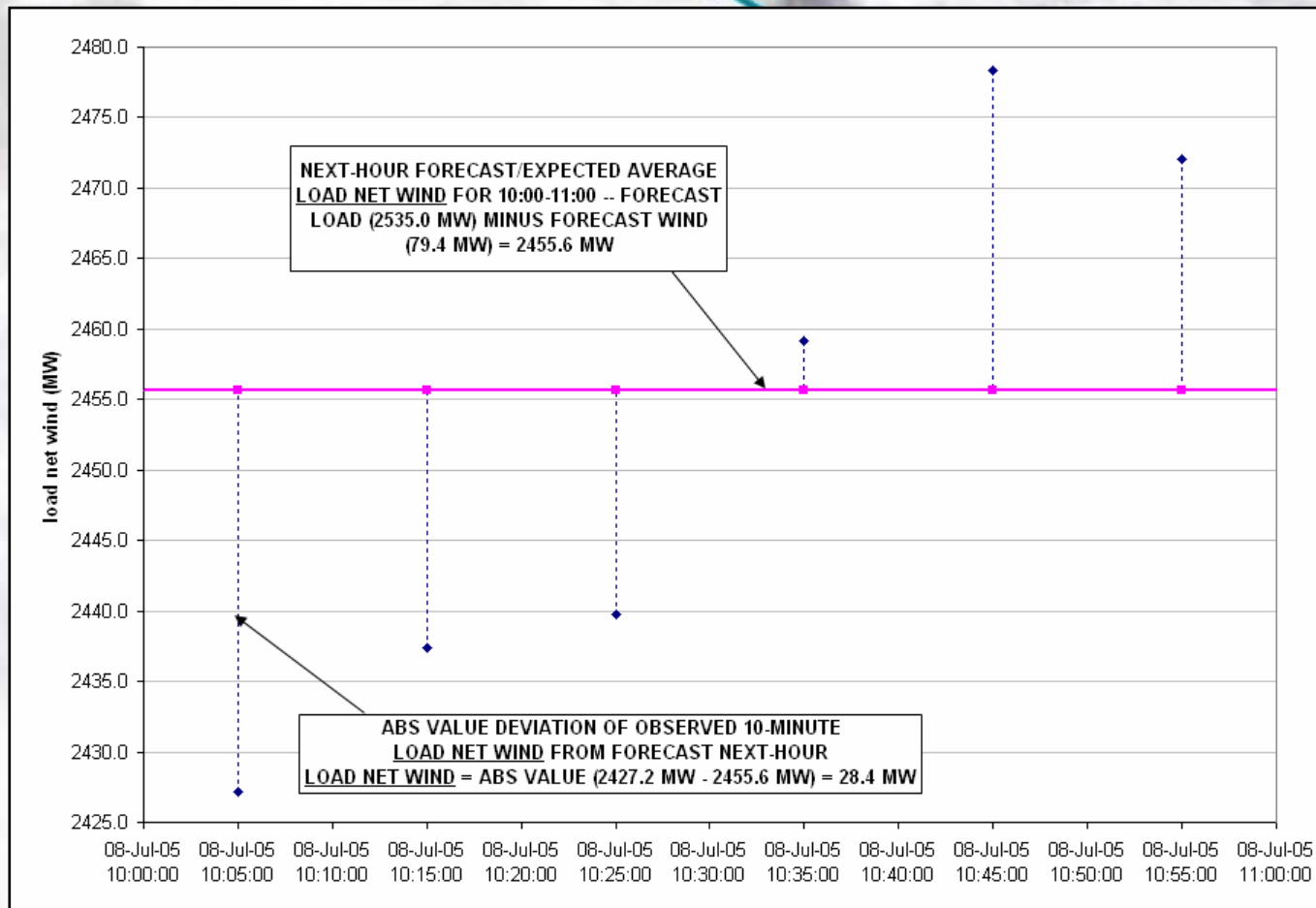
# 10-Minute Wind Data



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# 10-Minute Load Net Wind Data



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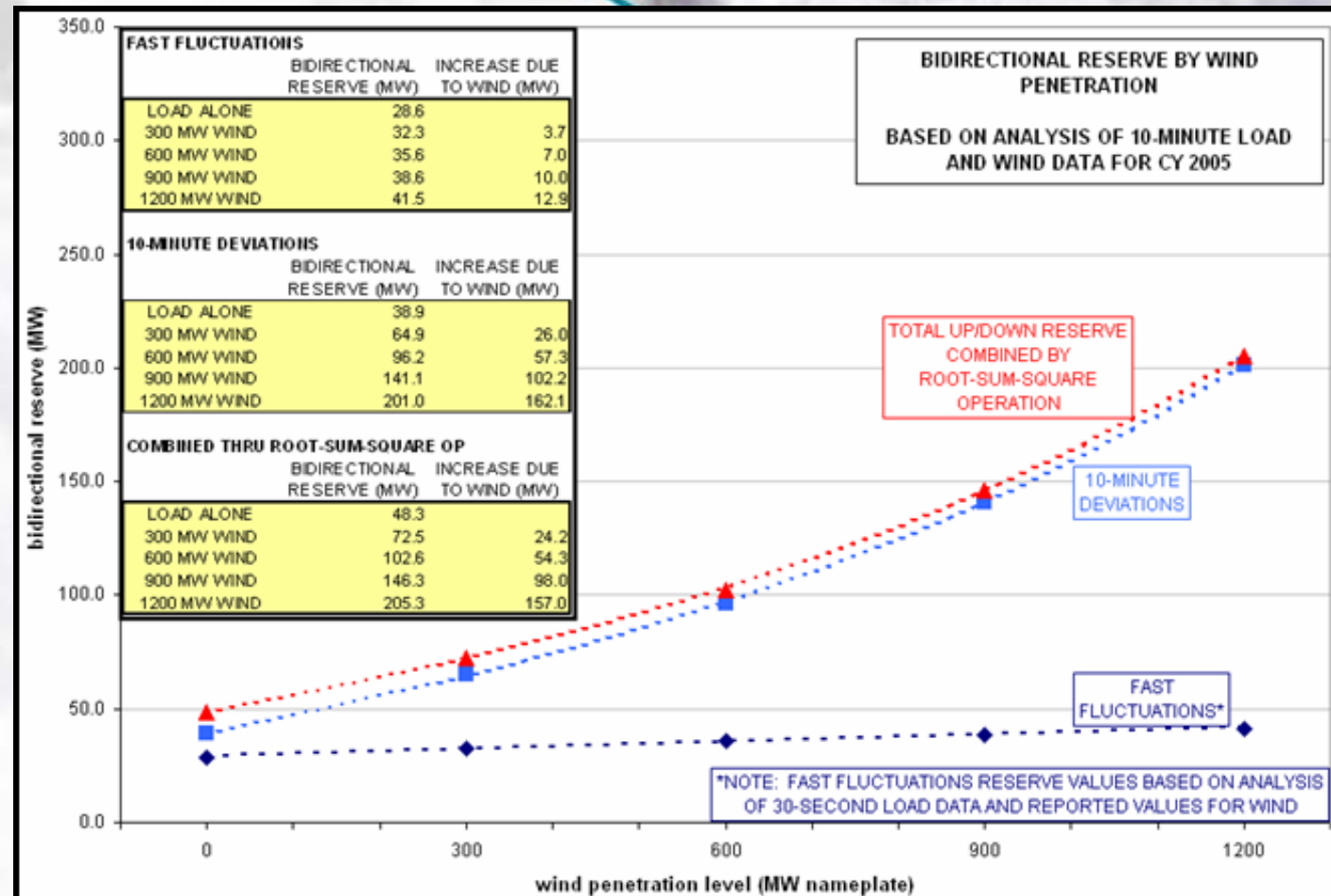
# 10-Minute Load Net Wind Data

		LOAD FORECAST	ABS VALUE LOAD	2% exceed level --->	38.9				2% exceed level --->	65.1
	TOT_SYS_LOD	ERROR %	FORECAST ERROR %	HRLY AVG FCST	DEV	300 MW WIND	HRLY AVG FCST	LOAD NET WIND	HRLY AVG FCST	DEV
01-Jan-05 03:05:00	1381.8	-1.49%	1.49%	1367.0	.	147.3	122.9	1234.5	1244.1	.
01-Jan-05 03:15:00	1383.8			1367.0	.	148.7	122.9	1235.1	1244.1	.
01-Jan-05 03:25:00	1385.0			1367.0	.	150.1	122.9	1234.9	1244.1	.
01-Jan-05 03:35:00	1395.0			1367.0	.	153.4	122.9	1241.6	1244.1	.
01-Jan-05 03:45:00	1388.3			1367.0	.	156.7	122.9	1231.6	1244.1	.
01-Jan-05 03:55:00	1392.3			1367.0	.	157.8	122.9	1234.5	1244.1	.
01-Jan-05 04:05:00	1404.4	-1.83%	1.83%	1384.7	.	155.4	145.9	1248.9	1238.8	.
01-Jan-05 04:15:00	1407.1			1384.7	.	150.6	145.9	1256.5	1238.8	.
01-Jan-05 04:25:00	1407.0			1384.7	.	145.6	145.9	1261.4	1238.8	.
01-Jan-05 04:35:00	1407.9			1384.7	.	143.9	145.9	1264.0	1238.8	.
01-Jan-05 04:45:00	1412.8			1384.7	.	144.3	145.9	1268.6	1238.8	.
01-Jan-05 04:55:00	1423.5			1384.7	.3	144.2	145.9	1279.3	1238.8	2.1
01-Jan-05 05:05:00	1427.3	0.66%	0.66%	1448.6	.	144.9	157.8	1282.5	1290.8	.
01-Jan-05 05:15:00	1430.4			1448.6	.	146.3	157.8	1284.2	1290.8	.
01-Jan-05 05:25:00	1432.9			1448.6	.	147.3	157.8	1285.6	1290.8	.
01-Jan-05 05:35:00	1440.8			1448.6	.	148.0	157.8	1292.7	1290.8	.
01-Jan-05 05:45:00	1446.6			1448.6	.	149.6	157.8	1297.0	1290.8	.
01-Jan-05 05:55:00	1456.7			1448.6	.	151.9	157.8	1304.7	1290.8	.

# 10-Minute Load and Wind Data

Case	Bi-directional Reserve
	(MW)
Load only	38.9
300 MW Wind	64.9
600 MW Wind	96.2
900 MW Wind	141.1
1200 MW Wind	201.0

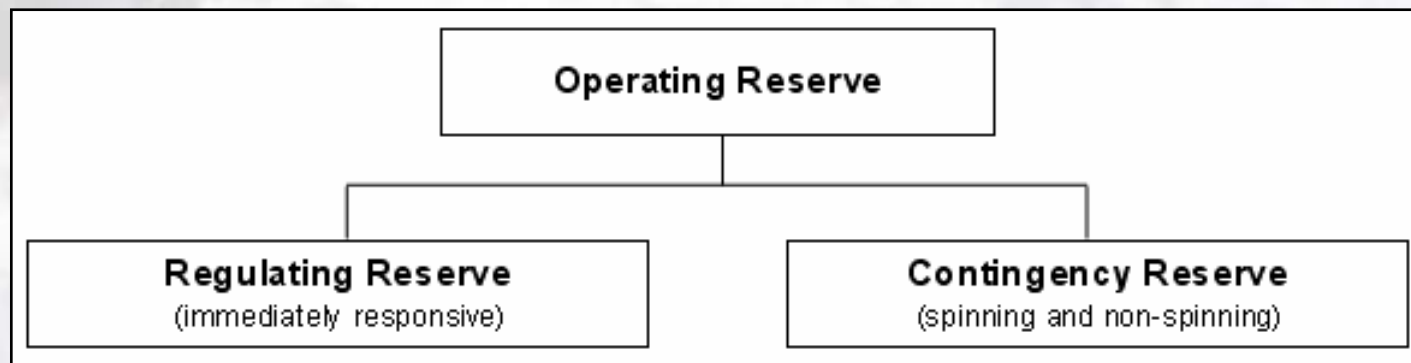
# Total Regulating Reserve



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# Contingency Reserves



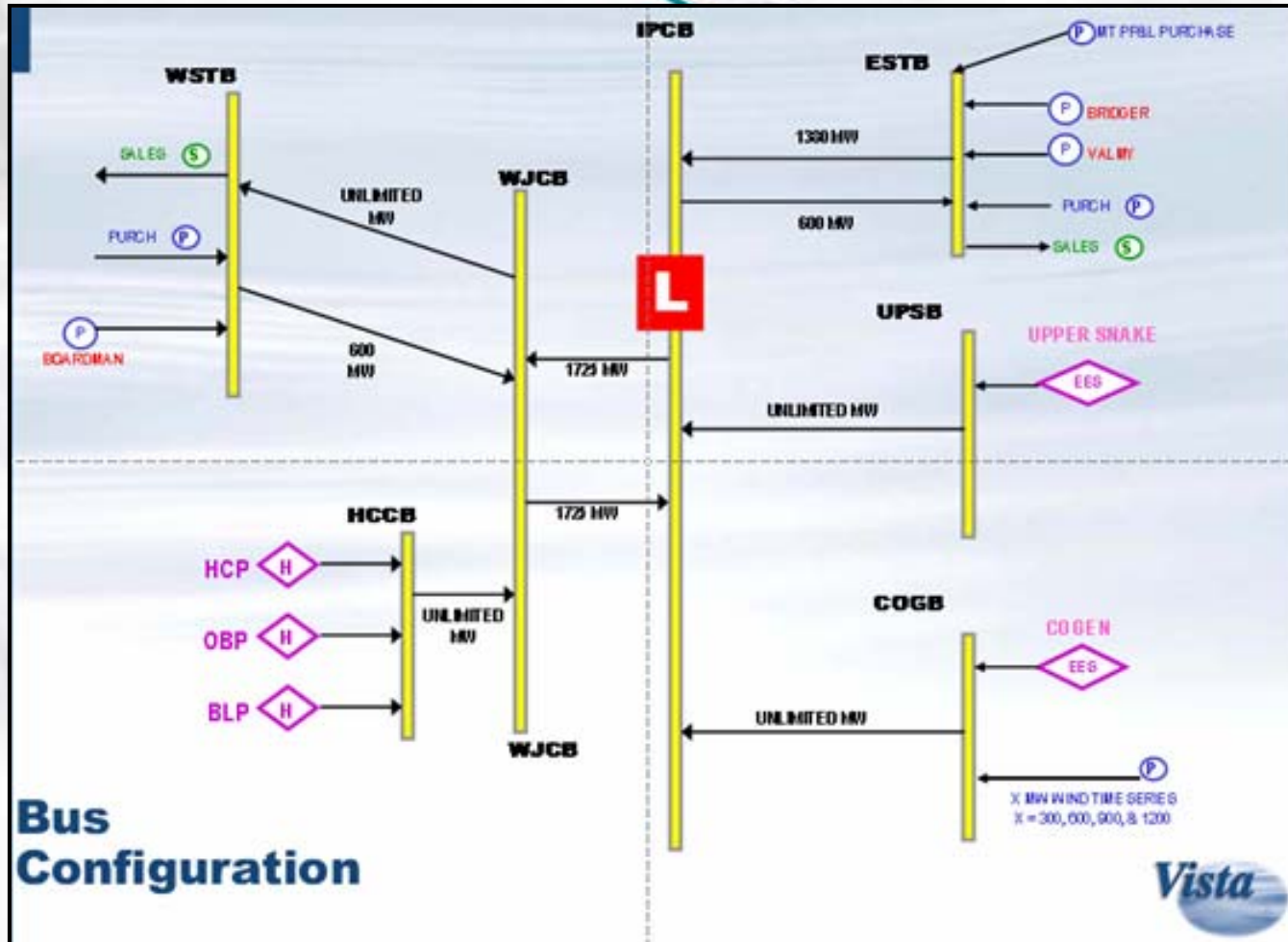
- Applied to flat wind & actual wind cases
- 5% of hydro and wind generation
- 7% of thermal generation
- At least half spinning (online)
- Essential for DCS compliance – recovery from major generator or transmission outage

# Imposition of Reserve Requirements in *Vista* DSS

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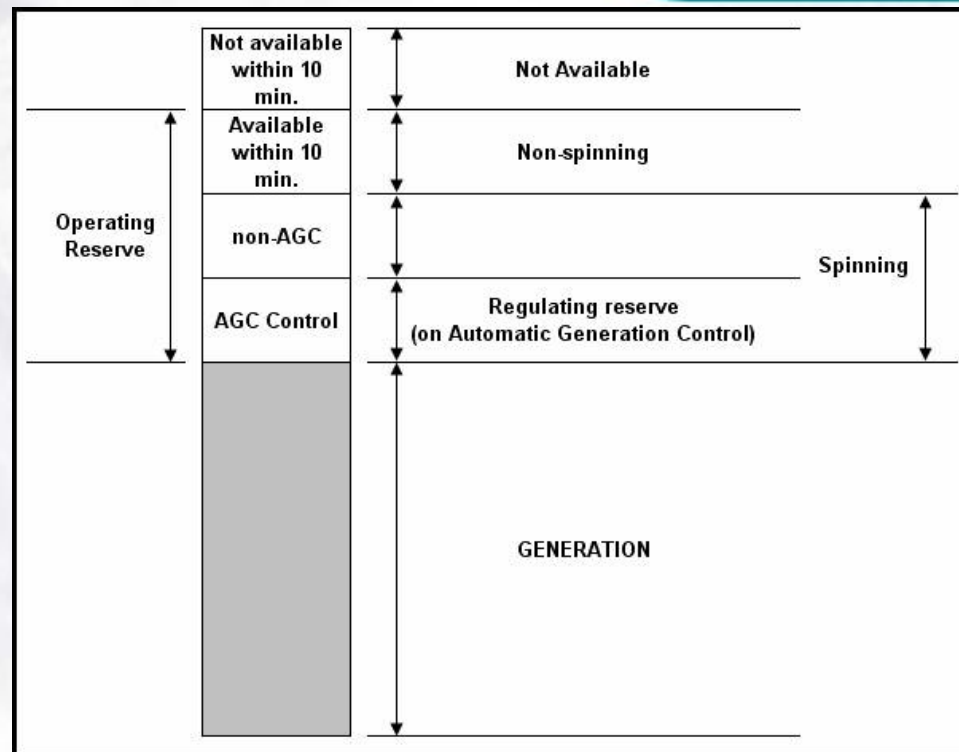
# Vista DSS



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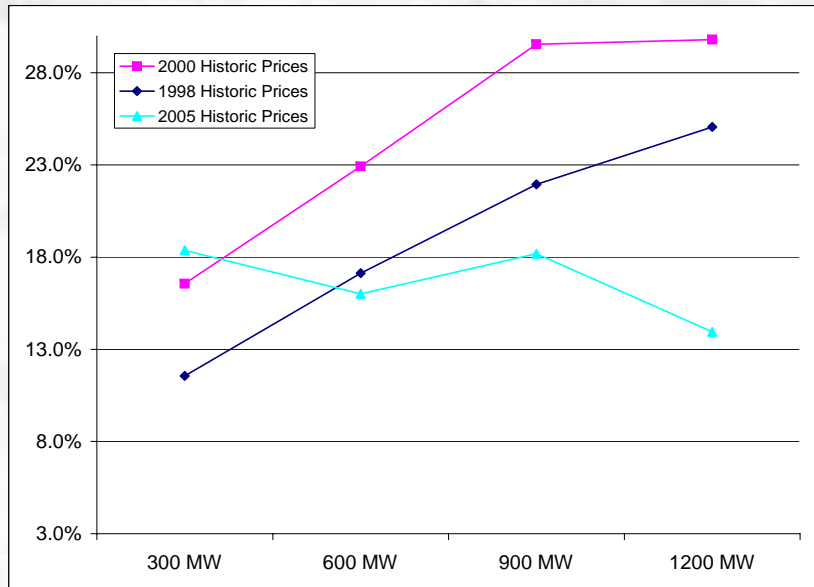
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# Reserve Modeling in *Vista DSS*



Source: Synexus Global  
 Online presentation – *Application of DSS to Study Wind Generation for Manitoba Hydro*  
<http://www.nwd-wc.usace.army.mil/PB/Workshop/Niagara05/presentations/1-7-BG.pdf>

## Wind integration cost by penetration level



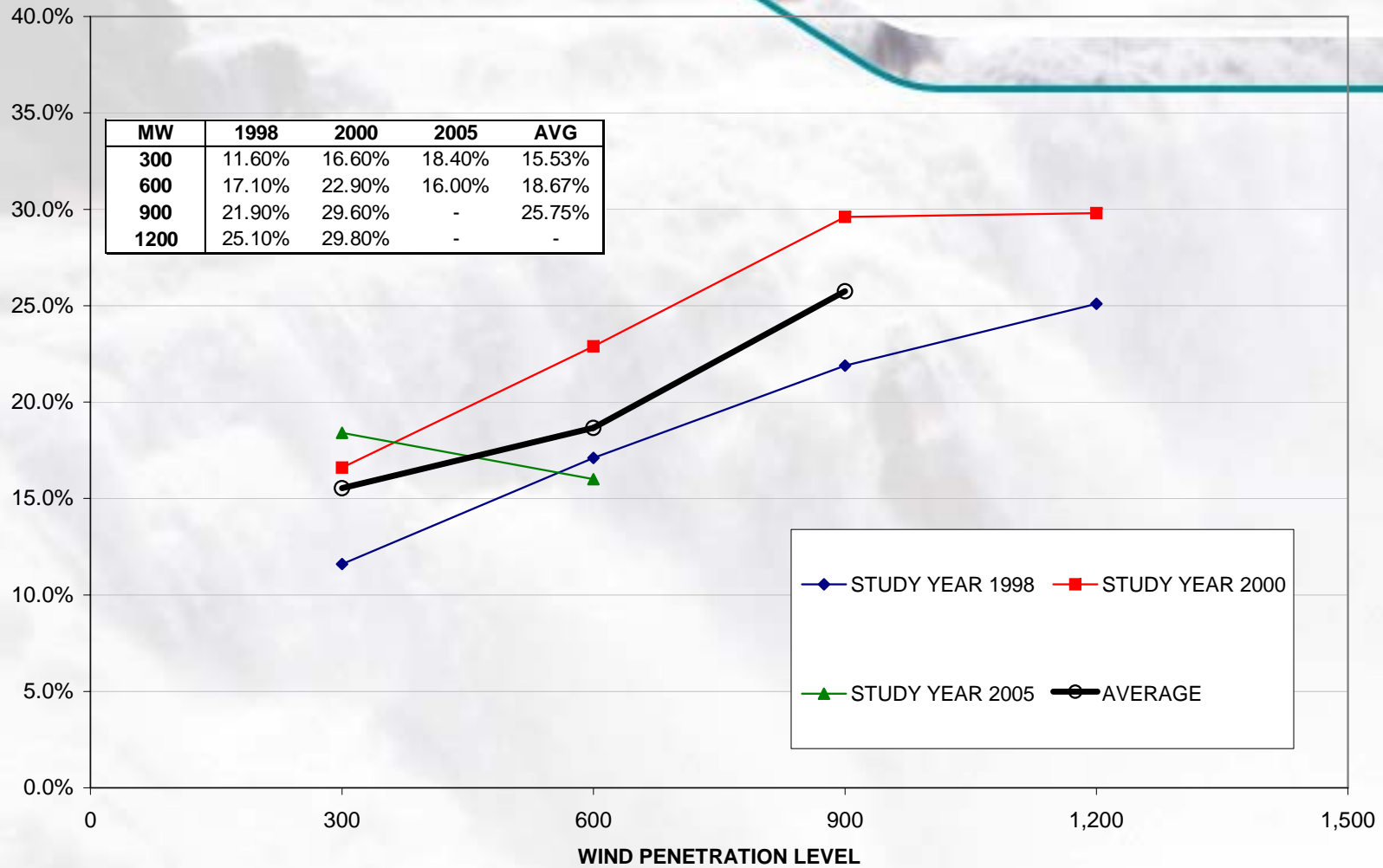
Vista Results Using Historical Mid-C prices as Benchmark					Vista AGC Res Constraint Violations Flat Case	Vista AGC Res Constraint Violations Var Case
Study Year	Penetration Level (MW)	Cost per MWh Wind	Annual Mid-C Avg Energy Price	Cost as % Energy Price		
1998	300	\$3.19	\$27.61	11.6%	43	38
1998	600	\$4.73	\$27.61	17.1%	50	51
1998	900	\$6.06	\$27.61	21.9%	49	102
1998	1200	\$6.92	\$27.61	25.1%	36	319
2000	300	\$21.89	\$132.17	16.6%	37	46
2000	600	\$30.30	\$132.17	22.9%	37	76
2000	900	\$39.06	\$132.17	29.6%	58	373
2000	1200	\$39.40	\$132.17	29.8%	53	1,059
2005	300	\$10.69	\$58.19	18.4%	20	47
2005	600	\$9.32	\$58.19	16.0%	45	96
2005	900	\$10.58	\$58.19	18.2%	32	792
2005	1200	\$8.12	\$58.19	14.0%	34	2,132

Table 13. Summary of Vista DSS results with AGC constraint violation data

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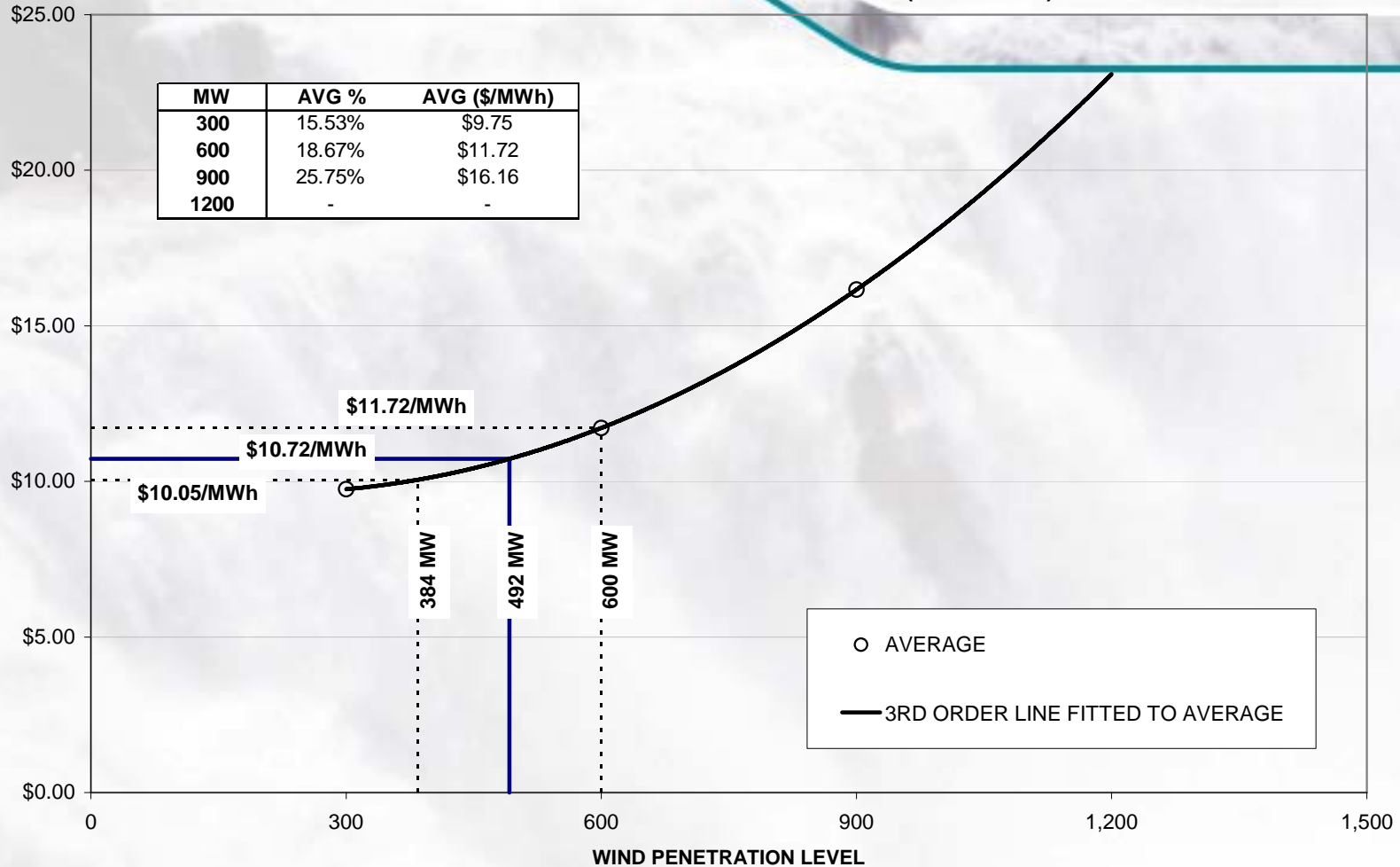
**IDAHO POWER COST AS PERCENTAGE OF MID-COLUMBIA MARKET**



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**IDAHO POWER COST IN DOLLARS PER MWh OF WIND (\$/MWh)  
COST BASED ON 2007 LEVELIZED PURPA RATE (\$62.77/MWh)**



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## Hydrologic Sensitivity HCC Generation Output MWh @ 300, 600 MW

Wind		Flat	Variable	Difference
• 1998	300	8,073,189	7,972,745	(100,440)
• 1998	600	8,023,189	7,713,782	(309,407)
• 2000	300	6,337,282	6,304,673	(32,609)
• 2000	600	6,350,878	6,250,816	(100,062)
• 2005	300	4,849,747	4,776,864	(72,883)
• 2005	600	4,844,634	4,835,293	(161,922)

## Sensitivity to Market prices - PV set to Mid-C Prices -

System Peak %	MW	1998	2000	2005	AVG
10%	<b>300</b>	12.46%	11.04%	17.87%	13.79%
20%	<b>600</b>	18.54%	17.50%	16.03%	17.35%
30%	<b>900</b>	20.95%	21.91%	<b>29.67%</b>	21.43%
40%	<b>1200</b>	<b>22.97%</b>	<b>22.14%</b>	<b>13.70%</b>	-

## Sensitivity to AGC Reserve Changes @ HCC 600 MW Wind

North West Wind Integration Working Group Draft Report  
Comments Resulted in (among other things)

- Lengthening the Wind Forecast Time Horizon
- Including a Load Forecast Error
- Including L-10 Reserve

Resulted in a Modeled Reserve Changes to the Final Report of  
Flat Case Reserves changed from 72.5 to 48.3

Variable Case Reserves changed from 116.4 to 102.6

## Sensitivity to AGC Reserve Changes @ HCC 600 MW Wind

Flat Case Reserves changed from 72.5 to 48.3

Value

- 1998 600 97,430, MWh more output \$2,366,573
- 2000 600 43,039 MWh more output \$15,982,267
- 2005 600 50,510 MWh more output \$4,852,448

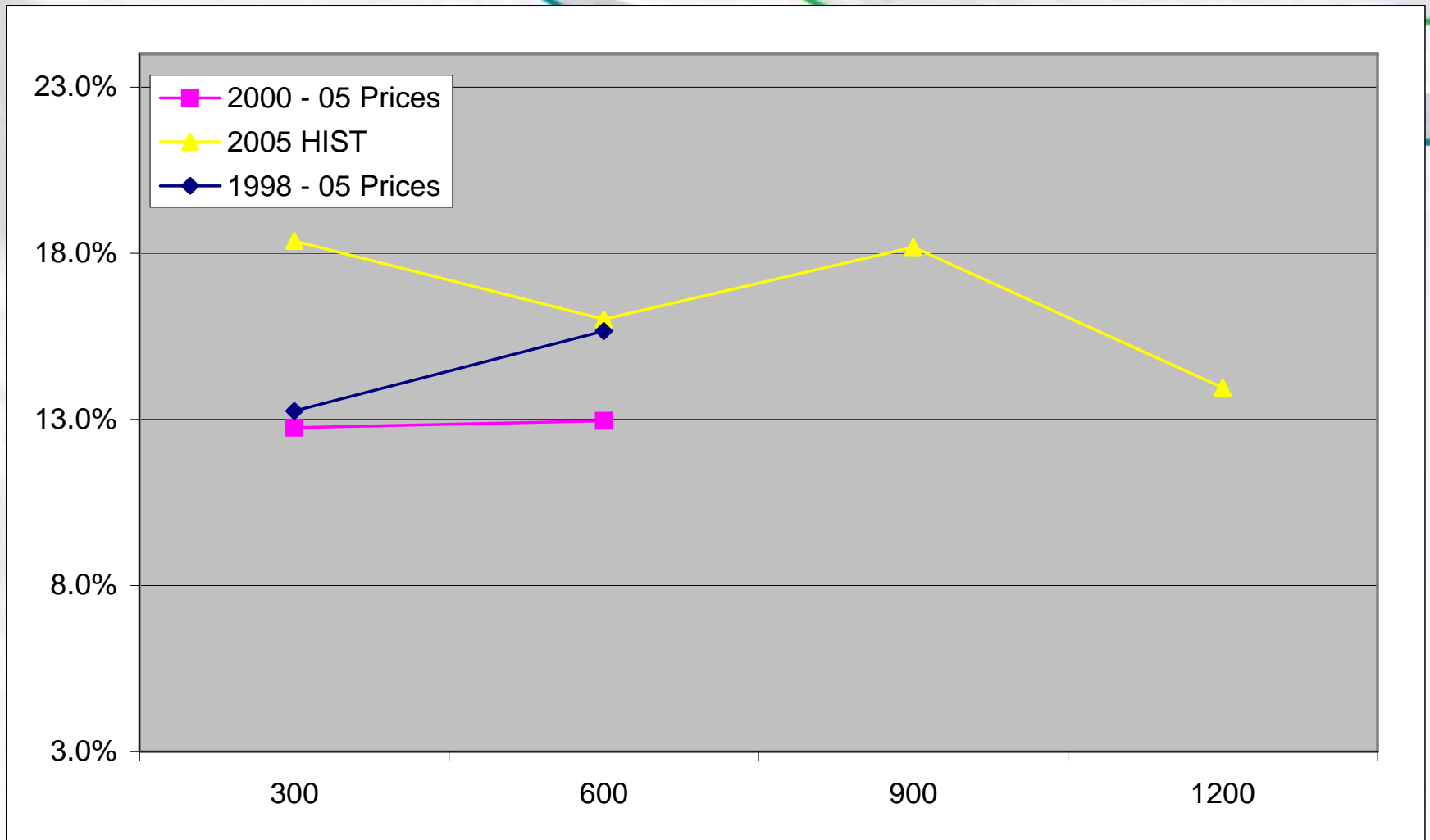
Variable Case Reserves changed from 116.4 to 102.6

- 1998 600 23,240 MWh more generation \$1,630,883
- 2000 600 29,138 MWh more generation \$25,446,093
- 2005 600 76,702 MWh more generation \$5,956,142

## Market Price Sensitivity

<b>Results with 2005 pricing</b>					AGC Violations Flat Case	AGC Violations Var Case
study year	penetrat ion level	cost per MWh wind	annual avg energy price	cost as % energy price		
1998	300	\$7.71	\$58.19	13.2%	19	30
1998	600	\$9.11	\$58.19	15.7%	24	125
2000	300	\$7.42	\$58.19	12.8%	30	64
2000	600	\$7.54	\$58.19	13.0%	31	76
2005	300	\$10.69	\$58.19	18.4%	20	47
2005	600	\$9.32	\$58.19	16.0%	45	96
2005	900	\$10.58	\$58.19	18.2%	32	792
2005	1200	\$8.12	\$58.19	14.0%	34	2,132

# Market Price Sensitivity



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## Points for Discussions

- Actual versus Vista DSS reserve carrying capability of HCC
- Transmission for Integrating Wind Generation
- Relicensing of Hydro Power Projects
- Effect of Load Growth
- Market Prices in the Pacific Northwest
- Market Structure and Operating Agreements in the Pacific Northwest.
- Nature of Wind Generation Development in Idaho Power
- Modeling of Reserve Requirements
- Hydro Conditions
- Comfort Threshold