Competitive Markets for Imbalances, Not Penalties

Staff Technical Conference on Increasing Real-Time and Day-Ahead Market Efficiency through Improved Software Docket No. AD10-12-003

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Gaithersburg, Maryland

Lessons Learned From "The Price of Energy Storage" by Michael Ferris

- Adjusted PJM's Energy Storage Model
- Made prices vary with amount of storage
  - Control theory/economics produced natural limit on optimal amount of storage
    - Control theory/economics should produce a natural limit on optimal amount of wind systems
- Used 168 prices instead 24 prices
  - Smaller time granularity improved analysis of storage devices
    - Smaller time granularity should improve analysis of wind systems

Competitive Markets for Imbalances, Not Penalties

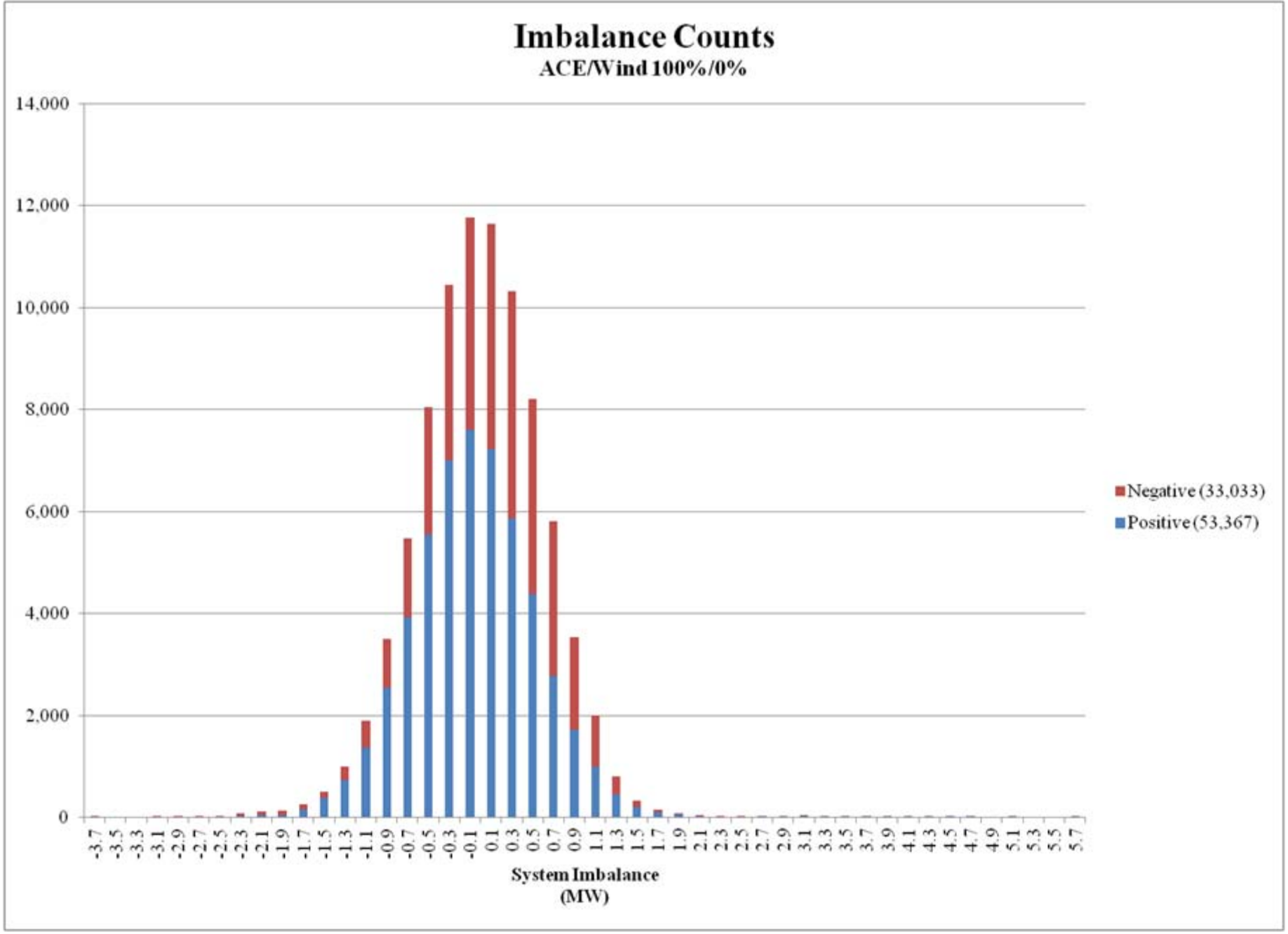
In *Frequency Regulation Compensation in the Organized Wholesale Power Markets*, Docket Nos. RM11-7-000 and AD10-11-000, FERC ordered the various independent system operators (ISOs) to create an ancillary service for frequency regulation, nominally a service for fast response storage systems. Frequency compensation regulation would be a market with extremely short compensation intervals, perhaps relying on one second metering data to pay storage systems that respond to commands from system operators.

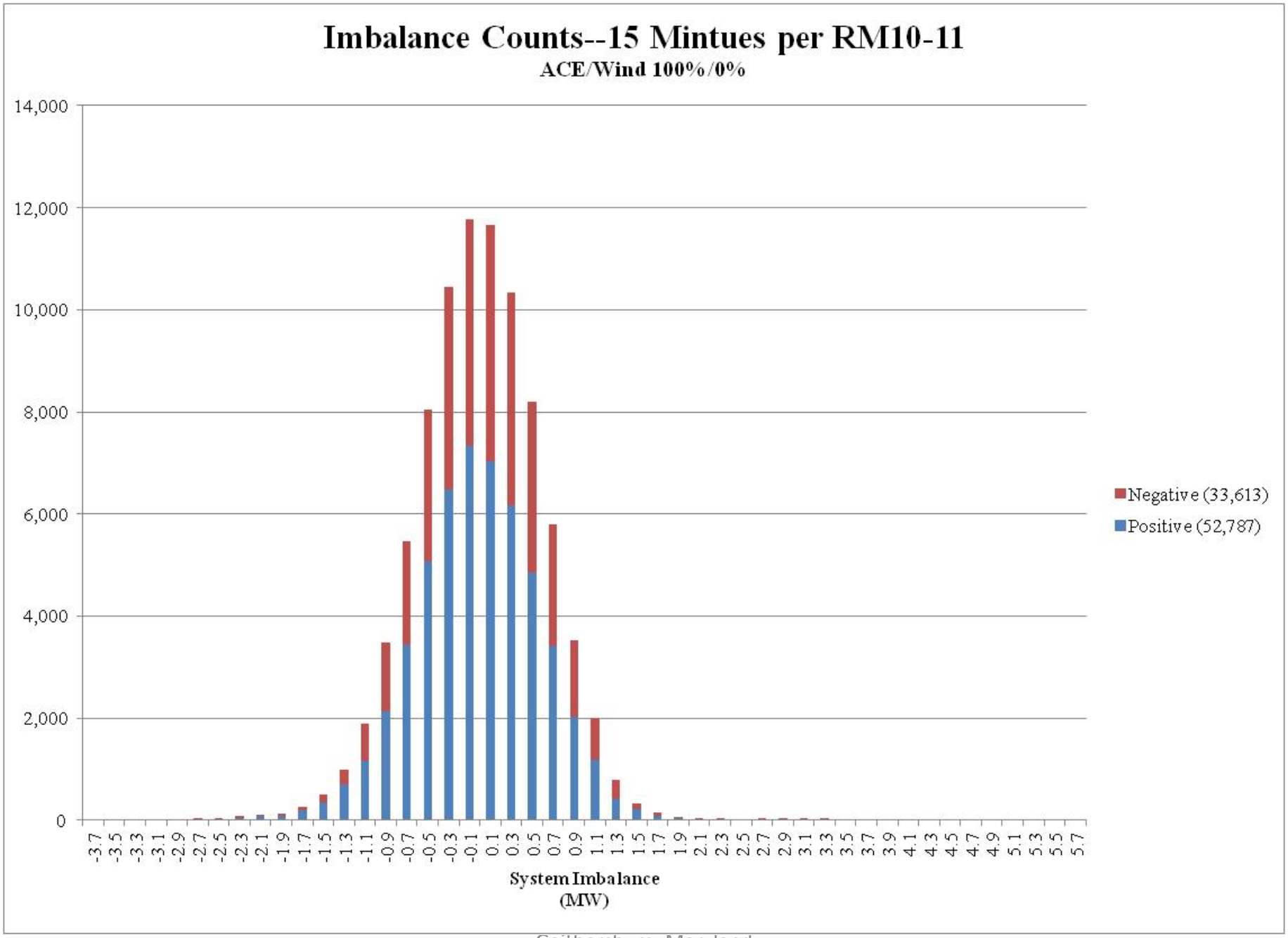
Competitive Markets for Imbalances, Not Penalties

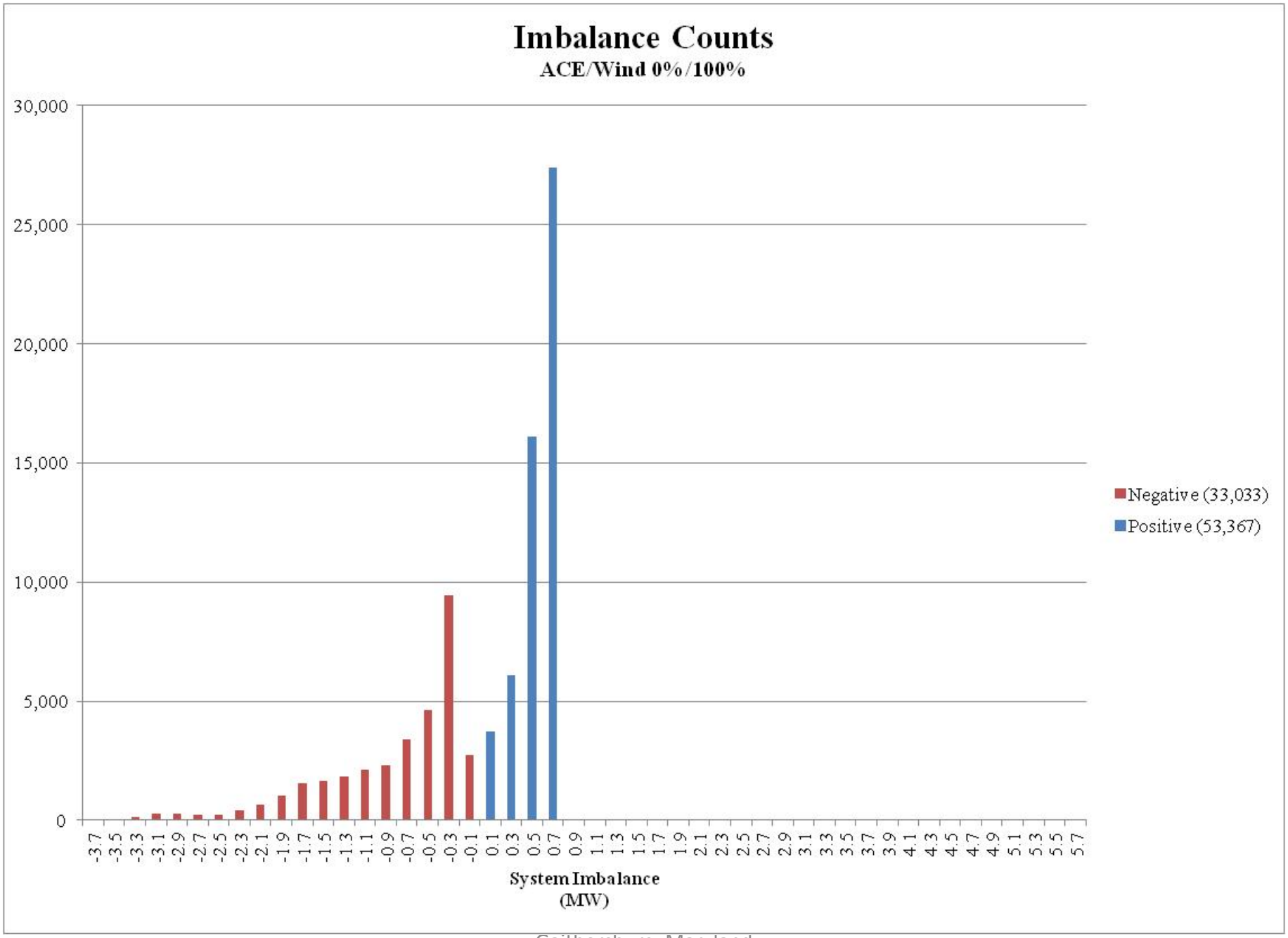
- Structure in *Frequency Regulation Compensation in the Organized Wholesale Power Markets*, Docket Nos. RM11-7-000 and AD10-11-000 may be infeasible
- The structure drastically limits the number of participants that can provide the identified ancillary service
- The structure reduces the incentive for most generators and other market participants to help the ISOs regulate system frequency

Competitive Markets for Imbalances, Not Penalties

- Many utilities set the price for generator imbalances such the price structure is a penalty to the generator for that imbalance, with the rate for the penalty growing with the size of the imbalance.
- The imbalance payment can be restructured into a competitive market by having the rate vary with the size of the utility's imbalance with other utilities instead of the size of the generator's imbalance with the utility.
- The rate can be a continuous variable instead of the step changes associated with standard utility penalties.
- A generator imbalance rate that is based on the utility's imbalance with other utilities is self correcting, in that generator response to the imbalance rate moderates the rate.
- India implemented a similar rate and reduced its system imbalances by 50%.
- A competitive market for imbalances could be used for pricing the operation of fast response storage systems instead of creating a separate ancillary service for such system.


Imbalance Counts
ACE/Wind 100%/0%
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
-3.7 -3.5 -3.3 -3.1 -2.9 -2.7 -2.5 -2.3 -2.1 -1.9 -1.7 -1.5 -1.3 -1.1 -0.9 -0.7 -0.5 -0.3 -0.1 0.1 0.3 0.5 0.7 0.9 1.1 1.3 1.5 1.7 1.9 2.1 2.3 2.5 2.7 2.9 3.1 3.3 3.5 3.7 3.9 4.1 4.3 4.5 4.7 4.9 5.1 5.3 5.5 5.7
System Imbalance
(MW)
Negative (33,033)
Positive (53,367)


Imbalance Counts--15 Mintues per RM10-11
ACE/Wind 100%/0%
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
-3.7 -3.5 -3.3 -3.1 -2.9 -2.7 -2.5 -2.3 -2.1 -1.9 -1.7 -1.5 -1.3 -1.1 -0.9 -0.7 -0.5 -0.3 -0.1 0.1 0.3 0.5 0.7 0.9 1.1 1.3 1.5 1.7 1.9 2.1 2.3 2.5 2.7 2.9 3.1 3.3 3.5 3.7 3.9 4.1 4.3 4.5 4.7 4.9 5.1 5.3 5.5 5.7
System Imbalance
(MW)
Negative (33,613)
Positive (52,787)


Imbalance Counts
ACE/Wind 0%/100%
30,000
25,000
20,000
15,000
10,000
5,000
0
-3.7 -3.5 -3.3 -3.1 -2.9 -2.7 -2.5 -2.3 -2.1 -1.9 -1.7 -1.5 -1.3 -1.1 -0.9 -0.7 -0.5 -0.3 -0.1 0.1 0.3 0.5 0.7 0.9 1.1 1.3 1.5 1.7 1.9 2.1 2.3 2.5 2.7 2.9 3.1 3.3 3.5 3.7 3.9 4.1 4.3 4.5 4.7 4.9 5.1 5.3 5.5 5.7
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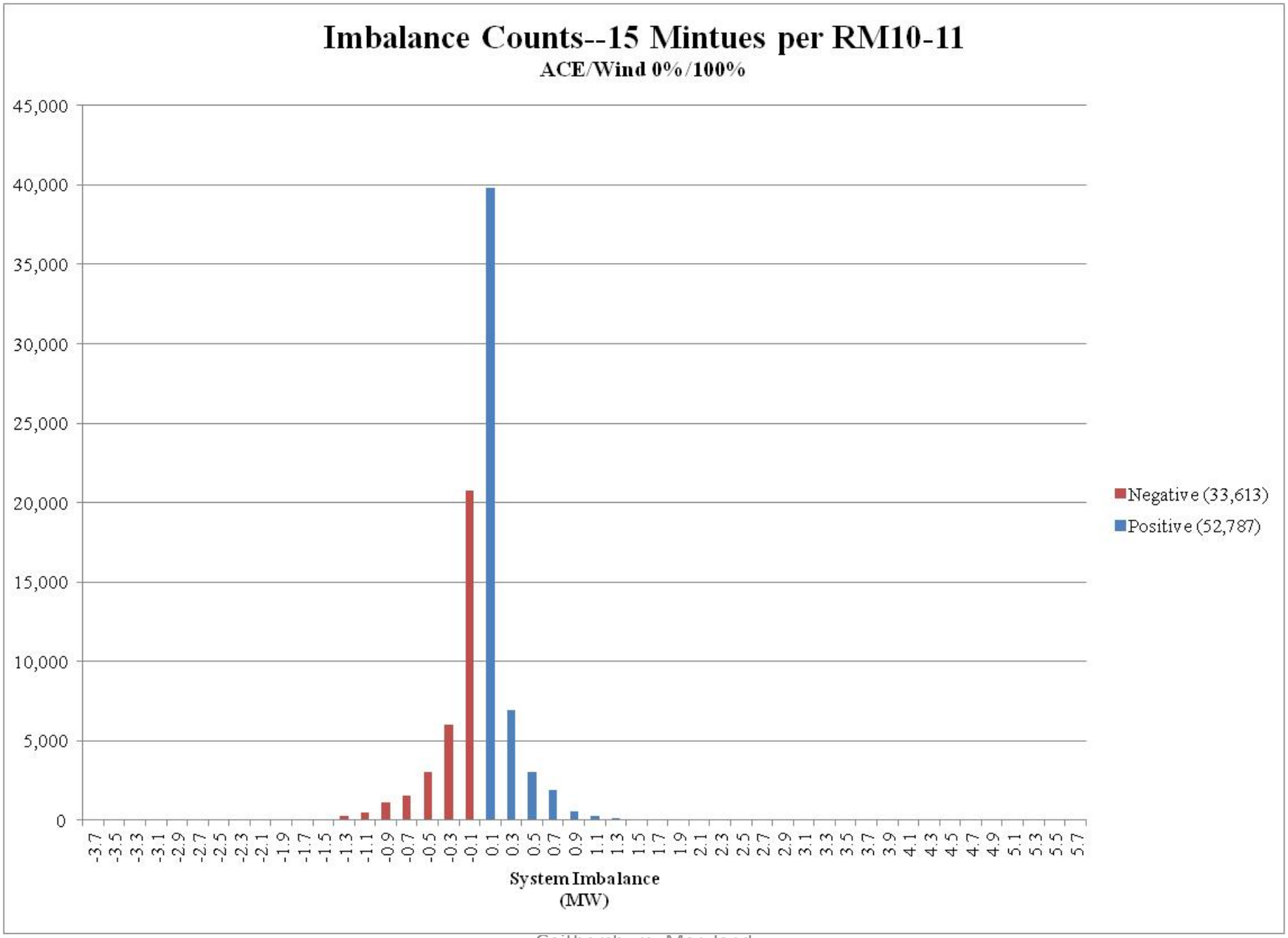
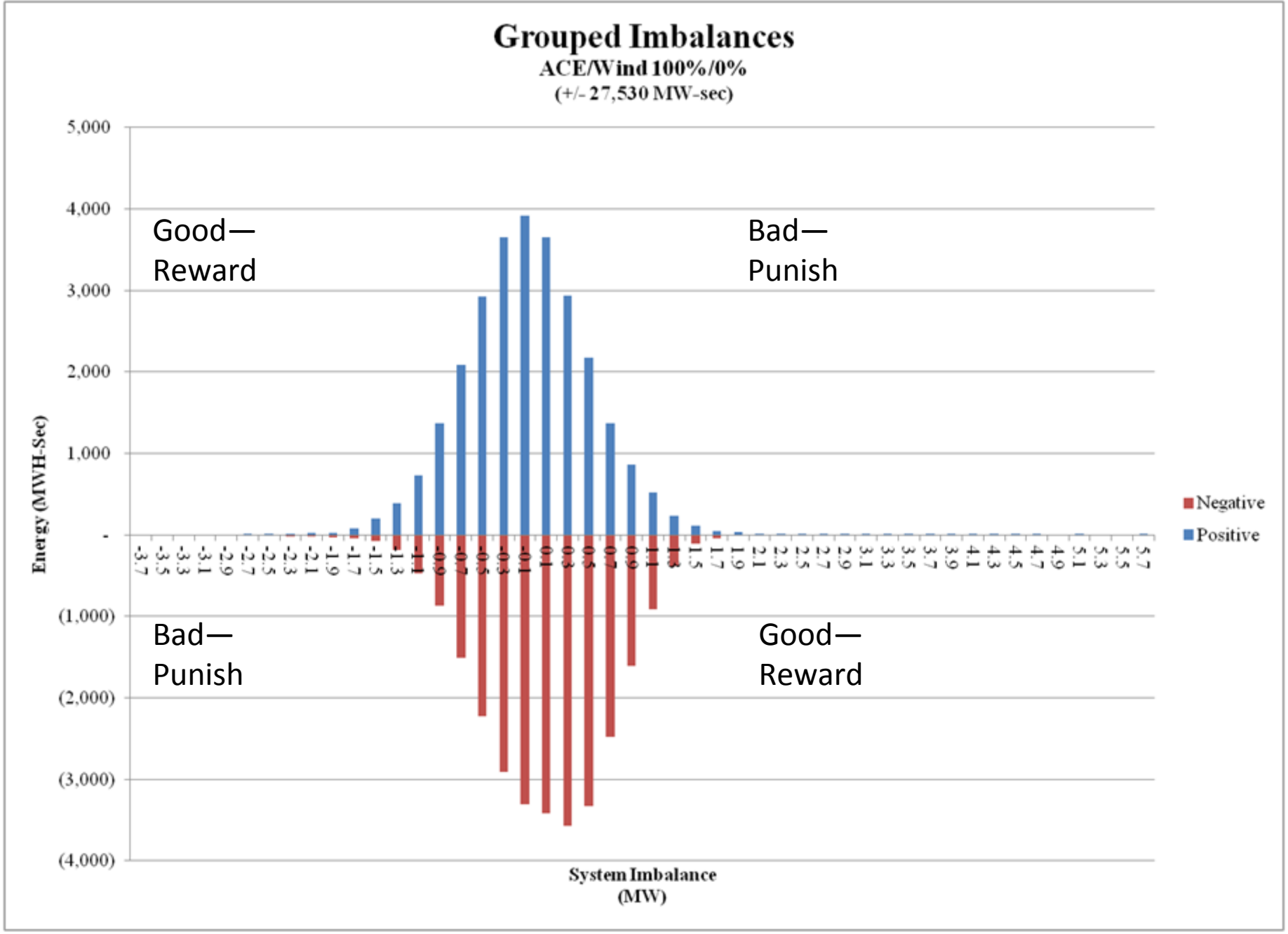
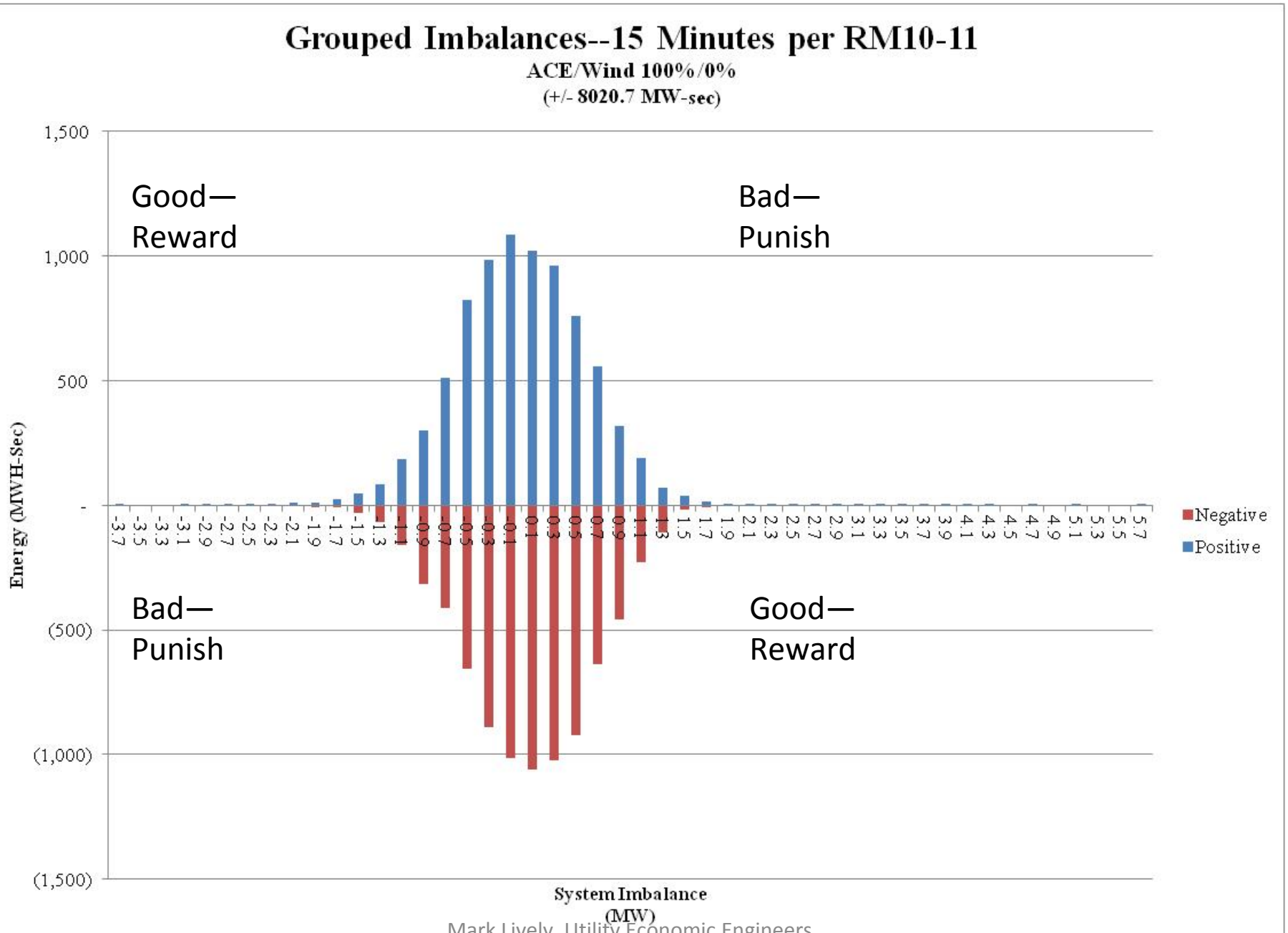
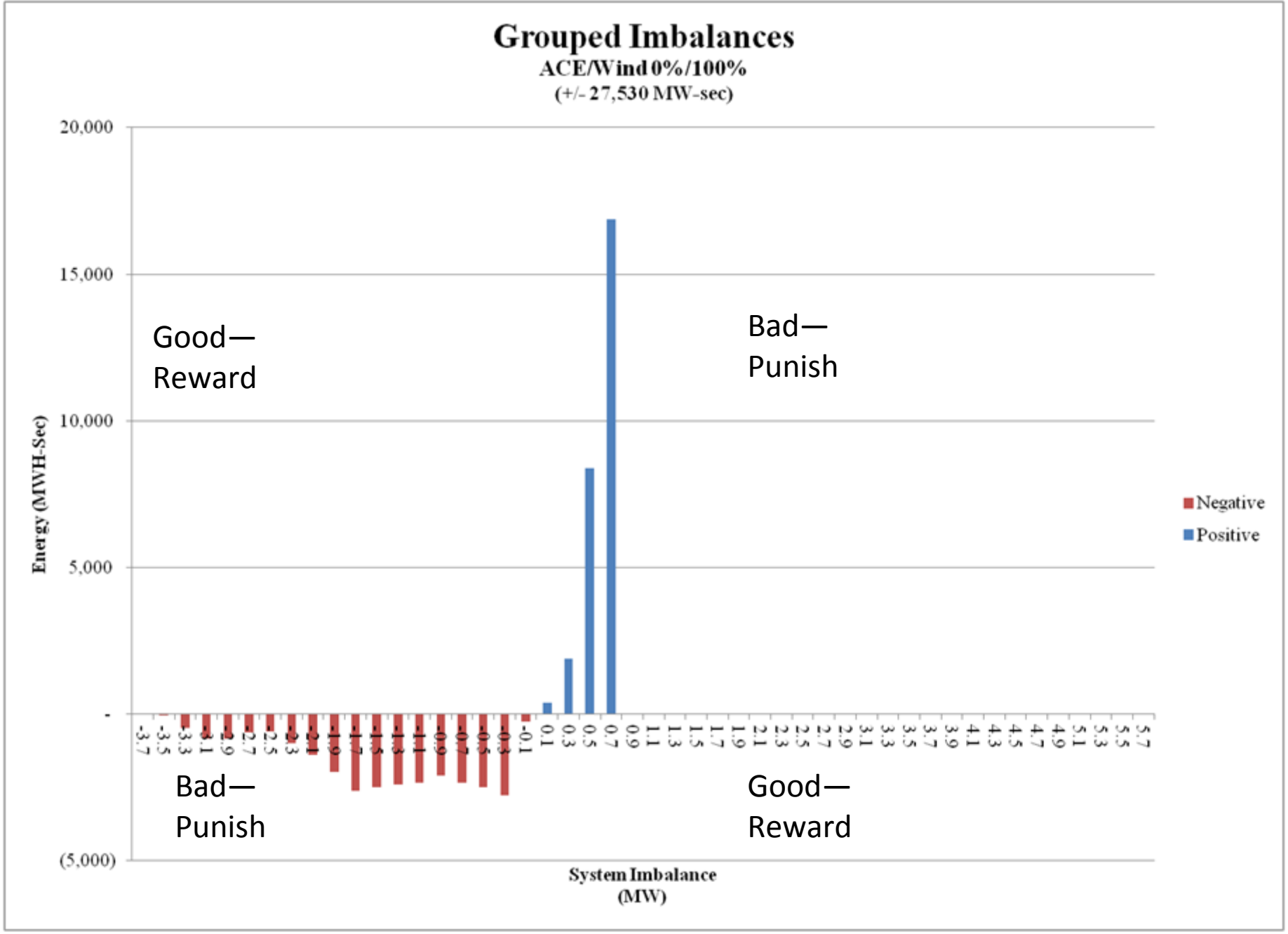
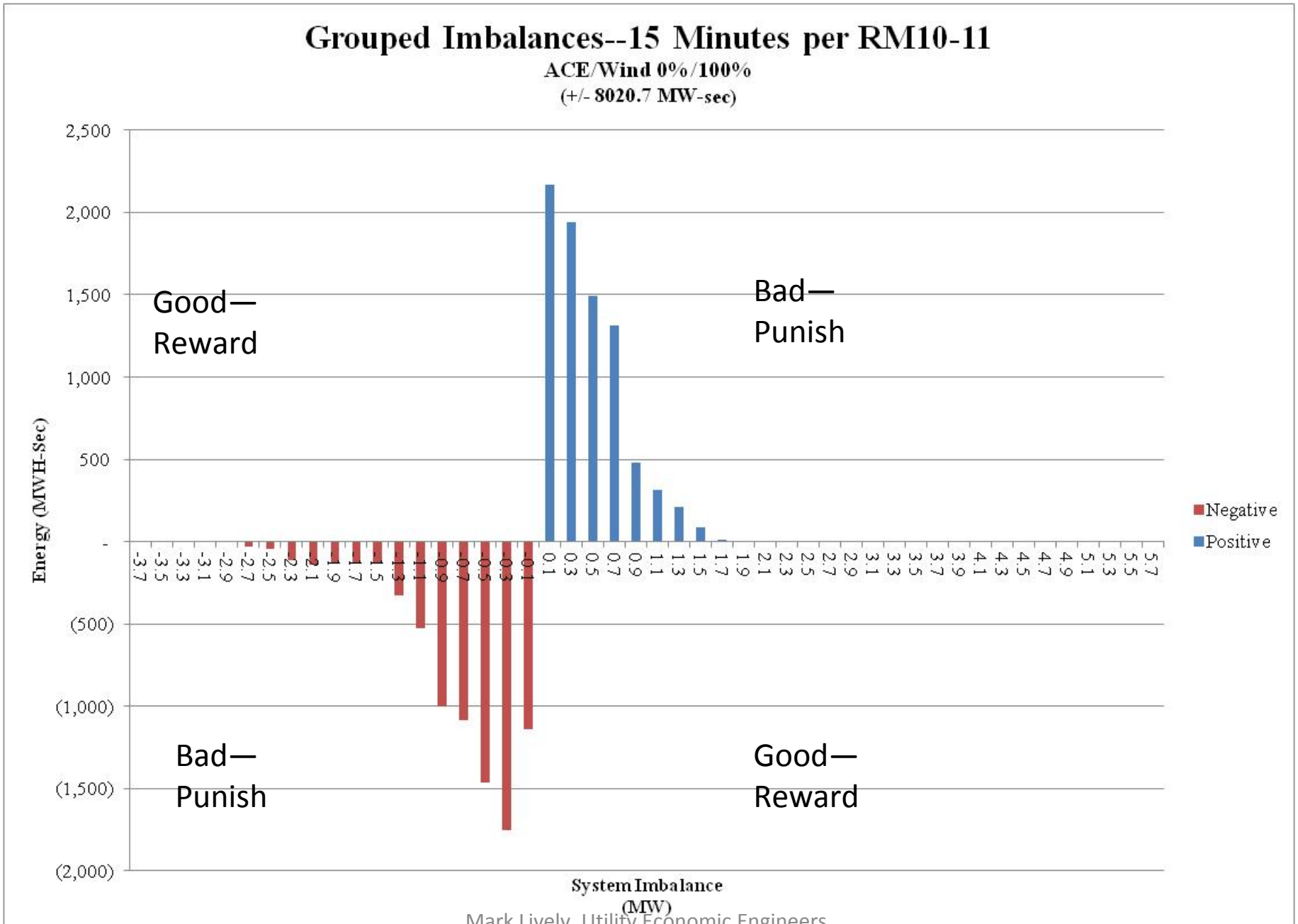
Positive (53,367)


Imbalance Counts--15 Mintues per RM10-11
ACE/Wind 0%/100%
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
-3.7 -3.5 -3.3 -3.1 -2.9 -2.7 -2.5 -2.3 -2.1 -1.9 -1.7 -1.5 -1.3 -1.1 -0.9 -0.7 -0.5 -0.3 -0.1 0.1 0.3 0.5 0.7 0.9 1.1 1.3 1.5 1.7 1.9 2.1 2.3 2.5 2.7 2.9 3.1 3.3 3.5 3.7 3.9 4.1 4.3 4.5 4.7 4.9 5.1 5.3 5.5 5.7
System Imbalance (MW)
Negative (33,613)
Positive (52,787)


Grouped Imbalances
ACE/Wind 100%/0%
(+/- 27,530 MW-sec)
Good—
Reward
Bad—
Punish
Bad—
Punish
Good—
Reward
Energy (MWH-Sec)
5,000
4,000
3,000
2,000
1,000
-
(1,000)
(2,000)
(3,000)
(4,000)
System Imbalance
(MW)
Negative
Positive


Grouped Imbalances--15 Minutes per RM10-11
ACE/Wind 100%/0%
(+/- 8020.7 MW-sec)
Good—
Reward
Bad—
Punish
Bad—
Punish
Good—
Reward
1,500
1,000
500
-
(500)
(1,000)
(1,500)
Energy (MWH-Sec)
-3.7 -3.5 -3.3 -3.1 -2.9 -2.7 -2.5 -2.3 -2.1 -1.9 -1.7 -1.5 -1.3 -1.1 -0.9 -0.7 -0.5 -0.3 -0.1 0.1 0.3 0.5 0.7 0.9 1.1 1.3 1.5 1.7 1.9 2.1 2.3 2.5 2.7 2.9 3.1 3.3 3.5 3.7 3.9 4.1 4.3 4.5 4.7 4.9 5.1 5.3 5.5 5.7
System Imbalance
(MW)
Negative
Positive


Grouped Imbalances
ACE/Wind 0%/100%
(+/- 27,530 MW-sec)
20,000
15,000
10,000
5,000
-
(5,000)
Energy (MWH-Sec)
Good—
Reward
Bad—
Punish
Bad—
Punish
Good—
Reward
Negative
Positive
System Imbalance
(MW)


Grouped Imbalances--15 Minutes per RM10-11
ACE/Wind 0%/100%
(+/- 8020.7 MW-sec)
Energy (MWH-Sec)
2,500
2,000
1,500
1,000
500
-
(500)
(1,000)
(1,500)
(2,000)
Good—
Reward
Bad—
Punish
Bad—
Punish
Good—
Reward
Negative
Positive
System Imbalance
(MW)

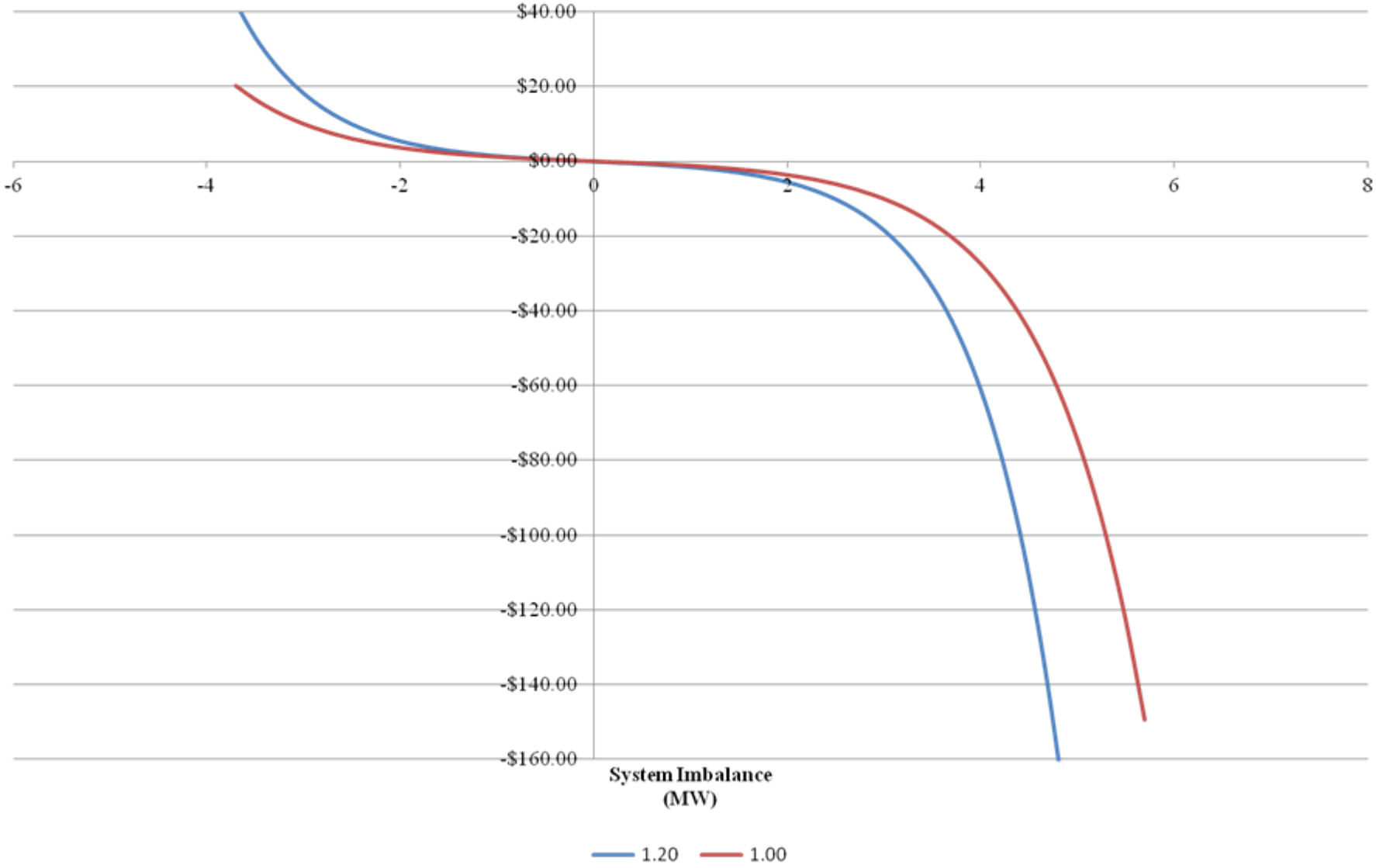
Good versus Bad Wind Imbalance
Based on Offsetting versus Adding to ACE
(MW-Secs)

ACE Weight	Positive Imbalance		Negative Imbalance		NET Imbalance Value
	Negative ACE	Positive ACE	Negative ACE	Positive ACE	
0%	-	27,530	(27,530)	-	(55,060)
10%	15	27,515	(27,515)	(14)	(55,001)
20%	116	27,414	(27,414)	(116)	(54,596)
30%	694	26,836	(26,899)	(631)	(52,410)
40%	2,498	25,032	(26,174)	(1,356)	(47,351)
50%	5,372	22,158	(25,194)	(2,336)	(39,645)
60%	8,155	19,375	(23,634)	(3,896)	(30,957)
70%	10,590	16,940	(21,077)	(6,453)	(20,974)
80%	12,590	14,940	(17,562)	(9,968)	(9,943)
90%	14,153	13,377	(14,208)	(13,322)	(110)
100%	15,449	12,081	(11,675)	(15,855)	7,548

Imbalance Price Adjustment

Hyperbolic Sine With Specified Multipliers

($/MWH)



Imbalance Price Adjustment

Hyperbolic Sine With Specified Multipliers

($/MWH)

	Price Adjustment				Price Adjustment	
MW	1.00 X	1.20X		MW	1.00 X	1.20X
-3.7	$20.21	$42.38		1.1	-$1.34	-$1.74
-3.5	$16.54	$33.34		1.3	-$1.70	-$2.27
-3.3	$13.54	$26.22		1.5	-$2.13	-$2.94
-3.1	$11.08	$20.62		1.7	-$2.65	-$3.78
-2.9	$9.06	$16.21		1.9	-$3.27	-$4.84
-2.7	$7.41	$12.75		2.1	-$4.02	-$6.17
-2.5	$6.05	$10.02		2.3	-$4.94	-$7.87
-2.3	$4.94	$7.87		2.5	-$6.05	-$10.02
-2.1	$4.02	$6.17		2.7	-$7.41	-$12.75
-1.9	$3.27	$4.84		2.9	-$9.06	-$16.21
-1.7	$2.65	$3.78		3.1	-$11.08	-$20.62
-1.5	$2.13	$2.94		3.3	-$13.54	-$26.22
-1.3	$1.70	$2.27		3.5	-$16.54	-$33.34
-1.1	$1.34	$1.74		3.7	-$20.21	-$42.38
-0.9	$1.03	$1.30		3.9	-$24.69	-$53.88
-0.7	$0.76	$0.94		4.1	-$30.16	-$68.50
-0.5	$0.52	$0.64		4.3	-$36.84	-$87.08
-0.3	$0.30	$0.37		4.5	-$45.00	-$110.70
-0.1	$0.10	$0.12		4.7	-$54.97	-$140.73
0.1	-$0.10	-$0.12		4.9	-$67.14	-$178.90
0.3	-$0.30	-$0.37		5.1	-$82.01	-$227.43
0.5	-$0.52	-$0.64		5.3	-$100.17	-$289.12
0.7	-$0.76	-$0.94		5.5	-$122.34	-$367.55
0.9	-$1.03	-$1.30		5.7	-$149.43	-$467.24

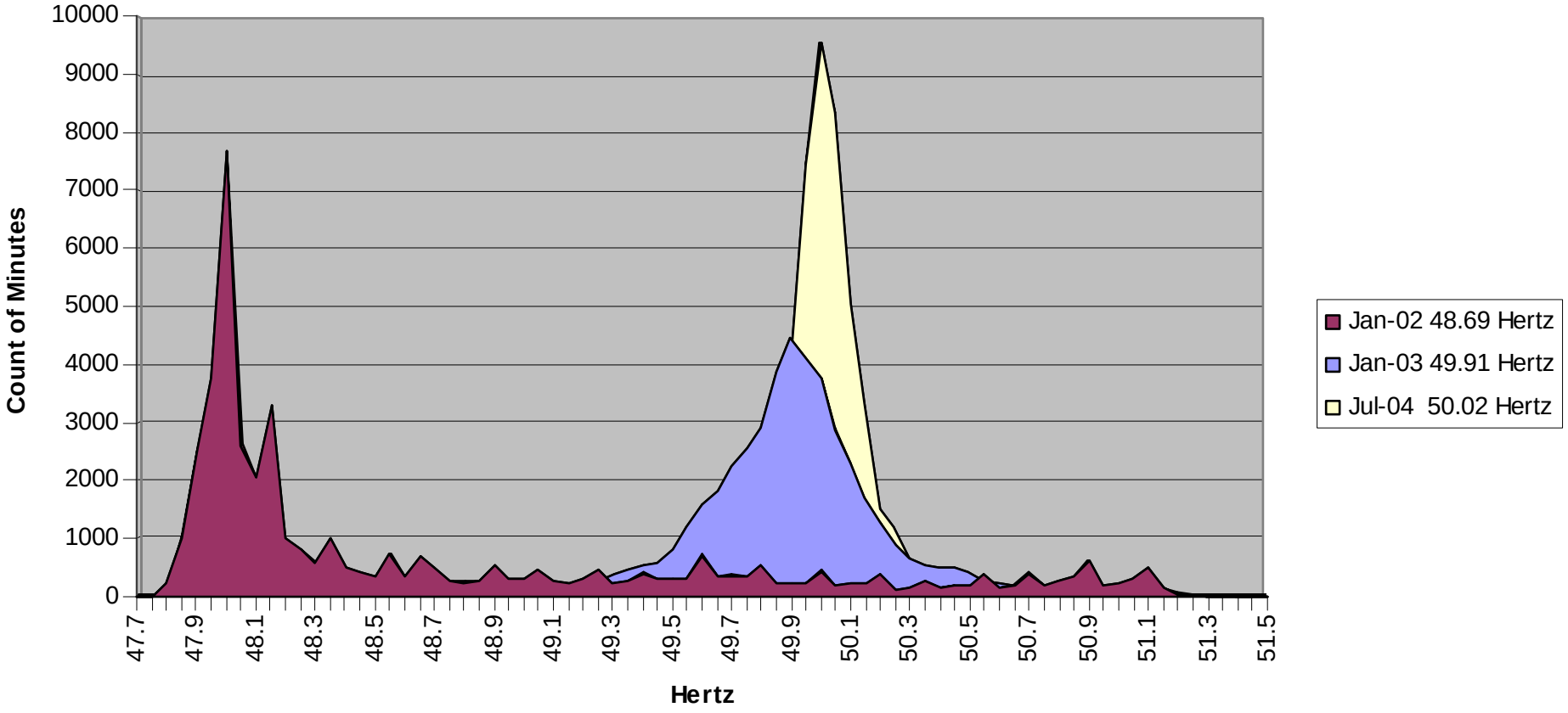
Pricing Wind Imbalance
Hyperbolic Sine (1.0 X)

ACE Weight	Positive Variance		Negative Variance		NET Imbalance Value
	Negative ACE	Positive ACE	Negative ACE	Positive ACE	
0%	$ -	$ (4.94)	$ (20.68)	$ -	$ (25.62)
10%	$ -	$ (3.95)	$ (16.25)	$ 0.00	$ (20.20)
20%	$ 0.00	$ (3.50)	$ (12.79)	$ 0.00	$ (16.29)
30%	$ 0.01	$ (3.01)	$ (10.07)	$ 0.02	$ (13.05)
40%	$ 0.05	$ (2.62)	$ (7.89)	$ 0.05	$ (10.41)
50%	$ 0.18	$ (2.34)	$ (6.09)	$ 0.12	$ (8.14)
60%	$ 0.43	$ (2.15)	$ (4.62)	$ 0.24	$ (6.11)
70%	$ 0.77	$ (2.05)	$ (3.44)	$ 0.47	$ (4.25)
80%	$ 1.19	$ (2.03)	$ (2.56)	$ 0.89	$ (2.50)
90%	$ 1.69	$ (2.06)	$ (2.00)	$ 1.57	$ (0.79)
100%	$ 2.29	$ (2.16)	$ (1.59)	$ 2.49	$ 1.03

Pricing Wind Imbalance
Hyperbolic Sine (1.2 X)

ACE Weight	Positive Variance		Negative Variance		NET Imbalance Value
	Negative ACE	Positive ACE	Negative ACE	Positive ACE	
0%	$ -	$ (6.10)	$ (32.92)	$ -	$ (39.02)
10%	$ -	$ (4.83)	$ (24.55)	$ 0.00	$ (29.38)
20%	$ 0.00	$ (4.28)	$ (18.48)	$ 0.00	$ (22.75)
30%	$ 0.01	$ (3.69)	$ (13.98)	$ 0.02	$ (17.64)
40%	$ 0.06	$ (3.23)	$ (10.61)	$ 0.07	$ (13.71)
50%	$ 0.21	$ (2.90)	$ (7.99)	$ 0.14	$ (10.54)
60%	$ 0.52	$ (2.71)	$ (5.95)	$ 0.29	$ (7.85)
70%	$ 0.95	$ (2.65)	$ (4.38)	$ 0.57	$ (5.50)
80%	$ 1.48	$ (2.71)	$ (3.25)	$ 1.10	$ (3.37)
90%	$ 2.13	$ (2.87)	$ (2.54)	$ 1.95	$ (1.32)
100%	$ 2.92	$ (3.22)	$ (2.04)	$ 3.14	$ 0.80

Monthly Distribution of Minute by Minute Frequencies



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