Regulation Market Issues: Brief Overview

RMISTF

November 11, 2015

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Monitoring Analytics

Current Design

- **Incorrectly defined marginal benefit factor function (MBF)**
  - **Evidence that MBF between RegA and RegD is incorrectly defined.**
- **Incorrectly applying the MBF in the optimization/market clearing**
  - **MBF use not consistent with derivation.**
  - **Area under MBF curve not used to determine effective MW.**
  - **Assumed RegA/RegD proportions in MBF function not maintained in system solution.**

Current Design

- **MBF inconsistently used in pricing/optimization and settlement**
  - **MBF used to convert offers/price into common units.**
  - **MBF used to convert regulation MW provided into common units.**
  - **MBF not used to make payment in common units.**
- **LOC not correctly determined**
  - **Uses lower of energy offer curve, not the operational curve.**

Incorrectly applying the MBF in the optimization: Not using area under curve

- **Current market design incorrectly accounting for the amount of RegD it is acquiring in the market solution.**
- **Undercounting the contribution of RegD to total effective regulation.**
- **Clearing engine acquiring too much RegD on an absolute and proportional basis.**

Incorrectly applying the MBF in the optimization: RegA/RegD proportions not being maintained

- **Clearing engine acquiring too much RegD on an absolute and proportional basis.**
  - **Operational Issues (even if MBF was correctly determined).**
- **Inefficient squeezing out of RegA.**
- **Lowers regulation price per MW of RegA while causing too much total Reg to clear.**

MBF not consistently used in pricing/optimization and settlement

- **Current market model assumes MBF in price and optimization but not settlement .**
- **Result in incorrect compensation of RegD in all hours.**
- **RegD always paid a little more than RegA**
  - **Results in artificial and inefficient signal to enter market as RegD resource.**

Incorrect calculation of LOC.

- **Where lower of price or cost <> operational offer**
  - **Internalized opportunity cost to provide regulation <> actual opportunity cost to provide regulation.**
  - **Reduced efficiency to market solution.**
  - **Artificial increase/decrease to regulation price when marginal.**
  - **Causes LOC undercollection/overcollection by resources depending on system conditions.**

Benefit Factor (MBF/BF) Derivation/Definition/Issues

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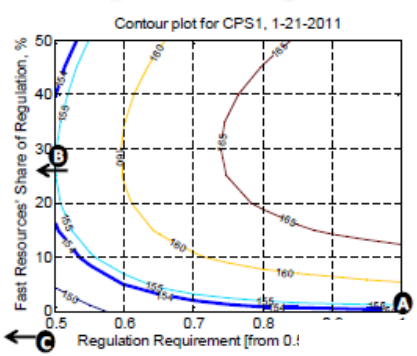
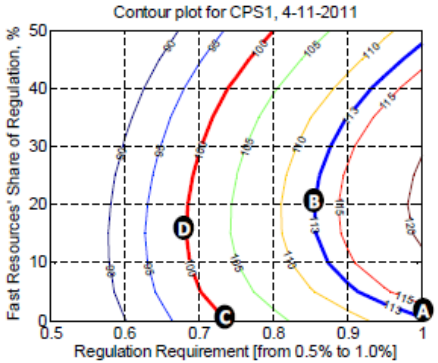
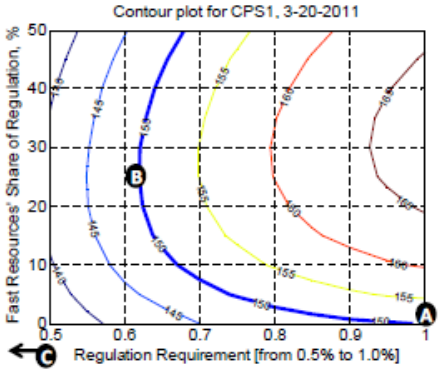
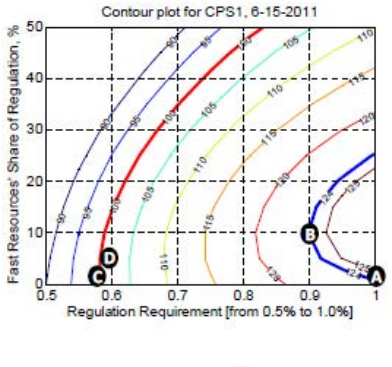
MBF varies with system conditions









Combinations of RegA and RegD that provide the same CPS1 Scores

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Benefit Factor (MBF/BF) Implementation Issues: 1. Incorrect Calculation of Effective MW (assuming BF curve properly defined)

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Current Design

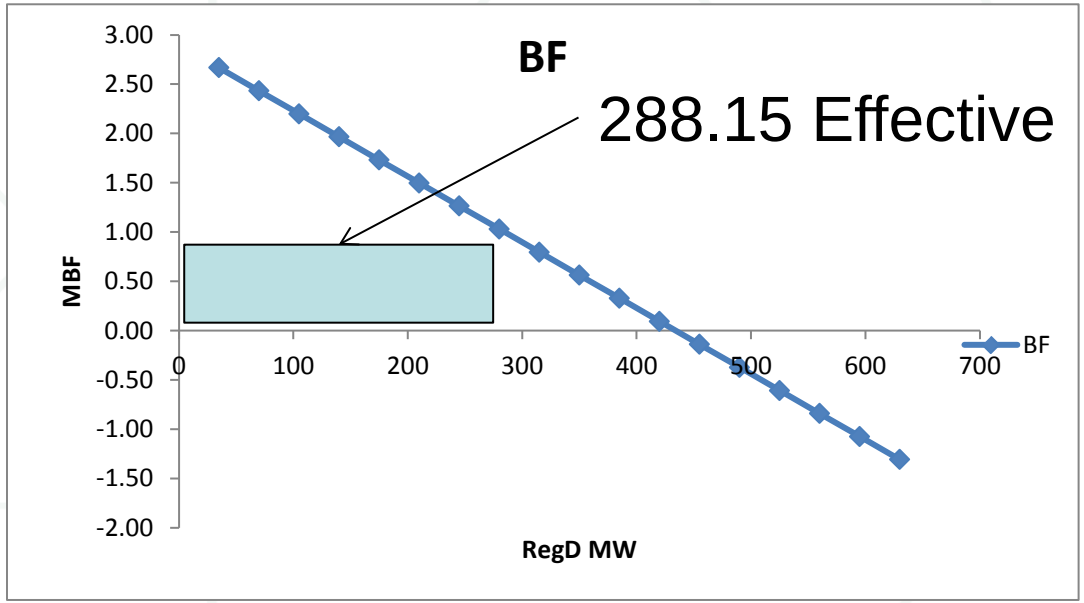
- **Issue 1: MBF of the last MW (of the last unit) of a price block is assigned to every MW of every unit of that price block for purposes of effective MW calculations.**
  - **Addressed (in part) in current proposal before the MRC.**
  - **Break block up into discrete unit MW.**
- **Issue 2: MBF of the last MW of a unit assigned to every MW of every unit of that unit for purposes of effective MW calculations.**
  - **Not addressed yet.**

Incorrectly applying the MBF in the optimization: Not using area under curve

- **Current market design incorrectly accounting for the amount of RegD it is acquiring in the market solution.**
- **Undercounting the contribution of RegD to total effective regulation.**
- **Clearing engine acquiring too much RegD on an absolute and proportional basis.**

PJM current approach effective MW calculations

RegD% /700	RegD MW	BF	PJM Effective Calculation (1 unit at each point)
5%	35	2.67	93.31
10%	70	2.43	170.26
15%	105	2.20	230.83
20%	140	1.96	275.04
25%	175	1.73	302.87
30%	210	1.50	314.33
35%	245	1.26	309.43
40%	280	1.03	288.15
45%	315	0.80	250.50



280 MW from 8 units offered at $0 treated as 1 unit for BF assignment

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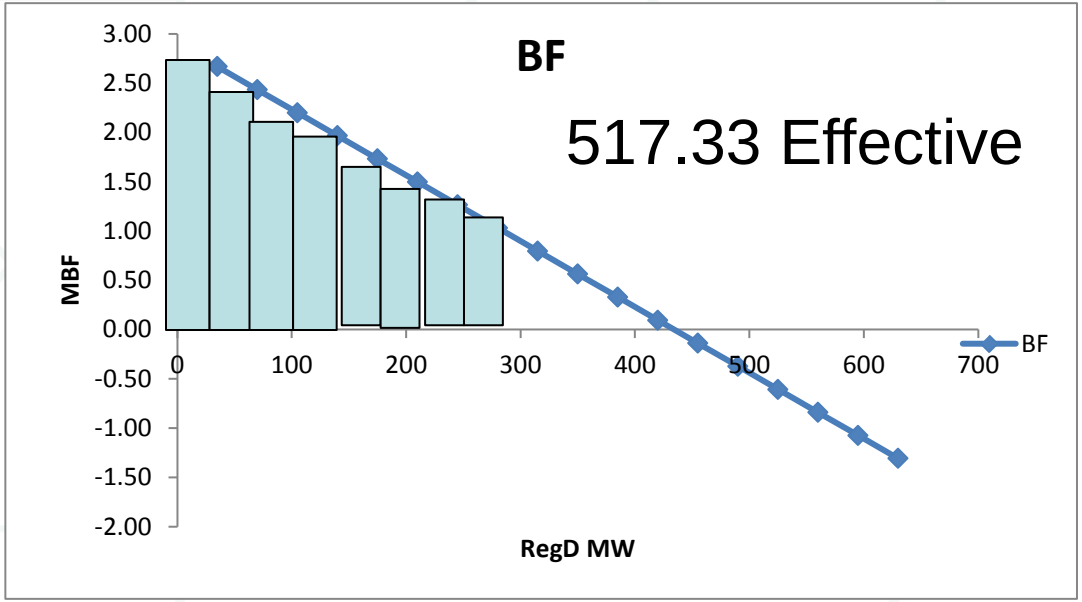
PJM current approach: The smaller the unit size, the closer effective equals area under curve

RegD% /700	RegD MW	BF	MW by Unit	PJM Effective Calculation (1 unit at each point)	Unit Specific Effective MW (PJM)	Cumulative Effective MW (PJM)
5%	35	2.67	35	93.31	93.31	93.31
10%	70	2.43	35	170.26	85.13	178.44
15%	105	2.20	35	230.83	76.94	255.39
20%	140	1.96	35	275.04	68.76	324.15
25%	175	1.73	35	302.87	60.57	384.72
30%	210	1.50	35	314.33	52.39	437.11
35%	245	1.26	35	309.43	44.20	481.31
40%	280	1.03	35	288.15	36.02	517.33
45%	315	0.80	35	250.50	27.83	545.17



280 MW from 8 units (35 MW blocks) treated as 8 unit for BF assignment

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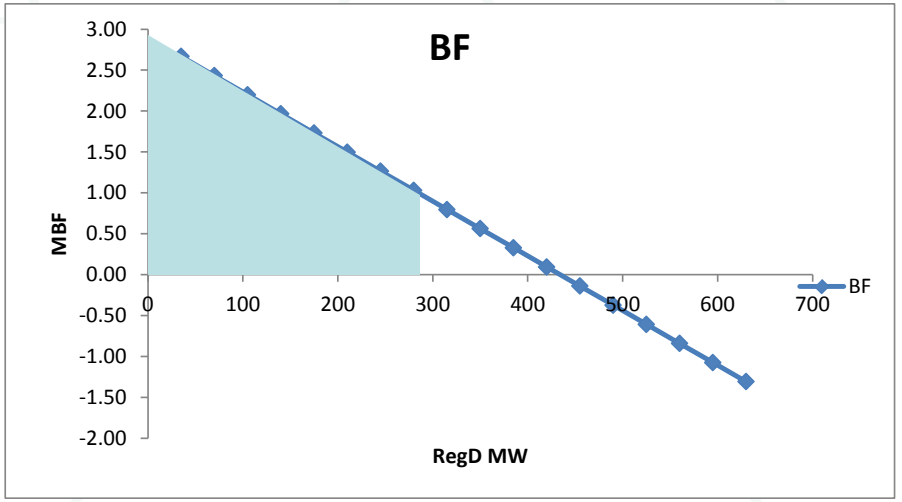
Should be area under curve

RegD% /700	RegD MW	BF	MW by Unit	PJM Effective Calculation (1 unit at each point)	Unit Specific Effective MW (PJM)	Cumulative Effective MW (PJM)	Area Under the Curve Effective MW
5%	35	2.67	35	93.31	93.31	93.31	97.41
10%	70	2.43	35	170.26	85.13	178.44	186.63
15%	105	2.20	35	230.83	76.94	255.39	267.67
20%	140	1.96	35	275.04	68.76	324.15	340.52
25%	175	1.73	35	302.87	60.57	384.72	405.18
30%	210	1.50	35	314.33	52.39	437.11	461.67
35%	245	1.26	35	309.43	44.20	481.31	509.96
40%	280	1.03	35	288.15	36.02	517.33	550.07
45%	315	0.80	35	250.50	27.83	545.17	582.00



Area under curve = 550.07 MW

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Current Design

- As unit size shrinks (and more units added), calculation gets closer to approximating the area under the curve.
  - Getting closer to correctly calculating the contribution of RegD to total effective regulation.
- Current approach causes effective MW to vary with the size of units cleared, not the cumulative MW (of all unit) cleared.
- Properly defined, effective MW calculated as area under the MBF function.

Benefit Factor (MBF/BF) Implementation Issues: Optimization/Market Clearing Issues

2. Implementation inconsistent with MBF/BF Definition

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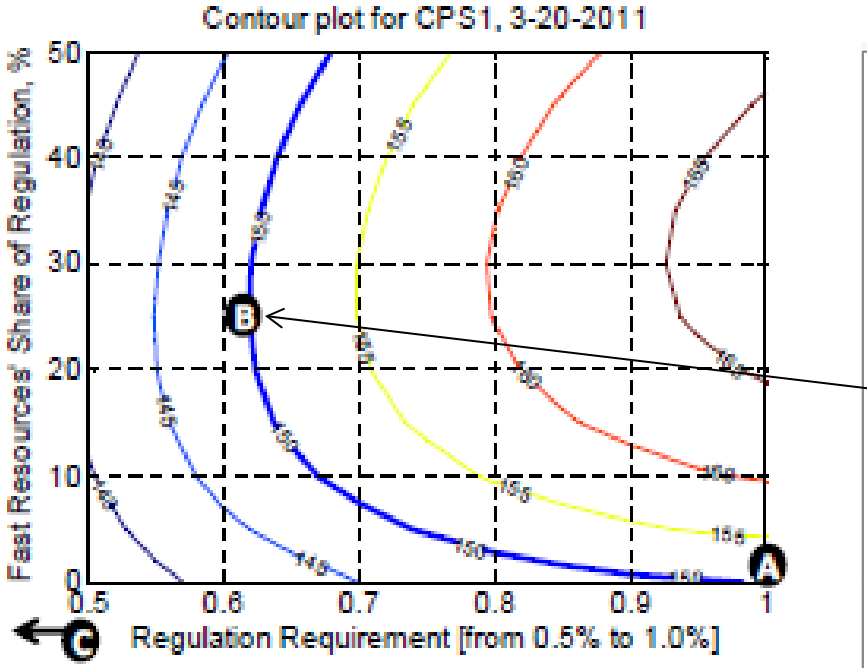
Incorrectly applying the MBF in the optimization: RegA/RegD proportions not being maintained

- **Clearing engine acquiring too much RegD on an absolute and proportional basis.**
  - **Operational Issues (even if MBF was correctly determined).**
- **Inefficient squeezing out of RegA.**
- **Lowers regulation price per MW of RegA while causing too much total Reg to clear.**

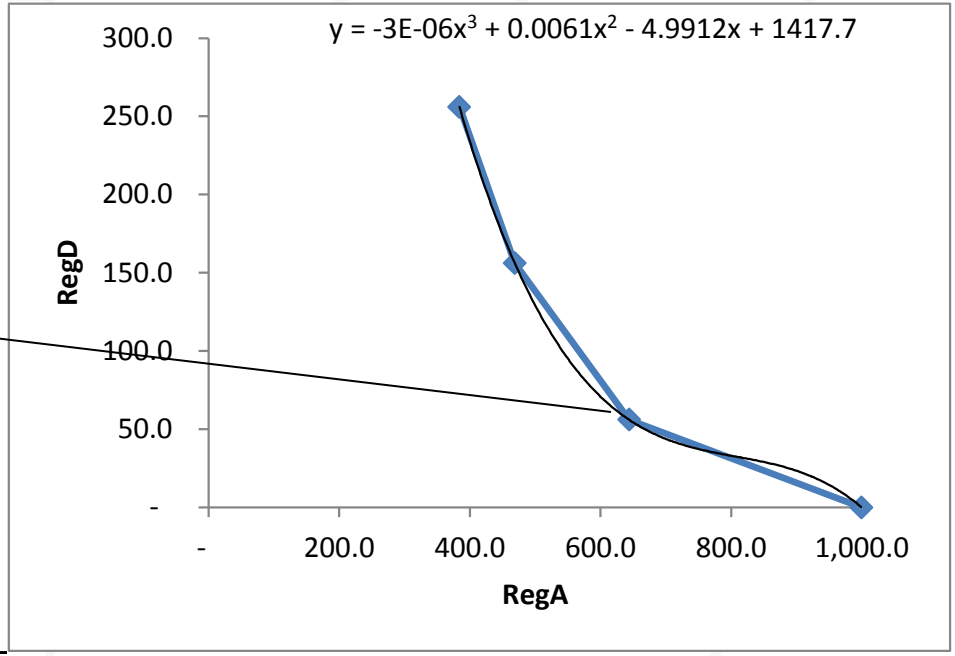
Incorrectly applying the MBF in the optimization: RegA/RegD proportions not being maintained

- **Current approach defines relationship based on percentage of RegD relative to fixed number, not RegD/RegA combinations that are the basis of the MBF derivation.**
- **Misinterprets axis (the relationship between RegD and RegA)**
- **Incorrect interpretation of the axis provides combinations inconsistent with MBF.**

KEMA: Assumed Relationship



Example curve in terms of MW



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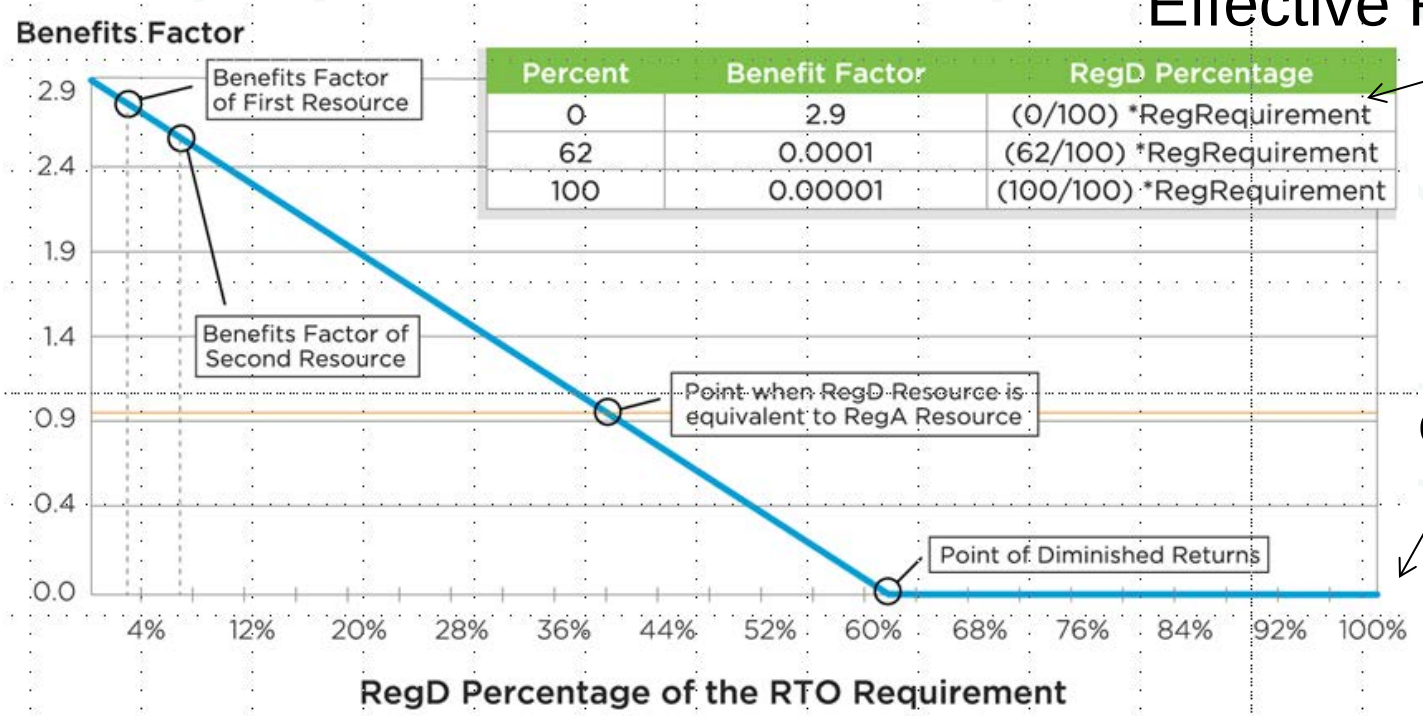
PJM Current Approach

Effective Reg Requirement



Percent	Benefit Factor	RegD Percentage
0	2.9	(0/100) *RegRequirement
62	0.0001	(62/100) *RegRequirement
100	0.00001	(100/100) *RegRequirement

% of 700 if peak

Not % of RegMW, % of 700 MW

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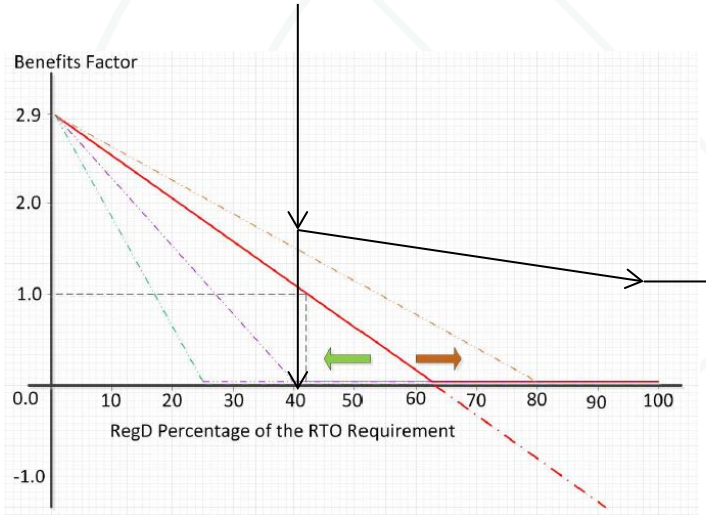
Current approach to RegA/RegD combinations

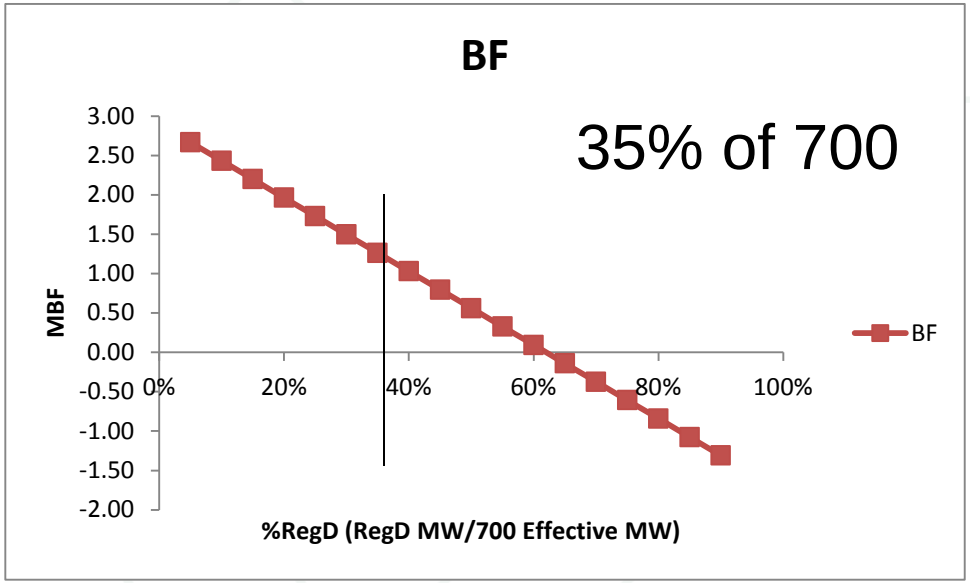
Assume % <> realized %

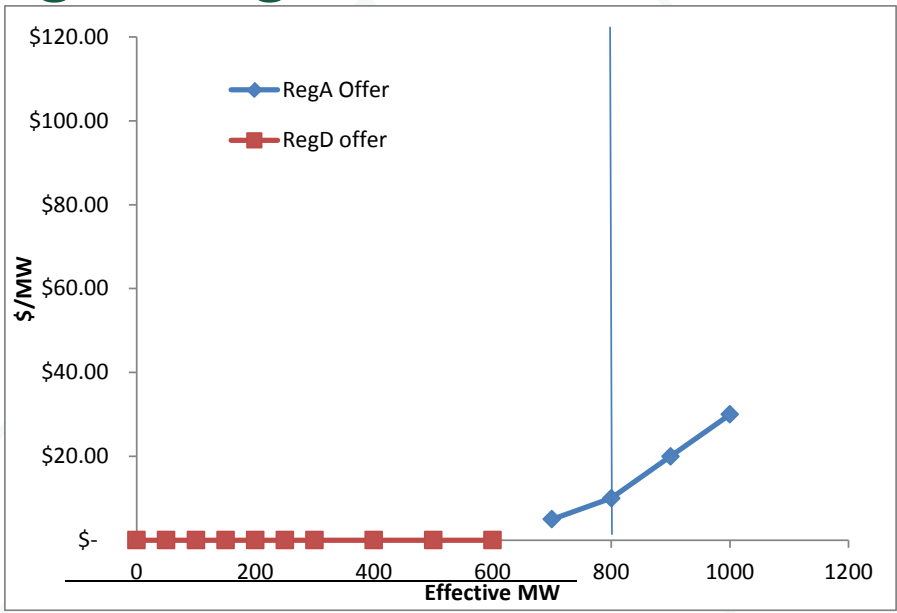


Too much RegD%

RegD% /700	RegD MW	Effective BF	Effective MW	Residual A	RegD/(RegA +RegD)	RegD% of Effective MW
5%	35	2.67	97.41	602.59	5%	14%
10%	70	2.43	186.63	513.37	12%	27%
15%	105	2.20	267.67	432.33	20%	38%
20%	140	1.96	340.52	359.48	28%	49%
25%	175	1.73	405.18	294.82	37%	58%
30%	210	1.50	461.67	238.33	47%	66%
35%	245	1.26	509.96	190.04	56%	73%
40%	280	1.03	550.07	149.93	65%	79%
45%	315	0.80	582.00	118.00	73%	83%
50%	350	0.56	605.74	94.26	79%	87%
55%	385	0.33	621.30	78.70	83%	89%
60%	420	0.09	628.67	71.33	85%	90%
65%	455	-0.14	627.85	72.15	86%	90%
70%	490	-0.37	618.85	81.15	86%	88%
75%	525	-0.61	601.66	98.34	84%	86%
80%	560	-0.84	576.29	123.71	82%	82%
85%	595	-1.08	542.74	157.26	79%	78%
90%	630	-1.31	501.00	199.00	76%	72%

PJM current approach to RegA/RegD combinations





Realized proportion of RegD and RegA not consistent. 56% of Reg, 73% of effective.

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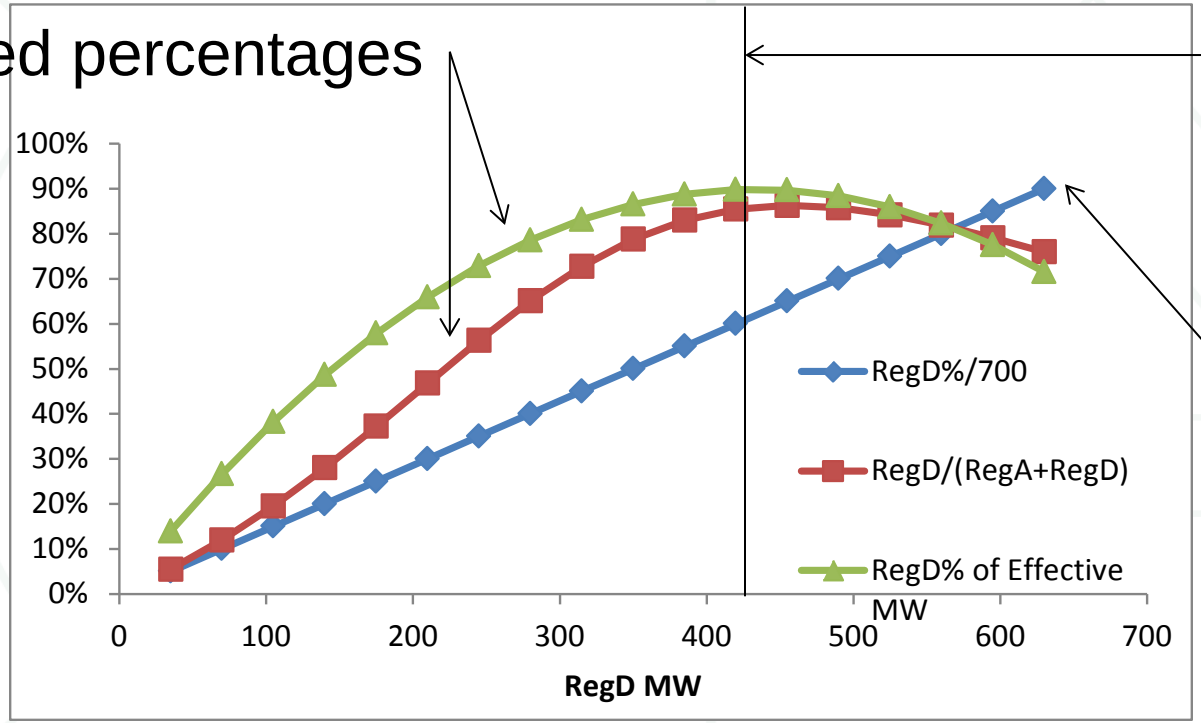
PJM current approach to RegA/RegD combinations

Realized percentages



Where MBF = zero

BF assumed percentages

Realized proportion <> assumed RegD proportion

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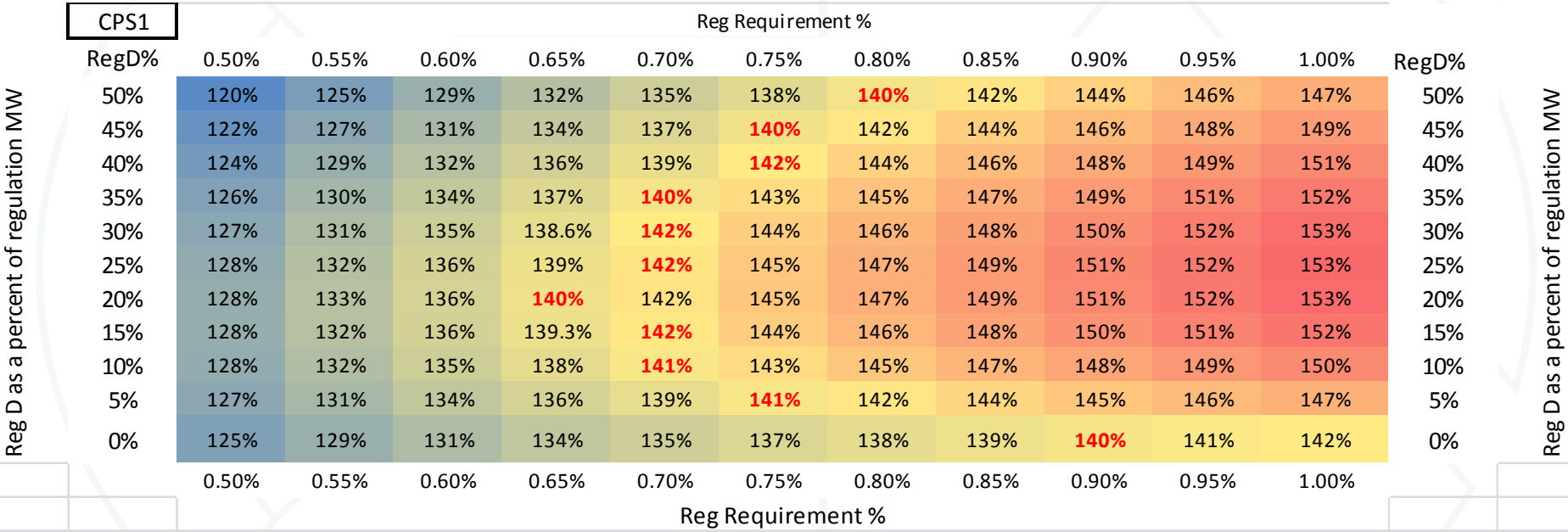
Ideally engine should produce relevant combinations

- **If defined relationship based on RegD/RegA combinations that meet operational requirements.**
- **Then market engine should provide RegD/RegA combinations consistent with operational requirements.**
- **Correct interpretation of MBF axis will allow consistent combinations**
  - **Axis in terms of RegD MW cleared, not on some percentage of RegD MW cleared.**

Average of all (12) KEMA Maps



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Average of all (12) KEMA Maps

Reg D as a percent of regulation MW	RegD MW	Total Regulation MW: 500.00	550.00	600.00	650.00	700.00	750.00	800.00	850.00	900.00	950.00	1,000.00	RegD MW	Reg D as a percent of regulation MW
	50%	250	275	300	325	350	375	400	425	450	475	500	50%	
	45%	225	248	270	293	315	338	360	383	405	428	450	45%	
	40%	200	220	240	260	280	300	320	340	360	380	400	40%	
	35%	175	193	210	228	245	263	280	298	315	333	350	35%	
	30%	150	165	180	195	210	225	240	255	270	285	300	30%	
	25%	125	138	150	163	175	188	200	213	225	238	250	25%	
	20%	100	110	120	130	140	150	160	170	180	190	200	20%	
	15%	75	83	90	98	105	113	120	128	135	143	150	15%	
	10%	50	55	60	65	70	75	80	85	90	95	100	10%	
	5%	25	28	30	33	35	38	40	43	45	48	50	5%	
	0%	-	-	-	-	-	-	-	-	-	-	-	0%	
		500.00	550.00	600.00	650.00	700.00	750.00	800.00	850.00	900.00	950.00	1,000.00		
		Total Regiulation MW												

Total Reg MW

RegD MW

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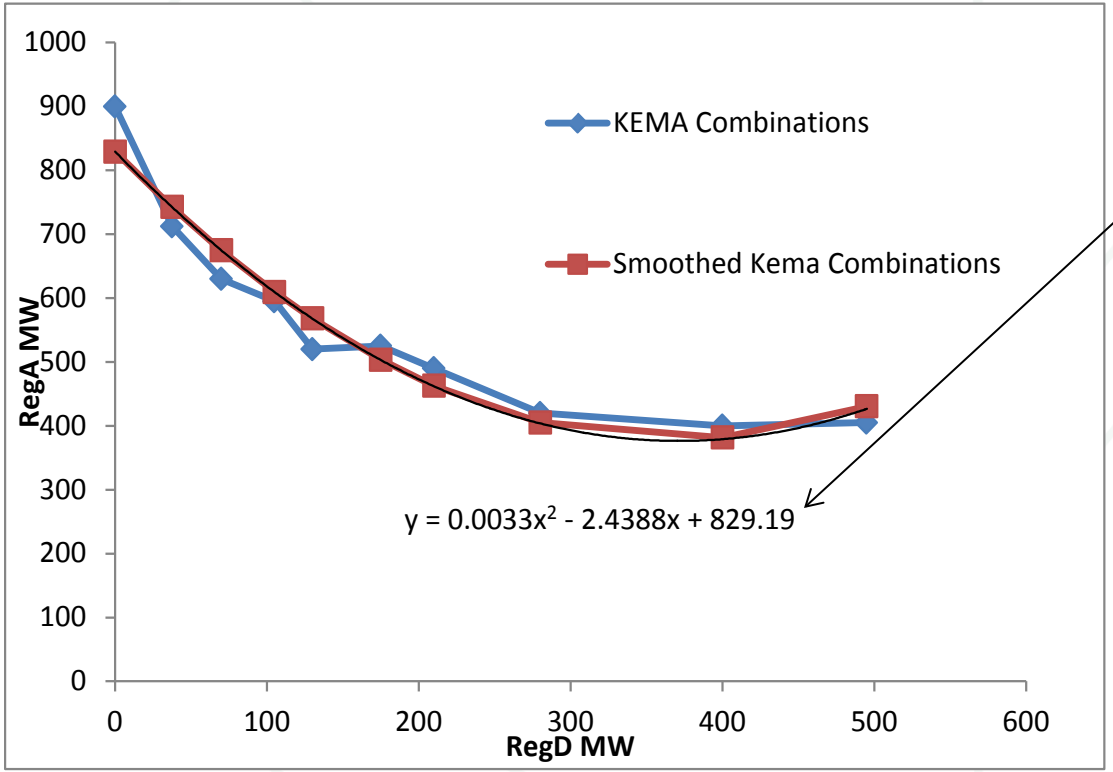
KEMA based combinations: Smooth the curve



Derivative of this function is MRTS = MBF Function

Change in RegA for Change in RegD

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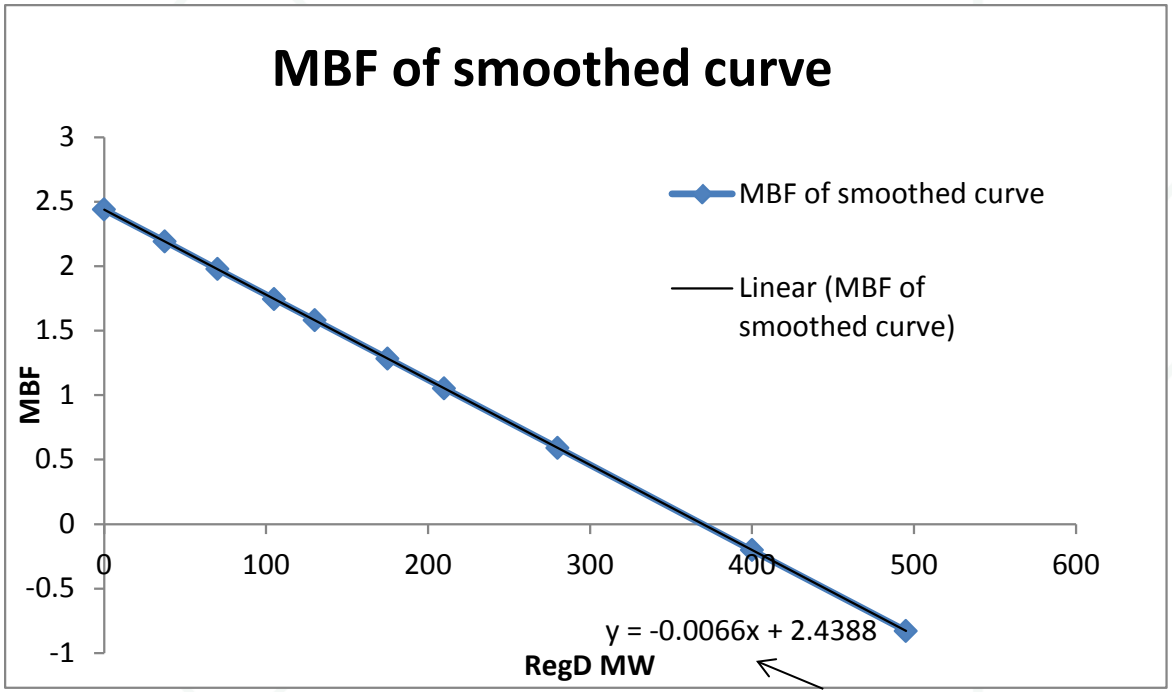
KEMA based combinations: MBF



Area under *this* curve = total effective MW from D.

Derivative of curve defining combinations of RegA/RegD

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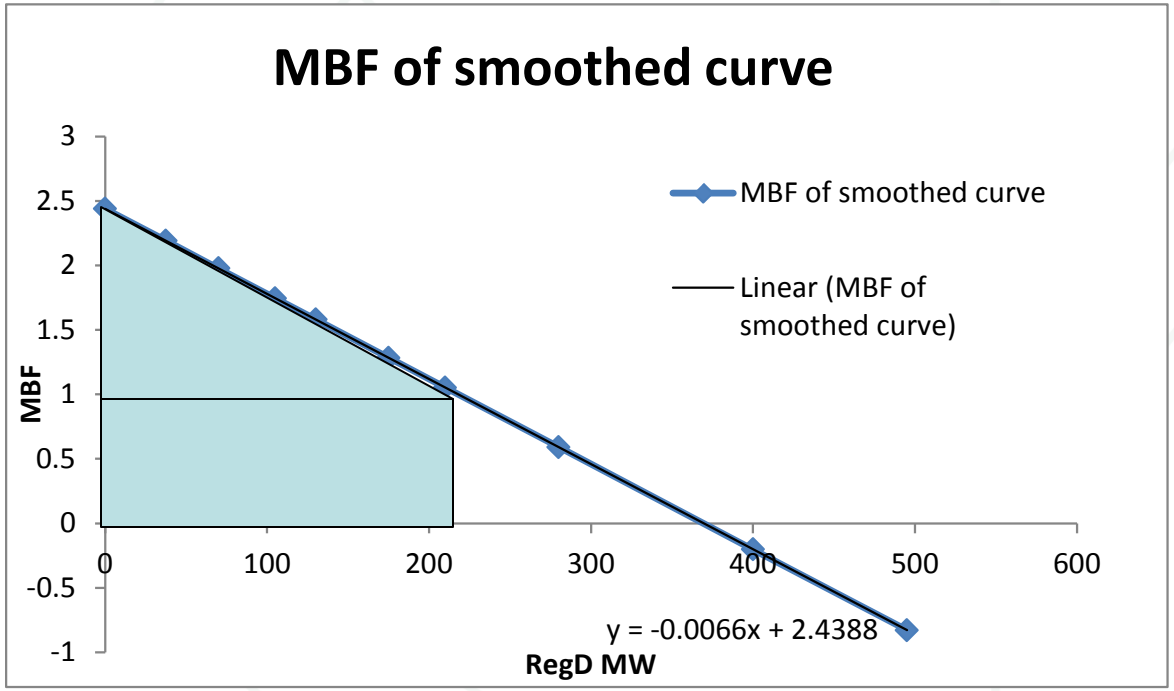
KEMA based combinations: MBF



- Effective MW from RegD = Area Under MBF Curve
- Works so long as MBF function defined in terms of discrete MW, not percentage.

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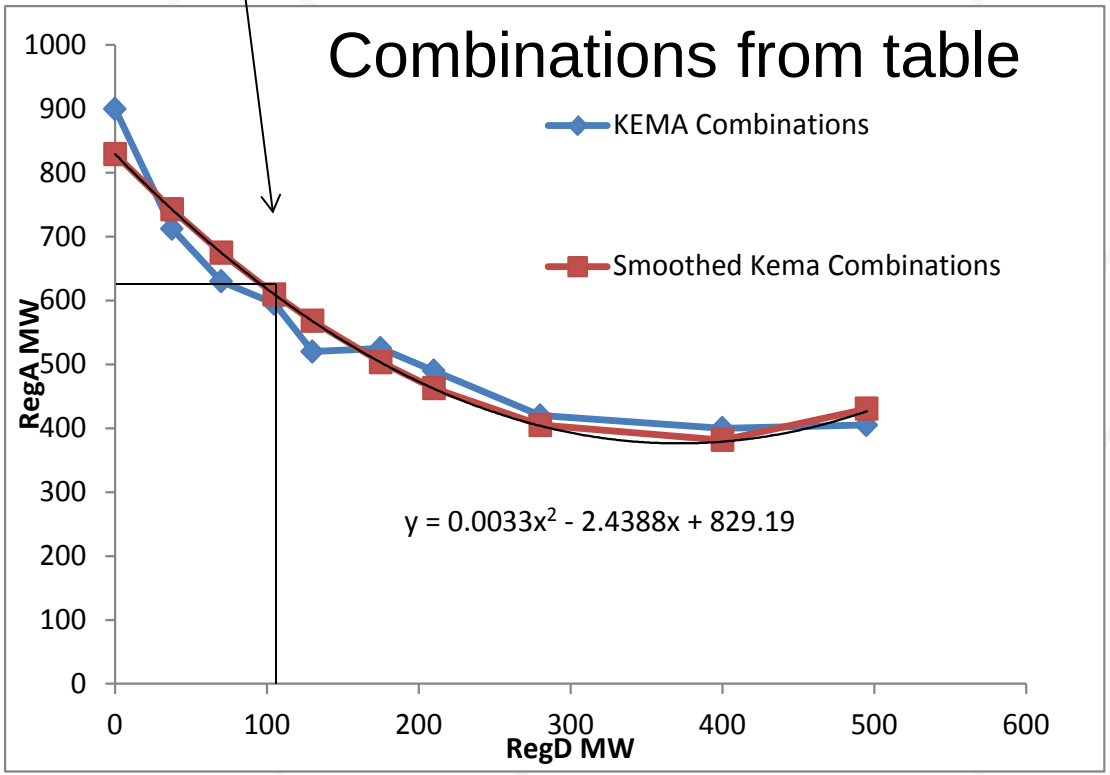
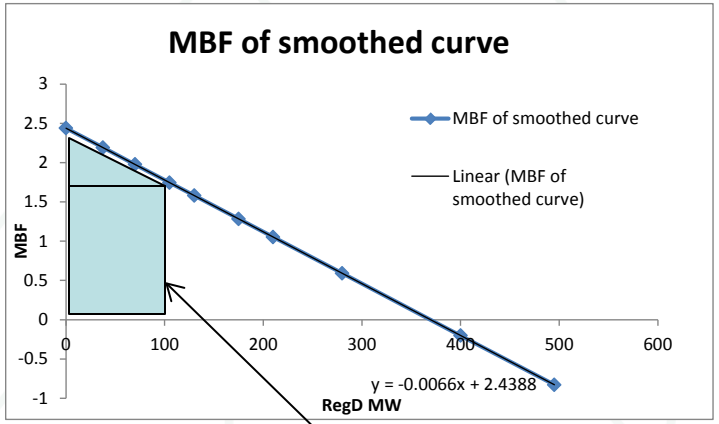
609.5 A, 105 D

KEMA based combinations





105 MW regD = 219.69 MW effective

829 MW – 219.69 = 609.5 RegA

Effective MW as area now works correctly.

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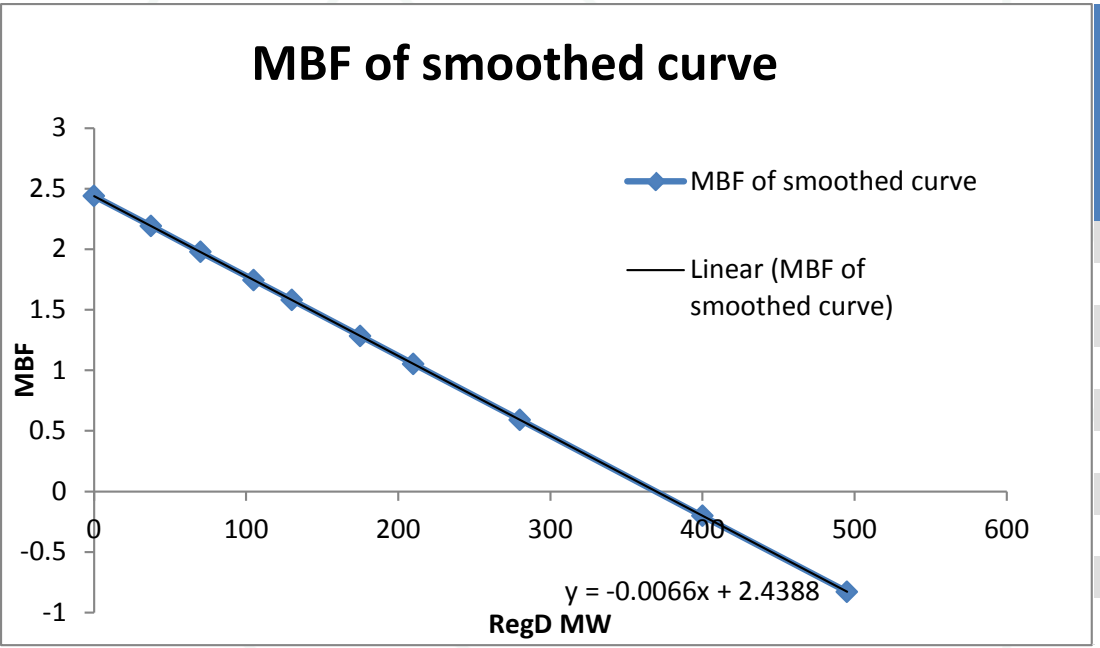
KEMA based combinations: MBF

Area under curve calculation

Results match curve



RegD MW	Smoothed Kema Combinations RegA	MBF of smoothed curve	Effective MW from RegD	Total effective MW
0	829.19	2.44	0.00	829.19
37.5	742.38	2.19	86.81	829.19
70	674.64	1.98	154.55	829.19
105	609.50	1.75	219.69	829.19
130	567.92	1.58	261.27	829.19
175	503.46	1.28	325.73	829.19
210	462.57	1.05	366.62	829.19
280	405.05	0.59	424.14	829.19
400	381.67	-0.20	447.52	829.19
495	430.57	-0.83	398.62	829.19

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Benefit Factor (MBF/BF): Consistent Application

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Marginal Benefit Factor is not uniformly applied in price and settlement

- **The Marginal Benefit Factor (MBF/BF) is not uniformly applied so that the valuation used in optimization process is consistent with the valuation used in settlement.**
- **MBF/BF used in price/offer conversion but not used in settlement.**
- **MBF/BF used to convert all offers to effective MW of RegA MW and $/effective MW of RegA.**

Inconsistent use of MBF: Effect of Current Design

- **Incorrectly compensating RegD in all hours**
  - **Sometimes too little (when MBF is >1)**
  - **Sometimes too much (when MBF is <1)**
- **Mileage multiplier distorts signal in all hours**
  - **RegD payment per MW slightly higher than RegA payments per MW**
    - Incentives to self schedule/price at zero
    - Inefficient squeezing out of RegA
      - Lowers regulation price per MW of RegA
    - Long term investment signals incorrect for RegA and RegD

Ideal Design: Consistent Application of MBF

- **Clearing price in terms of $/effective MW RegA**
- **Objective is to pay each resource for $/effective MW provided**
- **Price realized should be the same for each effective MW provided**

Components of Offers

- **Offers are composed of**
  - **Capability ($/MW)**
  - **PJM estimated LOC ($/MW)**
  - **performance ($/mile that is converted into $/MW)**
    - **$/Mile x historic mile/MW = $/MW**

- **Sum is $/MW reg offer.**
  - **Reg offer ($/MW) =capability ($/MW)+LOC ($/MW) + performance ($/MW)**

Example Offers

- **Sum is $/MW reg offer.**
  - **Reg offer ($/MW) =capability ($/MW)+LOC ($/MW) + performance ($/MW)**
- **Example offers:**
- **RegA offer:**
  - **$8/MW capability + ($1/mile) x 2mile/MW**
  - **= $8/MW + $2/MW = $10/MW**
- **RegD offer:**
  - **$6/MW capability +$1/mile x 4mile/MW**
  - **=$6/MW + $4/MW = $10/MW**

Example Offers: Conversion to Effective MW

- **Offers are converted into $/Effective MW**
- $\$/EffectiveMW = \frac{Offer}{Performance\%xBenefitFactor}$
- **$10 offer, 50% performance, 1 BF**
  - **1 MW offered providing 0.5 MW effective**
    - **$10/MW offer = $10/(50%x1)= $20/MW effective**
- **$10 offer, 100% performance, .5 BF**
  - **1 MW offered providing 0.5 effective**
  - **$10/MW offer = $10/(100% x 0.5) = $20/MW effective**

Conversion to offers to $/Effective MW

- **Prices in stack are provided in $/Effective MW**
- **Market Prices are set on the basis of $/Effective MW (marginal offer)**
- $\$/EffectiveMW = \frac{Offer}{Performance\%xBenefitFactor}$

Two Basic Components of Price

- **Marginal offer price is divided into two component pieces:**
- **Performance in $/effective MW**
  - **Set by most expensive effective MW based performance offer, whether part of the marginal offer or not**
- **Capability in $/effective MW**
  - **Capability price is determined as a residual (difference between total price and max performance price cleared stack)**

Settlement: Effect of Current Design

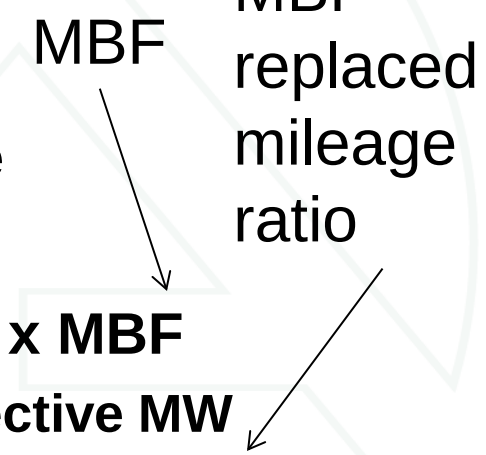
- **Clearing price in terms of $/Effective MW RegA**
- **Reg A Resource paid**
  - **$/Effective MW RegA for Capability**
  - **$/Effective MW RegA for Performance**
- **RegD Resources paid**
  - **RegA price for Capability x RegD MW**
  - **RegA price for Performance x RegD MW x Mile Ratio**

Depending on mileage rate, slight increase in payment to RegD, relative to RegA per MW.

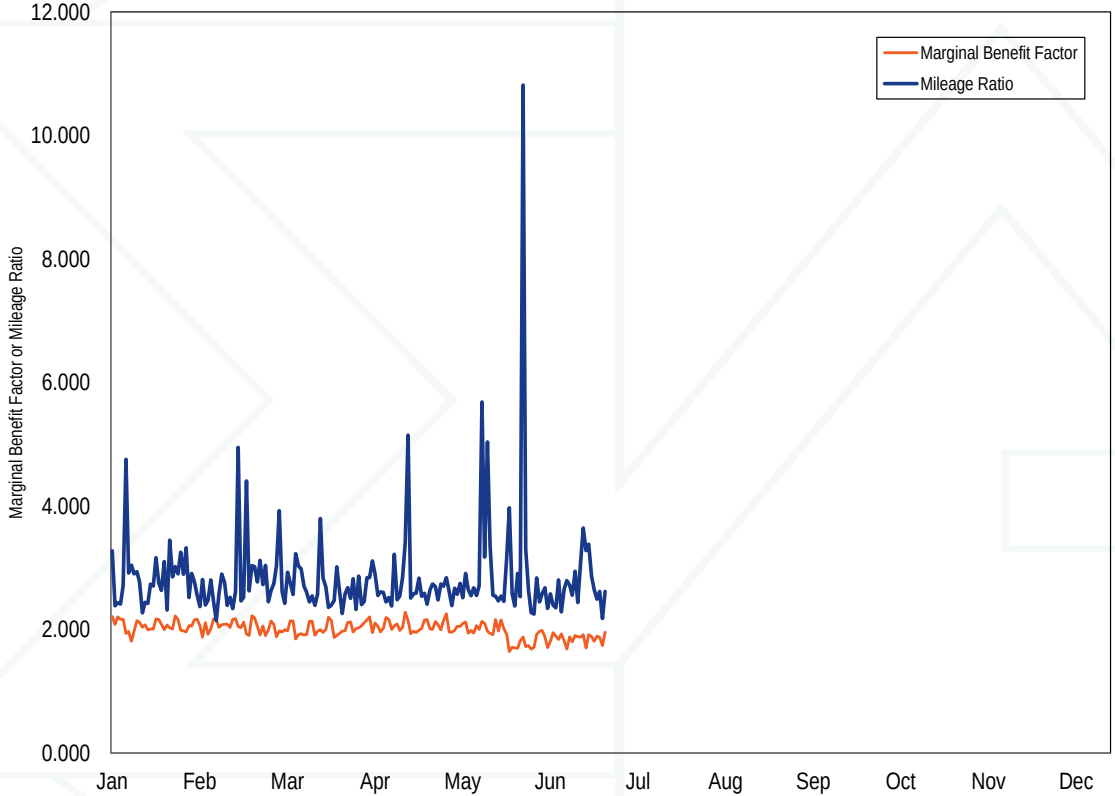
Note: Performance piece relative small portion of total price.

Ideal Design

- **Clearing price in terms of $/Effective MW RegA**
- **Reg A Resource paid**
  - **$/Effective MW RegA for Capability**
  - **$/Effective MW RegA for Performance**
- **RegD Resources paid**
  - **RegA price for Capability x RegD MW x MBF**
    - **Results in RegD paid in terms of $/Effective MW**
  - **RegA price for Performance x RegD MW x MBF**
    - **Results in RegD paid in terms of $/Effective MW**



MBF vs Mileage Ratio



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Effect of Current Design

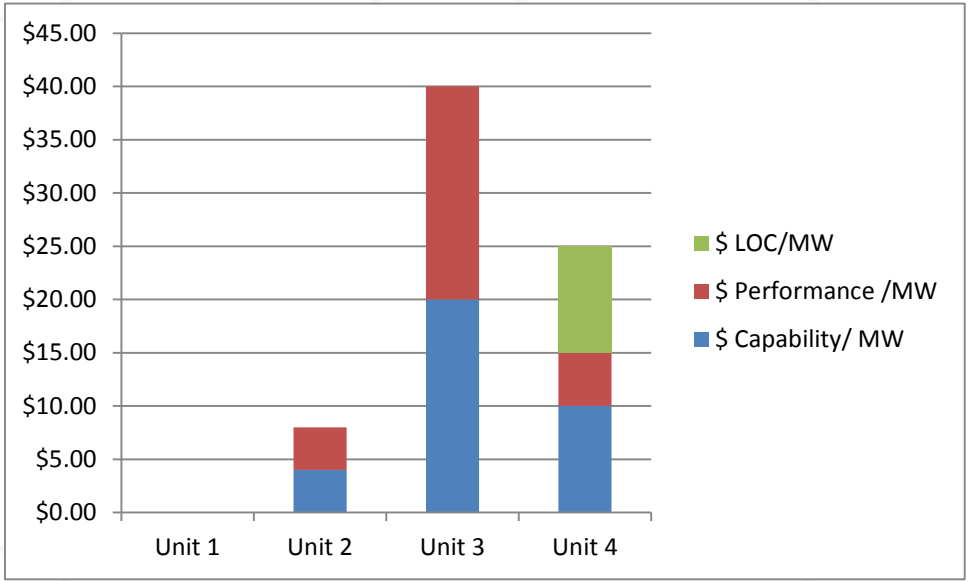
	Miles/MW
RegA	5
RegD	10
Mileage Ratio	2

Offer	$ Capability/ MW	$ Performance /MW	$ LOC/MW	Total Offer (Raw $/MW)	MW	RegA/RegD	BF	Modified Total Offer (Offer/BF)	Modified Performance Offer (offer/BF)	Effective MW	Regulation Requirement
Unit 1	$0.00	$0.00	$0.00	$0.00	10	RegD	2.8	$0.00	$0.00	29	300
Unit 2	$4.00	$4.00	$0.00	$8.00	10	RegD	2.6	$3.08	$1.54	28	300
Unit 3	$20.00	$20.00	$0.00	$40.00	10	RegD	2.5	$16.00	$8.00	27.5	300
Unit 4	$10.00	$5.00	$10.00	$25.00	300	RegA	1	$25.00	$5.00	300	300
									Total MW	384.5	300

Effect of Current Design

Offers

Offer	$ Capability/ MW	$ Performance /MW	$ LOC/MW	Total Offer (Raw $/MW)
Unit 1	$0.00	$0.00	$0.00	$0.00
Unit 2	$4.00	$4.00	$0.00	$8.00
Unit 3	$20.00	$20.00	$0.00	$40.00
Unit 4	$10.00	$5.00	$10.00	$25.00



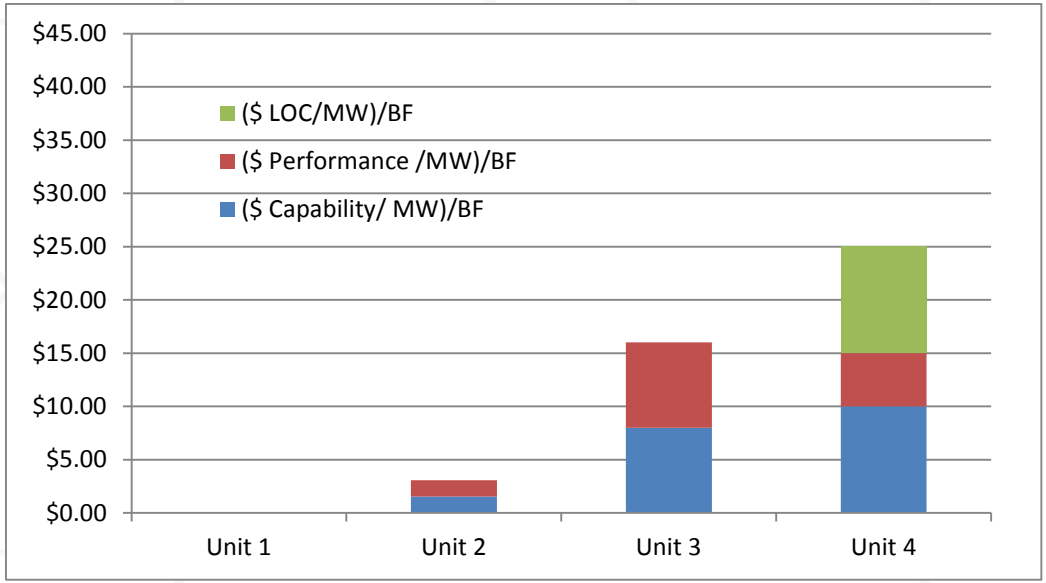
Monitoring Analytics

Effect of Current Design

BF Adjusted offers

Offer	$ Capability/ MW	$ Performance /MW	$ LOC/MW
Unit 1	$0.00	$0.00	$0.00
Unit 2	$4.00	$4.00	$0.00
Unit 3	$20.00	$20.00	$0.00
Unit 4	$10.00	$5.00	$10.00

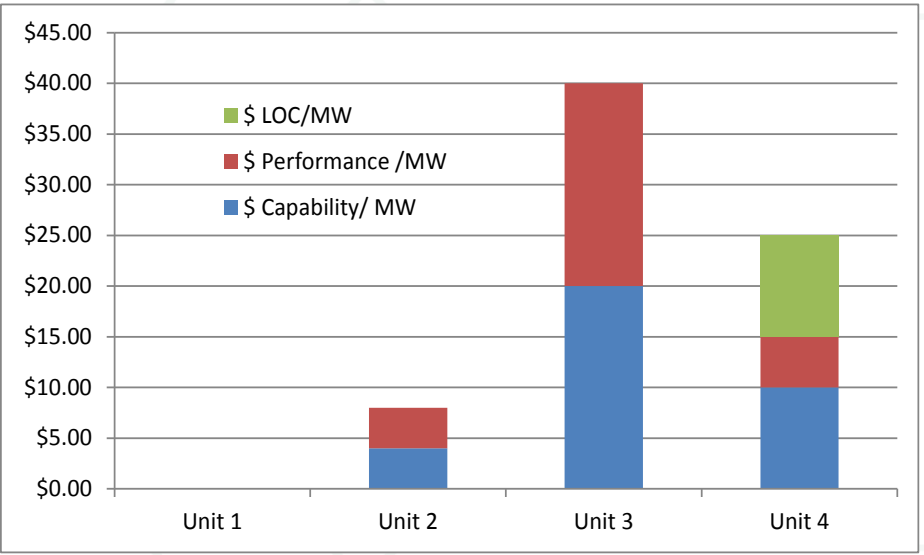
Offer	($ Capability/ MW)/BF	($ Performance /MW)/BF	($ LOC/MW) /BF
Unit 1	$0.00	$0.00	$0.00
Unit 2	$1.54	$1.54	$0.00
Unit 3	$8.00	$8.00	$0.00
Unit 4	$10.00	$5.00	$10.00



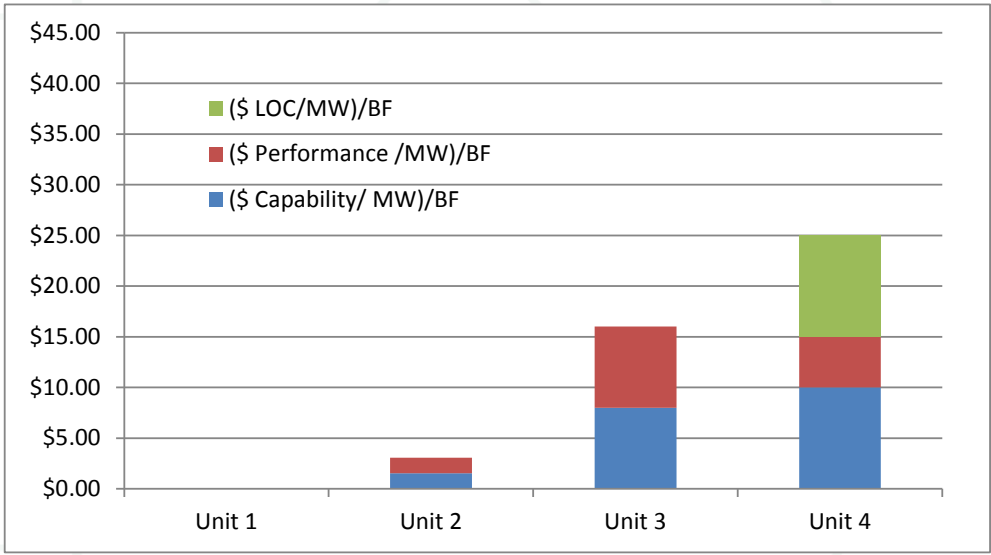
Monitoring Analytics

Effect of Current Design

No BF adjustment



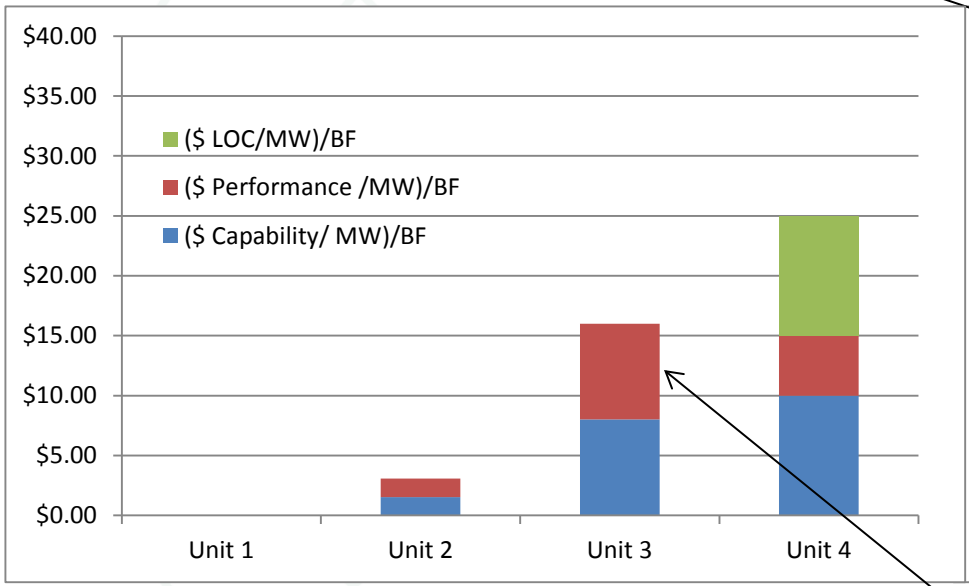
BF Adjusted

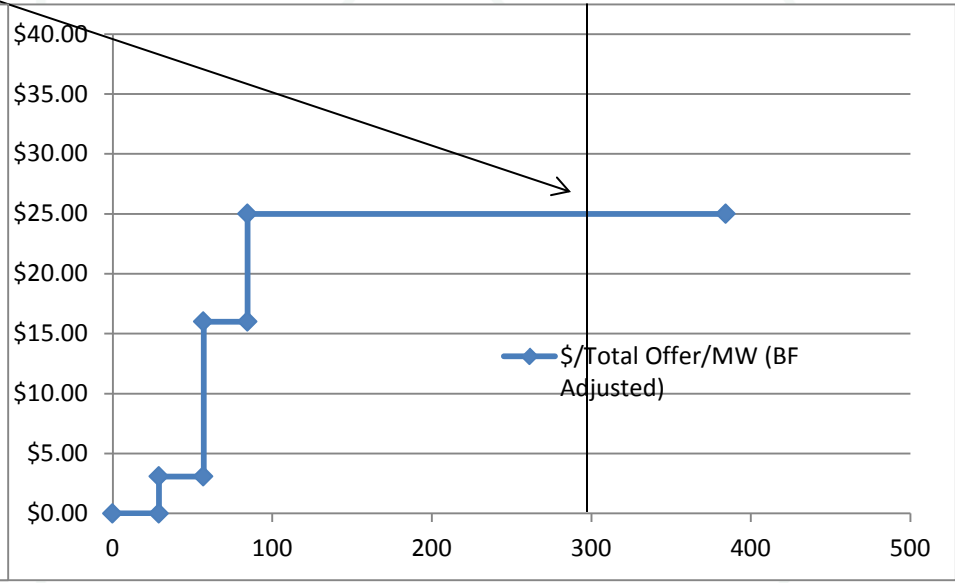


Monitoring Analytics

Effect of Current Design

Clearing price $/MW





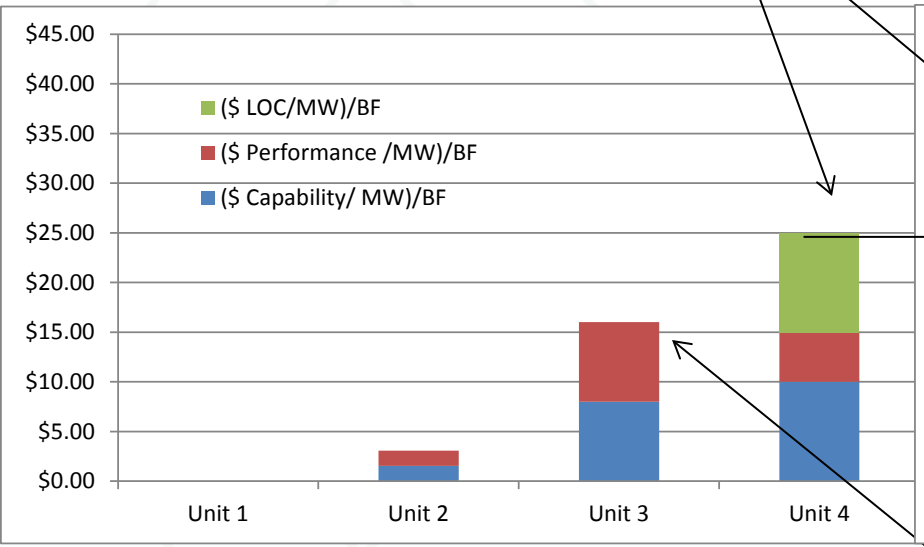
Performance price (biggest)

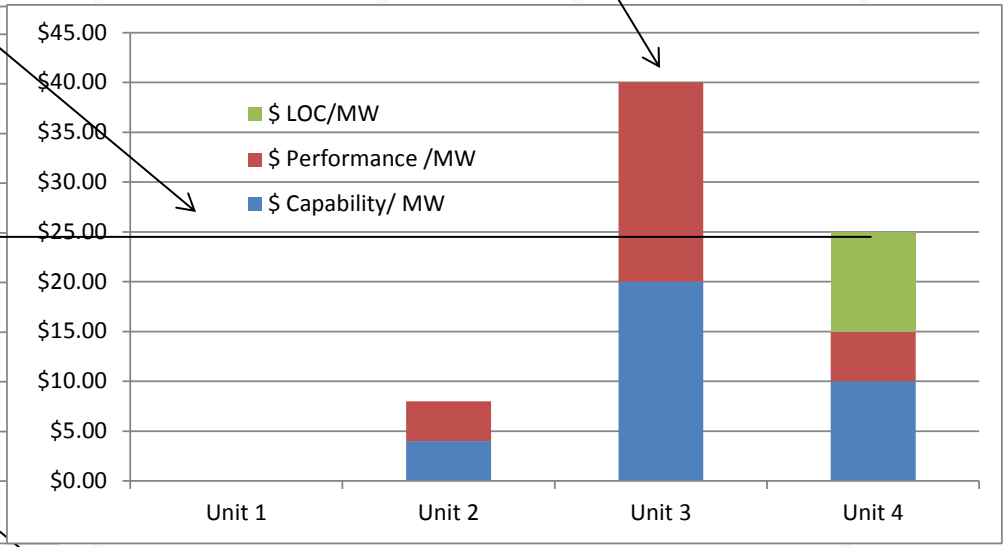
Monitoring Analytics

Settlement

Clearing price $/MW

Clearing price will not cover





Performance price (biggest)

Monitoring Analytics

Current Settlement: Mileage Ratio

Offer	$ Capability/ MW	$ Performance /MW	$ LOC/MW	Total Offer/MW	MW cleared	Total Cost of Offer
Unit 1	$0.00	$0.00	$0.00	$0.00	10.0	$0.00
Unit 2	$4.00	$4.00	$0.00	$8.00	10.0	$80.00
Unit 3	$20.00	$20.00	$0.00	$40.00	10.0	$400.00
Unit 4	$10.00	$5.00	$10.00	$25.00	215.5	$5,387.50

Offer	($ Capability/ MW)/BF	($ Performance /MW)/BF	($ LOC/MW) /BF	Clearing Price $/MW	Performance Clearing Price $/MW	Capability Price $/MW	Mileage Ratio	Capability Payment/ MW	Performance Payment/MW	Total Payment/MW	Total Payment	Total Profit
Unit 1	$0.00	$0.00	$0.00	$25.00	$8.00	$17.00	2.00	$17.00	$16.00	$33.00	$330.00	$330.00
Unit 2	$1.54	$1.54	$0.00	$25.00	$8.00	$17.00	2.00	$17.00	$16.00	$33.00	$330.00	$250.00
Unit 3	$8.00	$8.00	$0.00	$25.00	$8.00	$17.00	2.00	$17.00	$16.00	$33.00	$330.00	-$70.00
Unit 4	$10.00	$5.00	$10.00	$25.00	$8.00	$17.00	1.00	$17.00	$8.00	$25.00	$5,387.50	$0.00

- Higher payment for RegD per MW
- But payment inconsistent on effective MW basis.

Current Settlement: Mileage Ratio

Offer	($ Capability/ MW)/BF	($ Performance /MW)/BF	($ LOC/MW) /BF	Clearing Price $/MW	Performance Clearing Price $/MW	Capability Price $/MW	Total Payment/ MW	Total Payment	MBF	MW Cleared	Total Effective MW (at margin)	Effective Payment per Effective MW of RegA
Unit 1	$0.00	$0.00	$0.00	$25.00	$8.00	$17.00	$33.00	$330.00	2.50	10.00	25.00	$13.20
Unit 2	$1.54	$1.54	$0.00	$25.00	$8.00	$17.00	$33.00	$330.00	2.50	10.00	25.00	$13.20
Unit 3	$8.00	$8.00	$0.00	$25.00	$8.00	$17.00	$33.00	$330.00	2.50	10.00	25.00	$13.20
Unit 4	$10.00	$5.00	$10.00	$25.00	$8.00	$17.00	$25.00	$5,387.50	1.00	215.50	215.50	$25.00

- $/effective MW not equal across resource types
- Caused by failure to use BF/MBF consistently in market.
- Price provided in terms of $/Effective MW, needs to be settled in same terms.

Ideal Design

- Clearing price in terms of $/Effective MW RegA
- Objective is to pay each resource for $/effective MW provided
- Price realized should be the same for each effective MW provided
- Clearing price was $25 per effective MW
- RegA resources should realize $25 per effective MW
- RegD resources should realize $25 per effective MW

Ideal Design

- Clearing price in terms of $/Effective MW RegA
- Reg A Resource paid
  - $/Effective MW RegA for Capability
  - $/Effective MW RegA for Performance
- RegD Resources paid
  - RegA price for Capability x RegD MW x MBF
    - Results in RegD paid in terms of $/Effective MW
  - RegA price for Performance x RegD MW x MBF
    - Results in RegD paid in terms of $/Effective MW

Settlement

Current approach

Ideal

Offer	$ Capability/ MW	$ Performance /MW	$ LOC/MW	Total Offer/MW	MW cleared	Total Cost of Offer
Unit 1	$0.00	$0.00	$0.00	$0.00	10.0	$0.00
Unit 2	$4.00	$4.00	$0.00	$8.00	10.0	$80.00
Unit 3	$20.00	$20.00	$0.00	$40.00	10.0	$400.00
Unit 4	$10.00	$5.00	$10.00	$25.00	215.5	$5,387.50

Offer	($ Capability/ MW)/BF	($ Performance /MW)/BF	($ LOC/MW) /BF	Clearing Price $/MW	Performance Clearing Price $/MW	Capability Price $/MW	Mileage Ratio	Capability Payment/ MW	Performance Payment/MW	Total Payment/MW	Total Payment	Total Profit
Unit 1	$0.00	$0.00	$0.00	$25.00	$8.00	$17.00	2.00	$17.00	$16.00	$33.00	$330.00	$330.00
Unit 2	$1.54	$1.54	$0.00	$25.00	$8.00	$17.00	2.00	$17.00	$16.00	$33.00	$330.00	$250.00
Unit 3	$8.00	$8.00	$0.00	$25.00	$8.00	$17.00	2.00	$17.00	$16.00	$33.00	$330.00	-$70.00
Unit 4	$10.00	$5.00	$10.00	$25.00	$8.00	$17.00	1.00	$17.00	$8.00	$25.00	$5,387.50	$0.00

Offer	($ Capability/ MW)/BF	($ Performance /MW)/BF	($ LOC/MW) /BF	Clearing Price $/MW	Performance Clearing Price $/MW	Capability Price $/MW	MBF	Capability Payment/ MW	Performance Payment/MW	Total Payment/MW	Total Payment	Total Profit
Unit 1	$0.00	$0.00	$0.00	$25.00	$8.00	$17.00	2.50	$42.50	$20.00	$62.50	$625.00	$625.00
Unit 2	$1.54	$1.54	$0.00	$25.00	$8.00	$17.00	2.50	$42.50	$20.00	$62.50	$625.00	$545.00
Unit 3	$8.00	$8.00	$0.00	$25.00	$8.00	$17.00	2.50	$42.50	$20.00	$62.50	$625.00	$225.00
Unit 4	$10.00	$5.00	$10.00	$25.00	$8.00	$17.00	1.00	$17.00	$8.00	$25.00	$5,387.50	$0.00

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Current vs Proposed

Offer	($ Capability/ MW)/BF	($ Performance /MW)/BF	($ LOC/MW) /BF	Clearing Price $/MW	MW Provided	MBF	Effective MW provided at Margin	Total Payment Current Method	$/Effective MW Using Current Mileage Ratio Method	Total Payment MBF Adjusted Method	$/Effective MW Using Consistent Application of MBF
Unit 1	$0.00	$0.00	$0.00	$25.00	10.00	2.50	25.00	$330.00	$13.20	$625.00	$25.00
Unit 2	$1.54	$1.54	$0.00	$25.00	10.00	2.50	25.00	$330.00	$13.20	$625.00	$25.00
Unit 3	$8.00	$8.00	$0.00	$25.00	10.00	2.50	25.00	$330.00	$13.20	$625.00	$25.00
Unit 4	$10.00	$5.00	$10.00	$25.00	215.50	1.00	215.50	$5,387.50	$25.00	$5,387.50	$25.00

Current approach (payment varies on $/Effective MW basis)

Proposed Approach (same $/Effective)

LOC: Optimization/Market Clearing Issues

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Lost Opportunity Cost: LOC

- **LOC is intended to reflect:**
  - **The lost opportunity associated with foregone energy sales incurred when providing regulation service**
  - **Costs associated with operating uneconomically to provide regulation (regulation set point above economic point for energy)**
  - **Real costs from not following economic dispatch signal**

Lost Opportunity Cost: LOC

- **LOC is intended to make participant indifferent to providing regulation (outside of regulation related costs/offer)**
- **In optimization, intended to reflect incremental cost to using resource to provide regulation rather than energy.**
- **To align incremental cost to provide regulation and incremental cost in terms of energy, need to base off the operational offer in use.**

Lost Opportunity Cost: LOC

- **Regulation market does not use the operational energy offer.**
- **Uses the lower of cost or price.**

Lost Opportunity Cost: LOC

- **Where lower of price or cost <> operational offer**
  - **Internalized opportunity cost to provide regulation <> actual opportunity cost to provide regulation.**
  - **Reduced efficiency to market solution.**
  - **Artificial increase/decrease to regulation price when marginal incorrect LOC used.**
  - **Causes LOC under collection/over collection by resources depending on system conditions.**

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