California ISO

Briefing on flexible ramping product

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Demand Curve

- The flexible ramping product demand curve should represent the marginal value of flexible capacity
  – i.e. the marginal reduction in expected Power Balance Constraint violation costs from flexible capacity

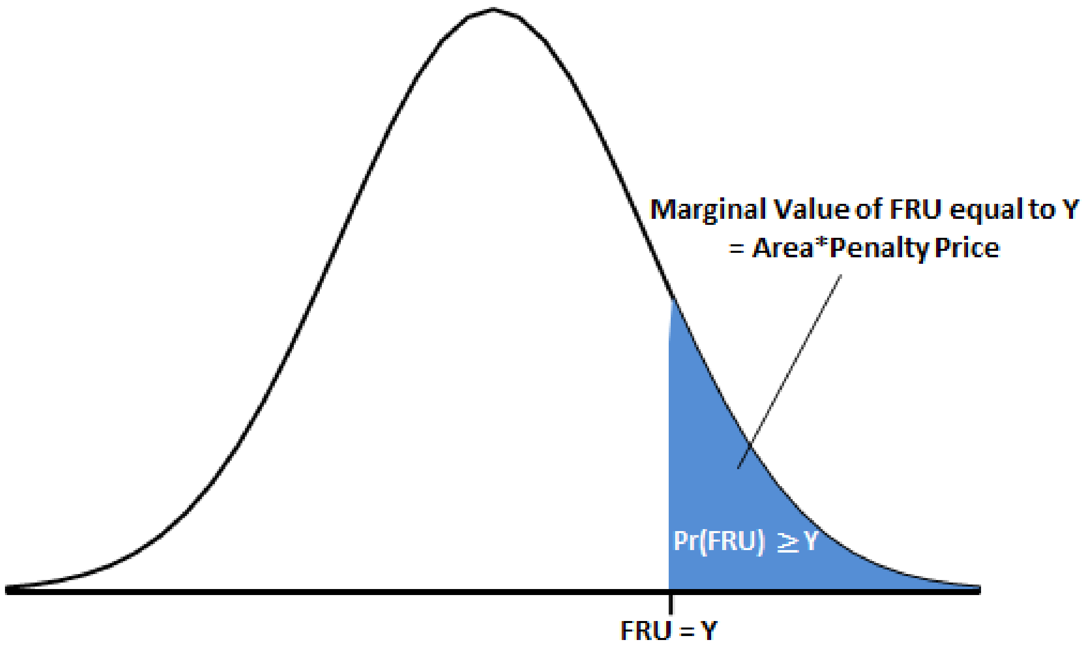
$$min\ Cost = \sum_{t=1}^{2} \sum_{i} MW_{i,t} * c(MW_{i,t}) + R_1^{short} * PC^{short} + R_2^{short} * PC^{short}$$

$$min\ Cost = \sum_{t=1}^{2} \sum_{i} MW_{i,t} * c(MW_{i,t}) + R_1^{short} * PC^{short} + \int_{-\infty}^{+\infty} PC^{short} * \max(0, \varepsilon_2 - Y_1^{up})\, P(\varepsilon_2) d\, \varepsilon_2$$

  – The flexible ramping up demand curve is the probability that the forecast error is greater than or equal to the amount of flexible ramping up capacity

$$\frac{\partial E[C(short)]}{\partial Y_1^{up}} = \int_{Y_1^{up}}^{+\infty} PC^{short} * P(\varepsilon_2) d\, \varepsilon_2$$

Depiction of Demand Curve Price at FRU Quantity



Expected PBC Violation Costs Given FRU Capacity (Discrete Probabilities)

- $PBC\ Violation\ Cost_i = Penalty * max(0\ ,\ Error_i - FRU\ Capacity)$
- $Expected\ PBC\ Violation\ Cost = \sum_i Penalty * (Error_i - FRU\ Capacity) * P_i$

Pr(Error=X)	6.25%	6.00%	5.75%	5.50%	5.25%	5.00%	4.50%	4.25%	4.00%	3.50%	Total Expected Cost	Change in Expected Cost
Error / Available Flexible Capacity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
0	$1,000	$2,000	$3,000	$4,000	$5,000	$6,000	$7,000	$8,000	$9,000	$10,000	$2,503	
1	$0	$1,000	$2,000	$3,000	$4,000	$5,000	$6,000	$7,000	$8,000	$9,000	$2,003	**$500.00**
2	$0	$0	$1,000	$2,000	$3,000	$4,000	$5,000	$6,000	$7,000	$8,000	$1,565	**$437.50**
3	$0	$0	$0	$1,000	$2,000	$3,000	$4,000	$5,000	$6,000	$7,000	$1,188	**$377.50**
4	$0	$0	$0	$0	$1,000	$2,000	$3,000	$4,000	$5,000	$6,000	$868	**$320.00**
5	$0	$0	$0	$0	$0	$1,000	$2,000	$3,000	$4,000	$5,000	$603	**$265.00**
6	$0	$0	$0	$0	$0	$0	$1,000	$2,000	$3,000	$4,000	$390	**$212.50**
7	$0	$0	$0	$0	$0	$0	$0	$1,000	$2,000	$3,000	$228	**$162.50**
8	$0	$0	$0	$0	$0	$0	$0	$0	$1,000	$2,000	$110	**$117.50**
9	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1,000	$35	**$75.00**
10	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$35.00**
Pr(E≥X)	50.00%	43.75%	37.75%	32.00%	26.50%	21.25%	16.25%	11.75%	7.50%	3.50%		
Pr(E≥X)*1,000	**$500.00**	**$437.50**	**$377.50**	**$320.00**	**$265.00**	**$212.50**	**$162.50**	**$117.50**	**$75.00**	**$35.00**		

Draft Technical Appendix Demand Curve Calculation

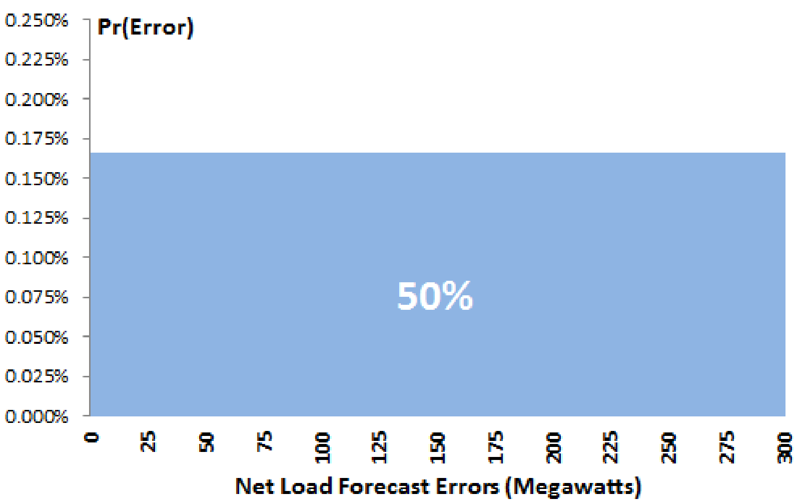
- Calculation in Draft Technical Appendix reduces to (Probability in Bin) * (Penalty Price)

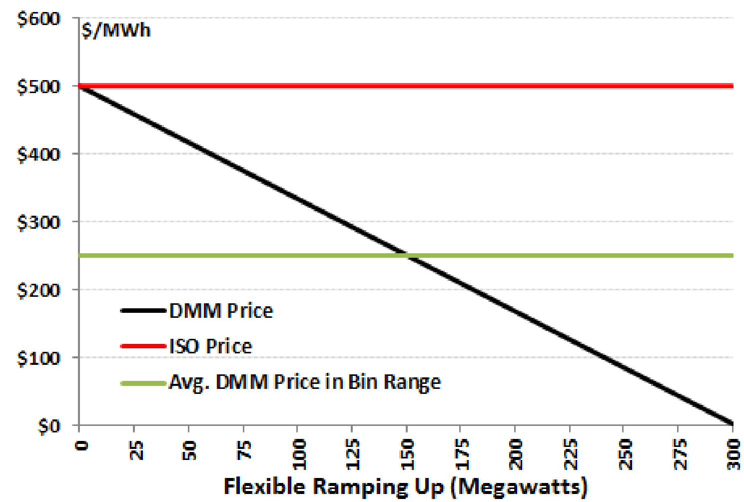
FRU	Surplus (MW)	Probability	Penalty ($/MWh)	Surplus Cost ($)	Surplus Incremental Cost ($/MWh)
	400	0.5	1,000	$\cancel{2200} + \cancel{100} \times 0.5 \times 1000 =$ 52,200	$(52200 - \cancel{2200}) / \cancel{100} =$ 500
	300	0.014	1,000	$\cancel{800} + \cancel{100} \times 0.014 \times 1000 =$ 2,200	$(2200 - \cancel{800}) / \cancel{100} =$ 14
	200	0.005	1,000	$\cancel{300} + \cancel{100} \times 0.005 \times 1000 =$ 800	$(800 - \cancel{300}) / \cancel{100} =$ 5
	100	0.003	1,000	$\cancel{100} \times 0.003 \times 1000 =$ 300	$(300 - 0) / \cancel{100} =$ 3
	0	0	1,000	0	

Table from pg. 16 of FRP Draft Technical Appendix

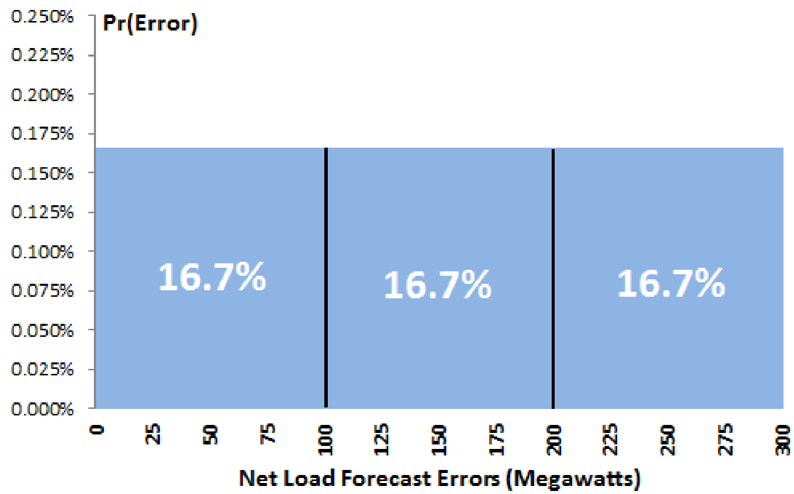
Demand Curves with Uniform Distribution of Errors

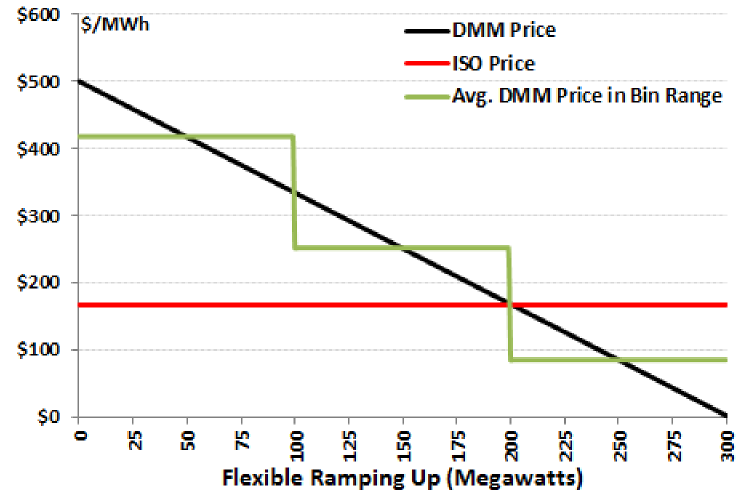
- ISO formulation dependent on histogram bins
  - Converges to zero as bins become more granular
- DMM formulation not dependent on bin choice when uniform distribution of errors
  - Bin choice can effect estimated probability that errors are greater than or equal to FRU capacity when distribution not uniform

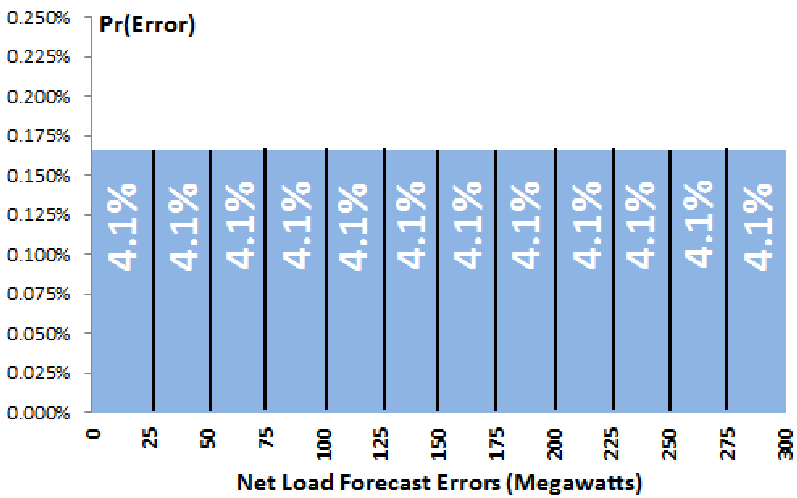


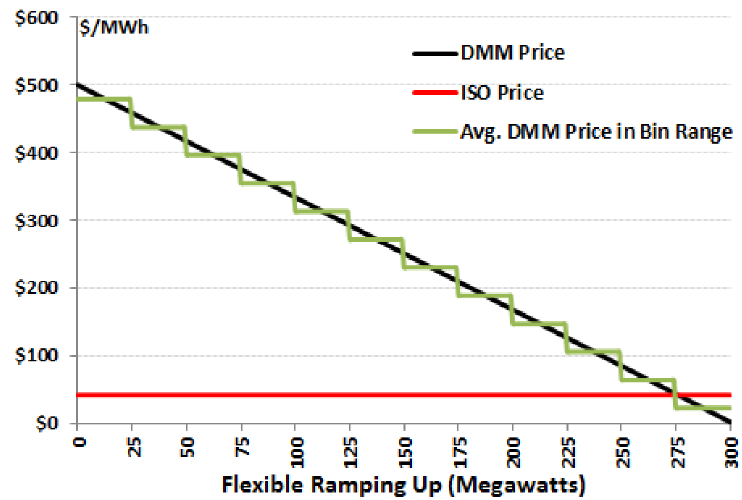


Demand Curves with Uniform Distribution of Errors









Proposal

- Change demand curve formulation to:

$$Price(FRU) = PC^{short} * \sum_i p_i \quad \forall\, p_i \; of \; \varepsilon_i \geq FRU \quad = \quad PC * \int_{EU_t - FRUS_t}^{EU_t} p_t(e)de$$

$$Price(FRD) = PC^{excess} * \sum_i p_i \quad \forall\, p_i \; of \; \varepsilon_i \leq FRD \quad = \quad PF * \int_{ED_t}^{ED_t - FRDS_t} p_t(e)de$$

- Change expected PBC violation cost functions in Draft Technical Appendix to:

$$CSU_t(FRUS_t) = PC^{short} * \int_{EU_t - FRUS_t}^{EU_t} \left(e - (EU_t - FRUS_t)\right) * p_t\,(e)de$$

$$CSD_t(FRDS_t) = PC^{excess} * \int_{ED_t}^{ED_t - FRDS_t} \left(e - (EU_t - FRDS_t)\right) * p_t\,(e)de$$