



California ISO

Day-ahead market enhancements discussion

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Principal

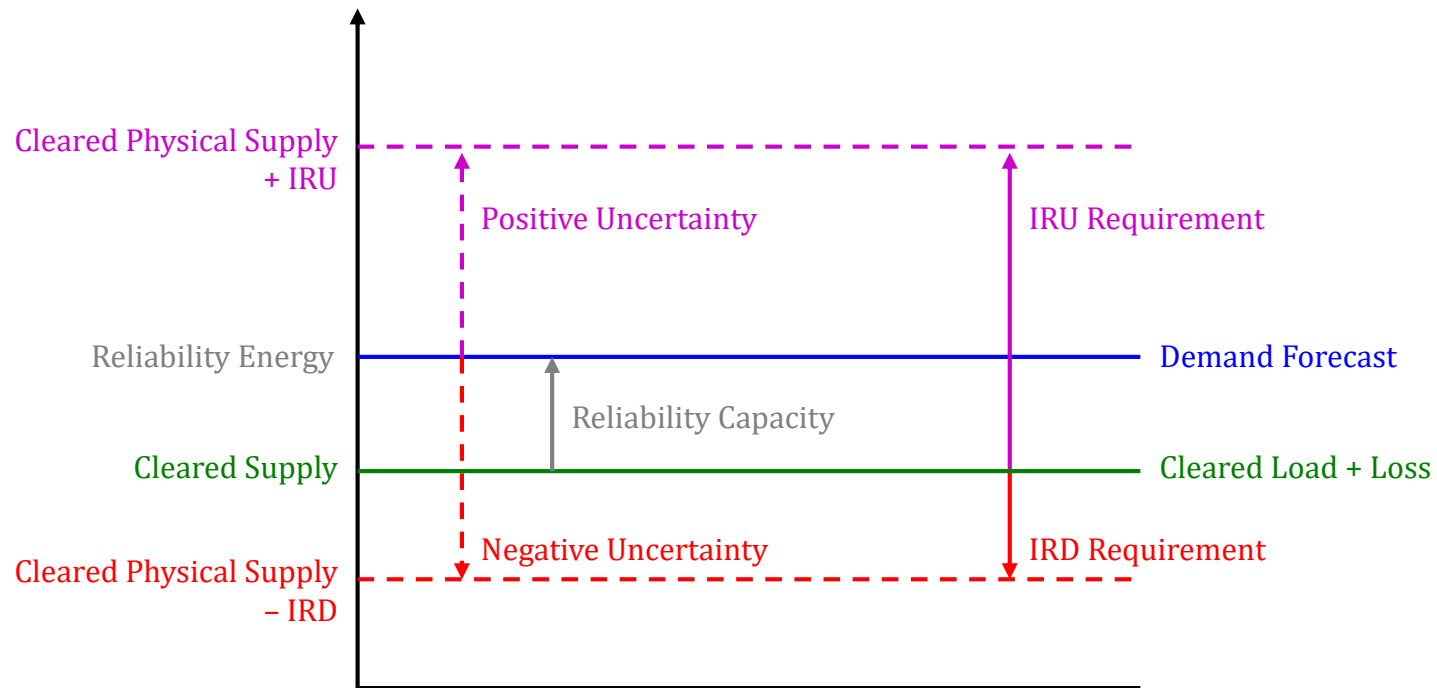
Power Systems Technology Development

Market Surveillance Committee Meeting

General Session

June 7, 2018

Day-ahead market targets



Power balance and Imbalance reserve procurement constraints

$$\sum_i EN_{i,t} + \sum_j EN_{j,t} = \sum_i L_{i,t} + \sum_j L_{j,t} + LOSS_t \quad \lambda$$

$$\sum_i EN_{i,t} + \sum_i IRU_{i,t} \geq D_t + IRUR_t \quad \rho$$

$$\sum_i EN_{i,t} - \sum_i IRD_{i,t} \leq D_t - IRDR_t \quad \sigma$$

i : physical resource index

j : Virtual resource index

Locational marginal price

- Physical Supply:
 - ◆ $LMP_i = \lambda + \rho + \sigma$
- Non-Participating Load and Virtual Supply/Demand
 - ◆ $LMP_j = \lambda$
- Imbalance Reserve Up capacity
 - ◆ $LMP_{IRU} = \rho$
- Imbalance Reserve Down capacity
 - ◆ $LMP_{IRD} = -\sigma$

Price simplification by bundling energy in the IRU/IRD awards

- Physical Supply, Non-Participating Load, and Virtual Supply/Demand:

- ◆ EN_i, EN_j, L_i, L_j ◆ $LMP_i = LMP_j = \lambda$

- Imbalance Reserve Up award

- ◆ $EN_i + IRU_i$ ◆ $LMP_{IRU} = \varrho$

- Imbalance Reserve Down award

- ◆ $EN_i - IRD_i$ ◆ $LMP_{IRD} = \sigma$

Deviation settlement between IRU/IRD and FRP

- IRU/IRD re-procured as Energy/FRU/FRD in RTM
- Bundle Energy in FRU/FRD awards internalizing Forecasted Movement

◆ Deviation settlement of movement/uncertainty across markets:

- $EN_i^{(DAM)} + IRU_i \rightarrow EN_i^{(FMM)} + FRU_i^{(FMM)} \rightarrow EN_i^{(RTD)} + FRU_i^{(FMD)}$
- $EN_i^{(DAM)} - IRD_i \rightarrow EN_i^{(FMM)} - FRD_i^{(FMM)} \rightarrow EN_i^{(RTD)} - FRD_i^{(RTD)}$

- Comprehensive cost allocation across markets

Cost allocation

■ Reliability Cost

- ◆ $RC = D - \sum_i EN_i$

- ◆ $\max(0, RC) \rho$

- Allocated to net negative demand deviation plus net virtual supply up to a user rate of ρ (existing tier-1 RUC cost allocation)

- ◆ $-\min(0, RC) \sigma$

- Allocated to net positive demand deviation plus net virtual demand up to a user rate of $-\sigma$ (tier-1)

- ◆ Remaining cost is allocated to metered demand (tier-2)

Cost allocation

■ Scheduled Movement cost

- ◆ $\left(EN_i^{(DAM)} - \max(0, RC) \right) \rho^{(DAM)} +$
 $\Delta EN_i^{(FMM)} \rho^{(FMM)} + \Delta EN_i^{(RTD)} \rho^{(RTD)} +$
 $\left(EN_i^{(DAM)} + \min(0, RC) \right) \sigma^{(DAM)} + \Delta EN_i^{(FMM)} \sigma^{(FMM)} +$
 $\Delta EN_i^{(RTD)} \sigma^{(RTD)}$
- ◆ Allocated to metered demand

Cost allocation

■ Upward uncertainty

- ◆ $IRU \rho^{(DAM)} + \Delta FRU \rho^{(FMM)} + \Delta FRU \rho^{(RTD)}$

- ◆ Allocated to upward uncertainty movement using existing FRU cost allocation

■ Downward uncertainty

- ◆ $-IRD \sigma^{(DAM)} - \Delta FRD \sigma^{(FMM)} - \Delta FRD \sigma^{(RTD)}$

- ◆ Allocated to downward uncertainty movement using existing FRD cost allocation

Excel solver example

California ISO	LOL (MW)	UOL (MW)	Ramp Rate (MW/min)	Energy Bid (\$/MWh)	IRU Bid (\$/MW)	IRD Bid (\$/MW)	Energy Schedule (MW)					IRU Award (MW)					IRD Award (MW)					
							0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	
Interval							0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	
G1	0	100	10	\$10	\$1	\$1	50	100	100	100	100	0	0	0	0	0	0	60	40	20	0	30
G2	0	100	10	\$20	\$2	\$2	50	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0
G3	0	100	10	\$30	\$3	\$3	50	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0
G4	0	100	10	\$40	\$4	\$4	50	0	0	0	0	0	50	70	90	80	0	0	0	0	0	0
VG5	0	100		\$35				70	70	70	70											
L1	0	140		\$60				140	140	140	140											
L2	0	230		\$50				230	230	230	230											
VL3	0	50		\$25				0	0	0	0											
Demand							340	360	380	370												
IRU Requirement												10	10	10	10							
IRD Requirement																	100	100	100	100	100	
Constraints																						
Objective Function				-\$44,490				-\$11,450	-\$11,450	-\$11,450	-\$11,450		\$200	\$280	\$360	\$320		\$60	\$40	\$20	\$30	
Power Balance								0	0	0	0											
IRU Procurement												0	0	0	0							
IRD Procurement																		0	0	0	0	
Shadow Prices																						
Power Balance								\$35	\$35	\$35	\$35											
IRU Procurement												\$4	\$4	\$4	\$4							
IRD Procurement																		-\$1	-\$1	-\$1	-\$1	
Settlement																						
G1								\$3,500	\$3,500	\$3,500	\$3,500		\$400	\$400	\$400	\$400		-\$40	-\$60	-\$80	-\$70	
G2								\$3,500	\$3,500	\$3,500	\$3,500		\$400	\$400	\$400	\$400		-\$100	-\$100	-\$100	-\$100	
G3								\$3,500	\$3,500	\$3,500	\$3,500		\$400	\$400	\$400	\$400		-\$100	-\$100	-\$100	-\$100	
G4								\$0	\$0	\$0	\$0		\$200	\$280	\$360	\$320		\$0	\$0	\$0	\$0	
VG5								\$2,450	\$2,450	\$2,450	\$2,450											
L1								-\$4,900	-\$4,900	-\$4,900	-\$4,900											
L2								-\$8,050	-\$8,050	-\$8,050	-\$8,050											
VL3								\$0	\$0	\$0	\$0											
Total								\$0	\$0	\$0	\$0		\$1,400	\$1,480	\$1,560	\$1,520		-\$240	-\$260	-\$280	-\$270	
Grand Total								\$0					\$5,960								-\$1,050	

Excel settlement spreadsheet

	IFM			FMM			RTD			Meter										
	Energy	Imbalance Reserve Up Uncertainty	Imbalance Reserve Down Uncertainty	Energy	Flexible Ramping Product Up	Flexible Ramping Product Down	Energy	Flexible Ramping Product Up	Flexible Ramping Product Down	Energy										
Awards / Schedule																				
Bid In Non-Participating Load	-1000	N/A	N/A	-1400	N/A	N/A	-1450	N/A	N/A	-1445										
Virtual Demand	-100	N/A	N/A	0	N/A	N/A	0	N/A	N/A	N/A										
Generator 1	200	400	0	600	100	0	650	80	0	655										
Generator 2	200	0	400	400	0	100	400	0	80	390										
Variable Energy Forecast	400	0	0	400	0	0	400	0	0	400										
Virtual Supply	300	N/A	N/A	0	N/A	N/A	0	N/A	N/A	N/A										
Check	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK										
Clearing Price	\$ 30.00	\$ 4.00	\$ (2.00)	\$ 35.00	\$ 2.00	\$ (1.00)	\$ 40.00	\$ 1.00	\$ (0.50)											
Convert to MWh Pricing for Interval	\$ 7.50	\$ 1.00	\$ (0.50)	\$ 8.75	\$ 0.50	\$ (0.25)	\$ 10.00	\$ 0.25	\$ (0.13)											
ISO Reliability Forecast	1115																			
Cleared Physical Supply	800																			
Reliability Forecast to FMM Uncertainty		300	300																	
FMM FRP Requirement		100	100				100	100												
RTD FRP Requirement		N/A	N/A				N/A	N/A												
	IFM			FMM			RTD			No Pay										
	Energy	Imbalance Reserve Up Energy Schedule	Imbalance Reserve Down Energy Schedule	Imbalance Reserve Up Uncertainty	Imbalance Reserve Down Uncertainty	Energy	Flexible Ramping Product Up Energy Schedule	Flexible Ramping Product Down Energy Schedule	Flexible Ramping Product Up Uncertainty	Flexible Ramping Product Down Uncertainty	Energy	Flexible Ramping Product Up Energy Schedule	Flexible Ramping Product Down Energy Schedule	Flexible Ramping Product Up	Flexible Ramping Product Down	Energy	Flexible Ramping Product Up No Pay	Flexible Ramping Product Down No Pay		
Bid In Non-Participating Load	\$ 7,500	N/A	N/A	N/A	N/A	\$ 3,500	N/A	N/A	N/A	N/A	\$ 500	N/A	N/A	N/A	N/A	\$ (50)	N/A	N/A		
Virtual Demand	\$ 750	N/A	N/A	N/A	N/A	\$ (875)	N/A	N/A	N/A	N/A	\$ -	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
Generator 1	\$ (1,500)	\$ (200)	\$ 100	\$ (400)	\$ -	\$ (3,500)	\$ (200)	\$ 100	\$ 150	\$ -	\$ (500)	\$ (13)	\$ 6	\$ 5	\$ -	\$ (50)	\$ 1	\$ -		
Generator 2	\$ (1,500)	\$ (200)	\$ 100	\$ -	\$ (200)	\$ (1,750)	\$ (100)	\$ -	\$ -	\$ 75	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 100	\$ -	\$ 1		
Variable Energy Forecast	\$ (3,000)	\$ (400)	\$ 200	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -		
Virtual Supply	\$ (2,250)	N/A	N/A	N/A	N/A	\$ 2,625	N/A	N/A	N/A	N/A	\$ -	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
Cost Allocation RUC Up	\$ 315	Allocated to Load and Net Virtual Supply																		
Cost Allocation RUC Down	\$ -	Allocated to Load and Net Virtual Demand																		
Cost Allocation Uncertainty Up	\$ 244	Allocated to IFM to FMM Uncertainty Movement																		
Cost Allocation Uncertainty Down	\$ 124	Allocated to IFM to FMM Uncertainty Movement																		
Cost Allocation Scheduled Movement	\$ 291	Allocated to Metered Demand																		
Total Cost Allocation	\$ 974																			