California ISO

Contingency modeling enhancements discussion

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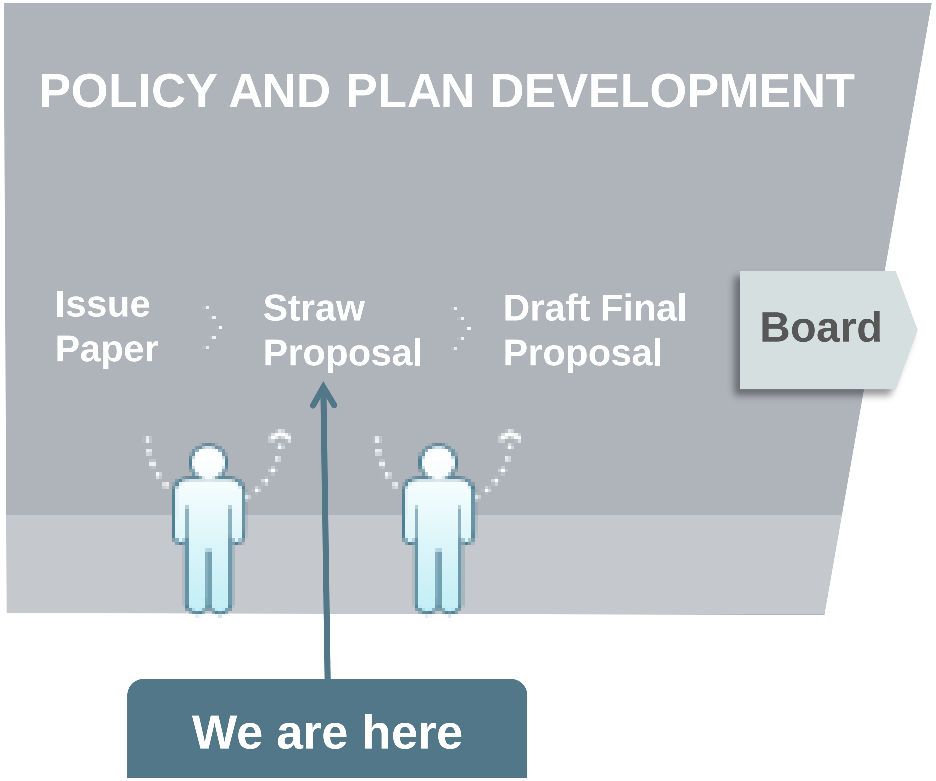
Market Surveillance Committee Meeting
General Session
December 11, 2015

Agenda

Time	Topic	Presenter
10:00 – 10:05	Introduction	Tom Cuccia
10:05 – 11:00	Background & Proposal	Perry Servedio
Updates from second revised straw proposal		
11:00 – 12:00	Congestion revenue & corrective capacity	Perry Servedio
1:00 – 2:00	CRR allocation enhancements for simultaneous feasibility	Perry Servedio
2:00 – 3:00	Settlement & no pay rules	Perry Servedio
3:00 – 3:15	Next Steps	Perry Servedio

ISO Policy Initiative Stakeholder Process



Background

- Initiative started in early 2013
- Positions available resources so that the ISO has sufficient capability to respond to contingency events impacting critical transmission facilities and return the system to a secure state within 30 minutes.
- Enhances the LMP formulation
- Creates a Locational Marginal Capacity Price (LMCP)
- Resources are paid for reserving the capacity at the LMCP
- Stakeholders requested we build a prototype to evaluate the market impact

Background

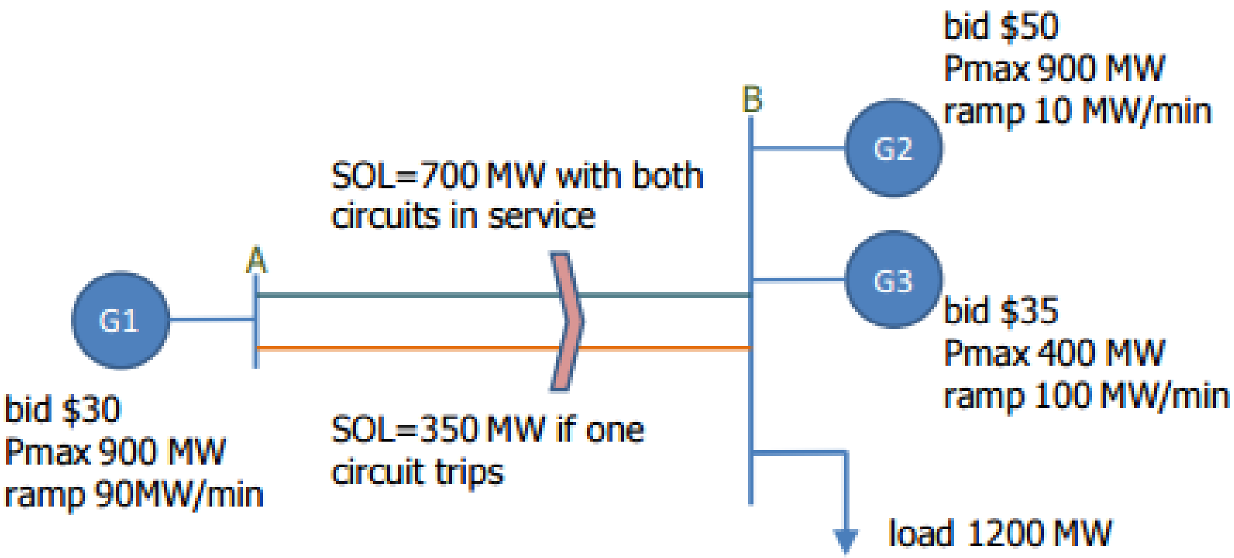
Transmission feasibility

- Meet N-1 criteria
- Meet N-1-1 criteria within 30 minutes

Today (weak preventive)	
Goal	Achieve transmission feasible dispatch.
Description	• Market dispatches for N-1 security. • ISO relies on out-of-market dispatch to achieve transmission feasibility.

Background

Today (weak preventive model)



Weak-preventive model energy in base case								
Generator	P^0	λ^0	SF^0_{AB}	μ^0_{AB}	LMP	Bid Cost	Revenue	Profit
G1	700	$50	1	-$20	$30	$21,000	$21,000	$0
G2	100	$50	0	-$20	$50	$5,000	$5,000	$0
G3	400	$50	0	-$20	$50	$14,000	$20,000	$6,000

Background

Tomorrow	
Goal	Achieve transmission feasible dispatch without relying on exceptional dispatch/MOC.

Option (strong preventive)	Option (preventive-corrective)
Enforce N-1-1 contingency as N-1.	Preventive-corrective model with procurement of corrective capacity.
• Transmission feasible. • No longer relies on ED/MOC. • Very restrictive.	• Transmission feasible. • No longer relies on ED/MOC. • Maximizes use of transmission.

What is CME?

Preventive-corrective LMP for energy dispatch at location i:

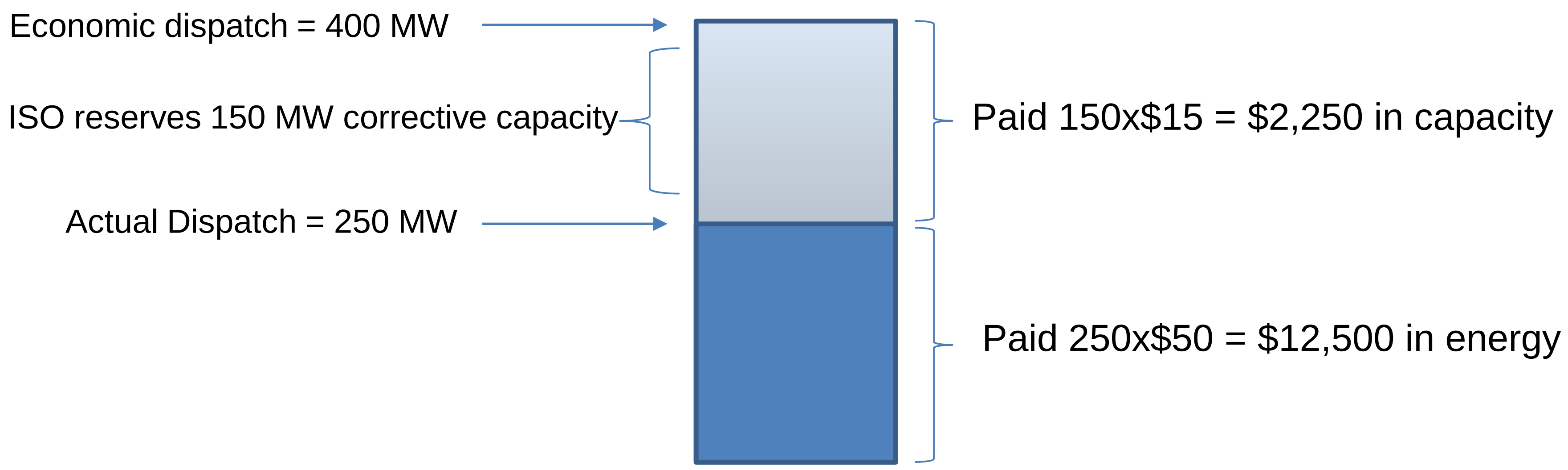
$$LMP_i = \lambda^0 + \sum_{k=0}^{K} \sum_{l=1}^{m} SF_{l,i}^{k} \cdot \mu_l^{k} + \sum_{kc=K+1}^{K+KC} \sum_{l=1}^{m} SF_{l,i}^{kc} \cdot \mu_l^{kc}$$

$$LMCP_i^{kc} = \lambda^{kc} + \sum_{l=1}^{m} SF_{l,i}^{kc} \cdot \mu_l^{kc}$$

What is CME?

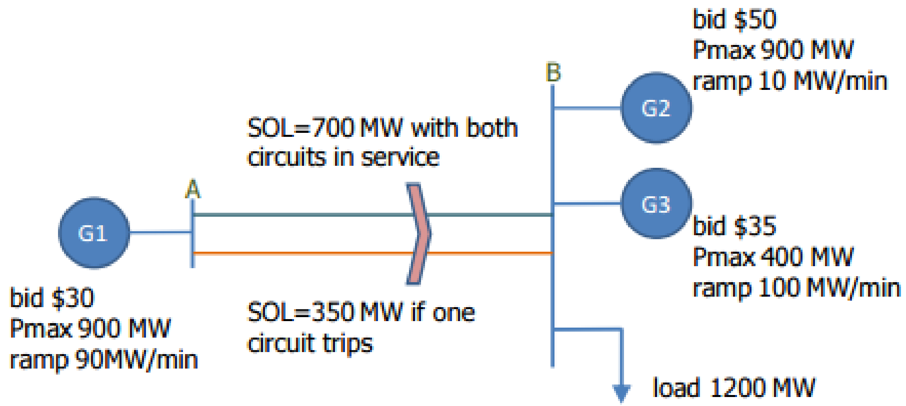
Resource paid for out-of-merit dispatch to reserve corrective capacity:

LMP = $50
Bid = 400 MW for $35



What is CME?

Tomorrow (preventive-corrective model)



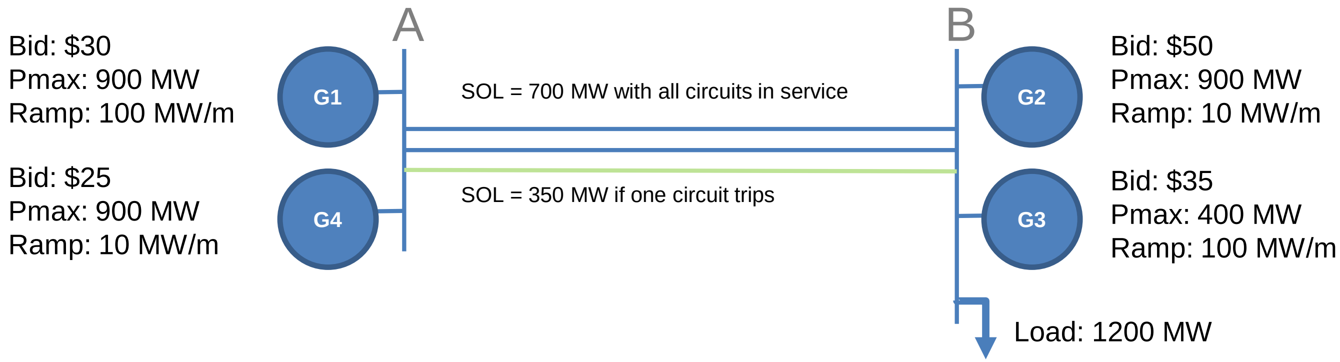
Weak-preventive model energy in base case								
Generator	P^0	λ^0	SF^0_{AB}	μ^0_{AB}	LMP	Bid Cost	Revenue	Profit
G1	700	$50	1	-$5	$30	$21,000	$21,000	$0
G2	250	$50	0	-$5	$50	$12,500	$12,500	$0
G3	250	$50	0	-$5	$50	$8,750	$12,500	$3,750

Corrective capacity in contingency kc=1								
Generator	ΔP^1	λ^1	SF^1_{AB}	μ^1_{AB}	$LMCP^1$	Bid Cost	Revenue	Profit
G1	-350	$15	1	$-15	$0	$0	$0	$0
G2	200	$15	0	$-15	$15	$0	$3,000	$3,000
G3	150	$15	0	$-15	$15	$0	$2,250	$2,250

What is CME?

Down capacity example: Today (weak preventive model)

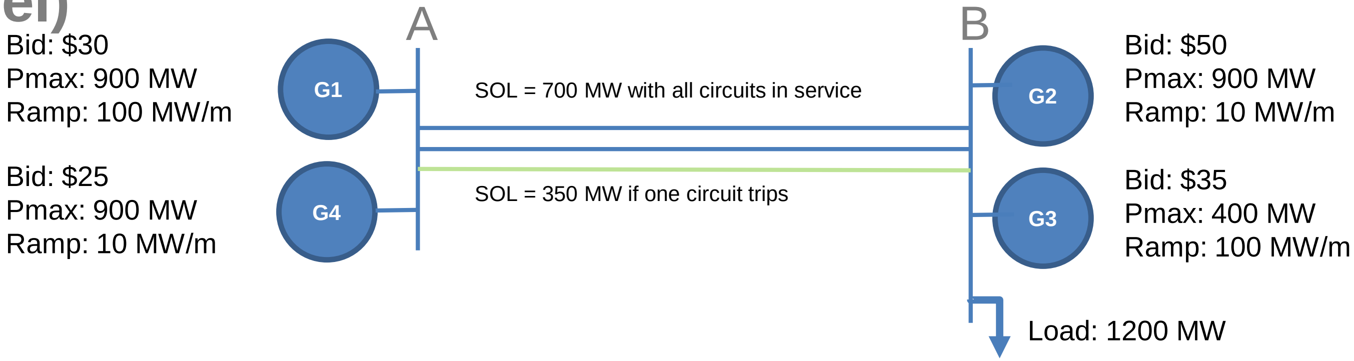
Introduce slow ramping marginal unit at A



Weak-preventive model energy in base case								
Generator	P^0	λ^0	SF^0_{AB}	μ^0_{AB}	LMP	Bid Cost	Revenue	Profit
G1	0	$50	1	-$25	$25	$0	$0	$0
G4	700	$50	1	-$25	$25	$17,500	$17,500	$0
G2	100	$50	0	-$25	$50	$5,000	$5,000	$0
G3	400	$50	0	-$25	$50	$14,000	$20,000	$6,000

What is CME?

Down capacity example: Tomorrow (preventive-corrective model)



Preventive-corrective model energy in base case								
Generator	P^0	λ^0	SF^0_{AB}	μ^0_{AB}	LMP	Bid Cost	Revenue	Profit
G1	150	$50	1	$-5	$25	$4,500	$3,750	-$750
G4	550	$50	1	$-5	$25	$13,750	$13,750	$0
G2	250	$50	0	$-5	$50	$12,500	$12,500	$0
G3	250	$50	0	$-5	$50	$8,750	$12,500	$3,750

Corrective capacity in contingency kc=1								
Generator	ΔP^1	λ^1	SF^1_{AB}	μ^1_{AB}	$LMCP^1$	Bid Cost	Revenue	Profit
G1	-150	$15	1	$-20	-$5	$0	$750	$750
G4	-200	$15	1	$-20	-$5	$0	$1,000	$1,000
G2	200	$15	0	$-20	$15	$0	$3,000	$3,000
G3	150	$15	0	$-20	$15	$0	$2,250	$2,250

Congestion Revenue & Corrective Capacity

Congestion Revenue & Corrective Capacity

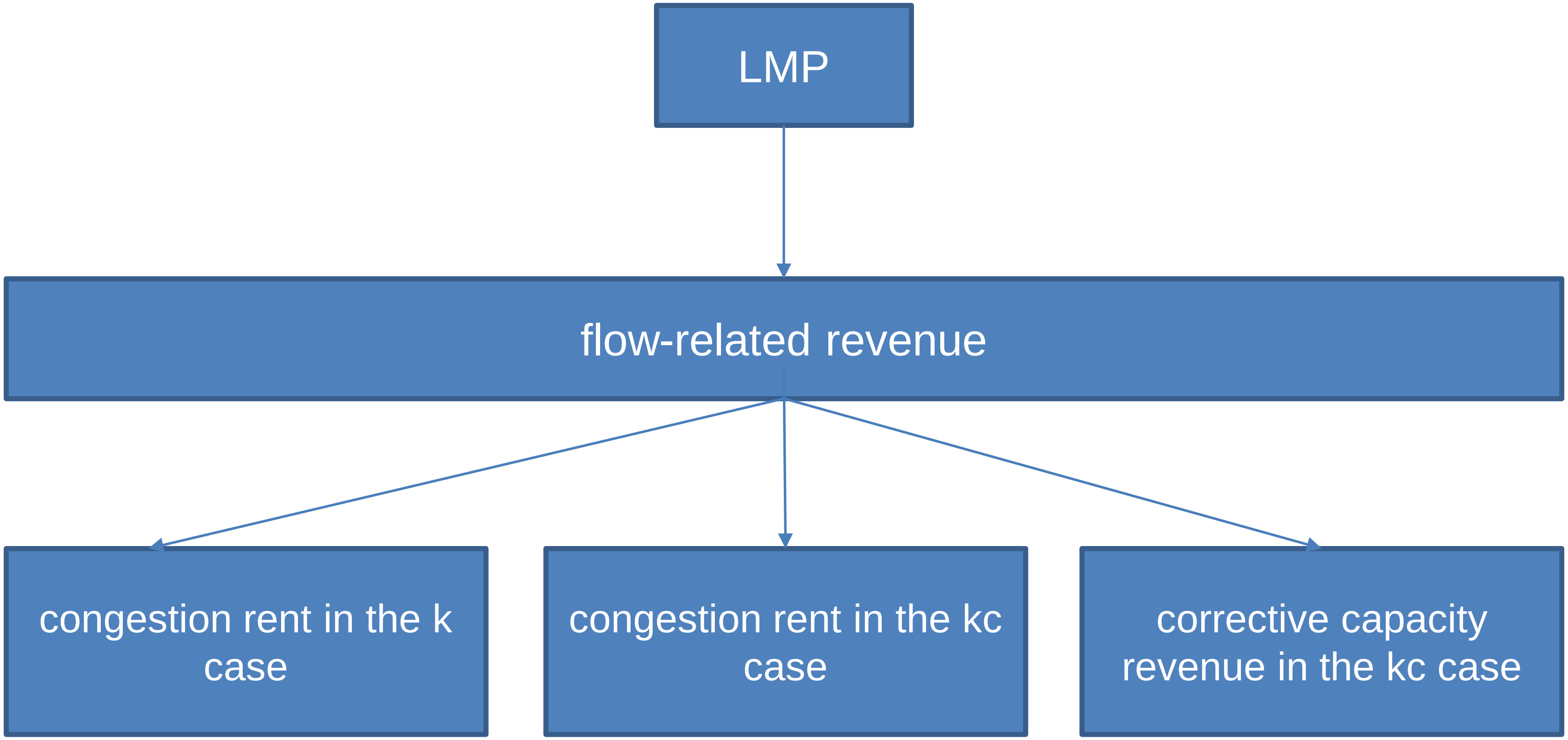
- Congestion costs on transmission paths are represented in the LMP when energy schedules cause transmission constraints to bind.
- Today, market creates a transmission infeasible dispatch
  - Any congestion shown due to N-1 constraint binding
- Operators take corrective action (ED) to restore transmission feasibility
  - Costs of ED are uplifted
- All CRRs are simultaneously feasible in the base case.
- All congestion revenues paid to CRR holders

Congestion Revenue & Corrective Capacity

Tomorrow	
Goal	Achieve transmission feasible dispatch without relying on exceptional dispatch/MOC.

Option (strong preventive)	Option (preventive-corrective)
Enforce N-1-1 contingency as N-1.	Preventive-corrective model with procurement of corrective capacity.
• Limit: 350 • All flow-related revenue collected = congestion rent	• Limit: 700 • CME Limit: 350 • Flow-related revenue collected = congestion rent + corrective capacity revenue
• Transmission feasible. • No longer relies on ED. • Very restrictive.	• Transmission feasible. • No longer relies on ED. • Maximizes use of transmission.

Congestion Revenue & Corrective Capacity



Congestion Revenue & Corrective Capacity

LMP's resulting revenue breaks into 3 components.

LMP_i flow related revenue =

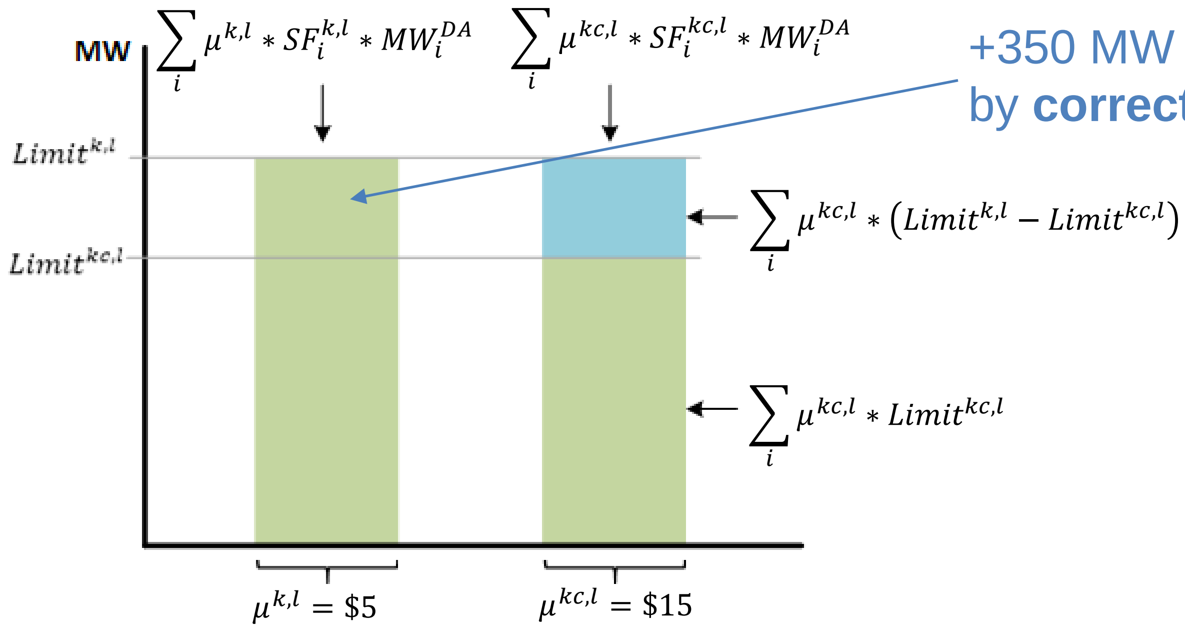
$$\sum_{k=0}^{K}\sum_{l=1}^{m}\left[\mu_l^{k*}\cdot F_l^{k,\max}\right]+\sum_{kc=K+1}^{KC}\sum_{l=1}^{m}\left[\mu_l^{kc*}\cdot F_l^{kc,\max}\right]-\sum_{kc=K+1}^{K+KC}\sum_{i}\left[\left(\lambda^{kc*}+\sum_{l=1}^{m}SF_{l,i}^{kc}\cdot\mu_l^{kc*}\right)\cdot\Delta P_i^{kc*}\right]$$

congestion rent collected

corrective capacity revenue collected

Congestion Revenue & Corrective Capacity

Congestion Rent from Energy Schedules



+350 MW of flow enabled by **corrective capacity**

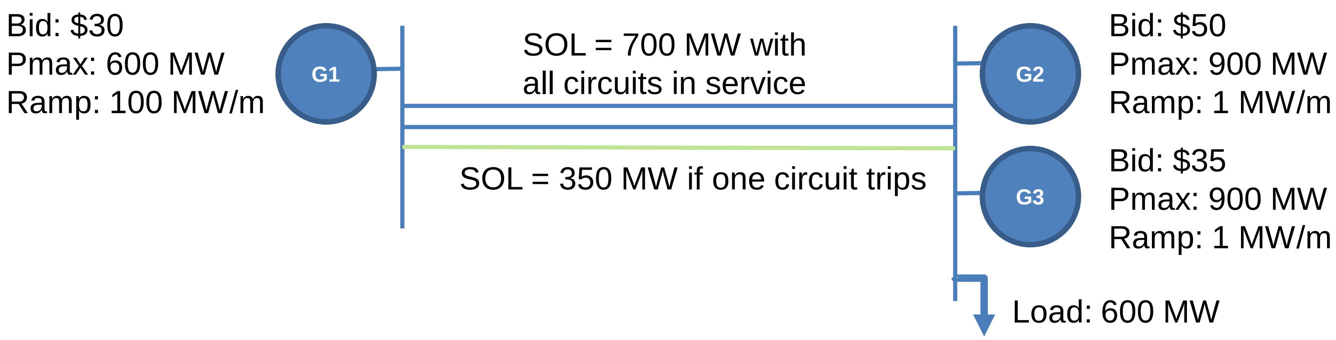
700MW*($5/MW) + 350MW*($15/MW) + 350MW*($15/MW) = $14,000

$3,500 + $5,250 + $5,250 = $14,000

No ED cost

Congestion Revenue & Corrective Capacity

Example: isolate congestion to kc case



Weak-preventive model energy in base case					
Generator	P^0	λ^0	SF^0_{AB}	μ^0_{AB}	LMP
G1	390	$35	1	$0	$30
G2	0	$35	0	$0	$35
G3	210	$35	0	$0	$35

Corrective capacity in contingency kc=1					
Generator	ΔP^1	λ^1	SF^1_{AB}	μ^1_{AB}	$LMCP^1$
G1	-40	$5	1	-$5	$0
G2	20	$5	0	-$5	$5
G3	20	$5	0	-$5	$5

Congestion Revenue & Corrective Capacity

Example: settlement

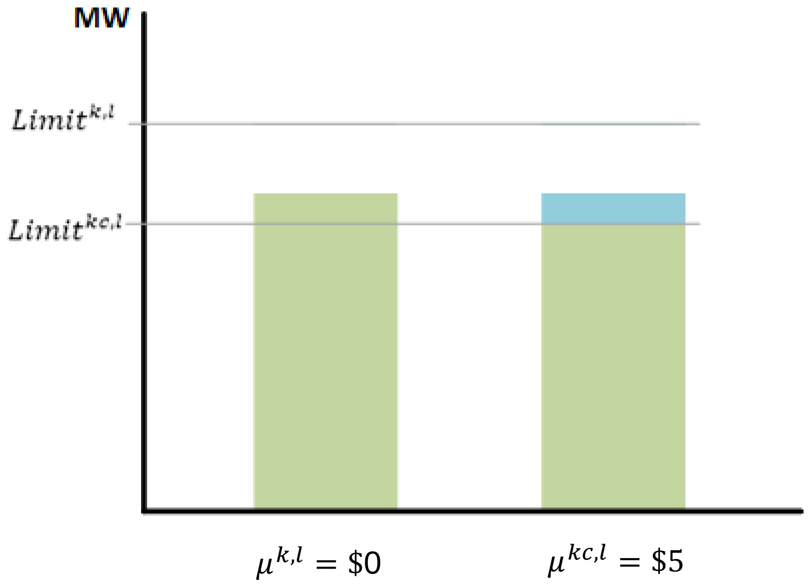
	Energy	LMP	Energy Revenue	Capacity	LMCP[1]	Capacity Revenues	Total Revenues
G1	390	$30	$11,700	-40	0	$0	$11,700
G2	0	$35	$0	20	$5	$100	$100
G3	210	$35	$7,350	20	$5	$100	$7,450
Total							$19,250
Load	600	$35					-$21,000

ISO collects $21,000
ISO pays $19,250

Revenue adequate w/
$1,750 in congestion

Congestion Revenue & Corrective Capacity

Congestion Rent from Energy Schedules



390MW*($0/MW) + 350MW*($5/MW) + 40MW*($5/MW) = $1,950

$0 + $1,750 + $200 = $1,950

Congestion Revenue & Corrective Capacity

Example: settlement w/ CRR

DAM Market Settlement							
	Energy	LMP	Energy Revenue	Capacity	LMCP[1]	Capacity Revenues	Total Revenues
G1	390	$30	$11,700	-40	0	$0	$11,700
G2	0	$35	$0	20	$5	$100	$100
G3	210	$35	$7,350	20	$5	$100	$7,450
Total							$19,250
Load	600	$35					-$21,000
CRR Settlement							
	MW Allocated	MCC_B-MCC_A					Total Revenues
CRR_{AB}	600	$5					$3,000

California ISO

CRR allocation enhancements for simultaneous feasibility

CRR Allocation Enhancements

Background

- Congestion rents collected in IFM
- Congestion rents from the corrective constraint fund the corrective capacity.
- CRR revenue inadequate because not feasible in the contingency case
- Must enhance CRR allocation to maintain revenue adequacy

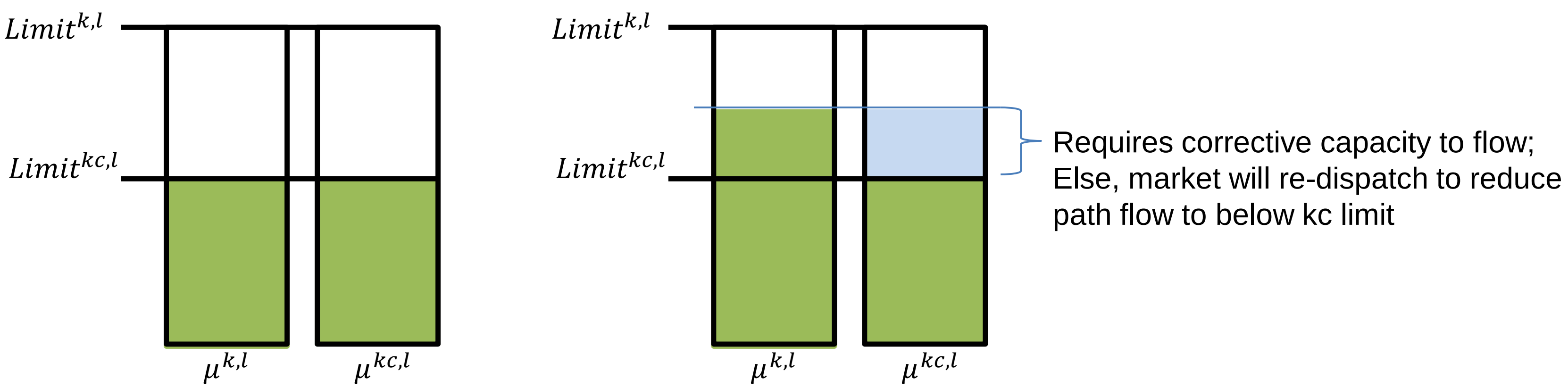
CRR Allocation Enhancements
Considerations

- Considered allocating CRRs up to the k limit (status quo)
  – Does not maintain revenue adequacy
  – Over allocates CRRs
- Considered only allocating CRRs up to the kc limit
  – Would maintain revenue adequacy
  – Overly restrictive

CRR Allocation Enhancements

Background

Flows over 350 MW on the path are enabled by corrective capacity.



CRR Allocation Enhancements

Proposal

- CRR allocation/auction performed same as today
- Define new type of CRR that mimics the effects on transmission flows of procuring corrective capacity for each corrective contingency that is only used in the contingency case (CCRRs).
- After each allocation/auction, ISO proposes to automatically allocate Contingency CRRs (CCRRs) to CRR holders

CRR Allocation Enhancements

CCRR Allocation

- Allocate CRRs that settle against the congestion components of the LMPs

CRRs allocated as today

- Allocate CCRRs for each corrective contingency that settle against the congestion components of the LMCPs for the given corrective contingency.

CCRRs allocated based on corrective contingency cases

CRR Allocation Enhancements

CCRR Allocation

The SFT evaluates whether:

- the transmission flows caused by scheduling injections and withdrawals corresponding to the CRRs result in transmission flows that are feasible for the base case as well as for the N-1 contingency cases, and
- for each corrective contingency, as a post-processing step, the CRR flow will be evaluated in the post-contingency case and any overload will result in pro-rata allocation of CCRRs

CRR Allocation Enhancements

CCRR Allocation

If total CRR flow is over the post-contingency limit in the post-contingency case, we allocate CCRRs which represent the corrective capacity flow, enabling the feasibility of the base case CRR.

$$\alpha = \max\left\{0, \frac{\sum_{p}\left(SF_{l,src(p)}^{kc} - SF_{l,snk(p)}^{kc}\right)\cdot CRR_{p} - F_{l}^{kc,\max}}{\sum_{p}\left(SF_{l,src(p)}^{kc} - SF_{l,snk(p)}^{kc}\right)\cdot CRR_{p}}\right\}$$

CRR Allocation Enhancements

CCRR Allocation Example

$$Limit^{k,l} = 700$$
$$Limit^{kc,l} = 350$$

Allocation					
Holder	**Flow k (A->B)**	**CRR MW Allocation**	**Flow kc (A->B)**	**α**	**CCRR MW Allocation**
SC1	800	800 A->B	800	0.50	400 B->A
SC2	200	200 A->B	200	0.50	100 B->A
SC3	-300	300 B->A	-300	0.50	150 A->B
Total	700	700	700		350

CRR Allocation Enhancements
CCRR Settlement

- CRRs are settled against the congestion components of the LMPs

$$CRR\ Payment = CRR\ MW_{AB}\ \times \left(MCC_B^k - MCC_A^k + MCC_B^{kc} - MCC_A^{kc}\right)$$

- CCRRs are settled against the congestion components of the LMCPs for the corrective contingencies

$$CCRR\ Payment_{BA} = CCRR\ MW_{BA}\ \times \left(MCC_A^{kc} - MCC_B^{kc}\right)$$

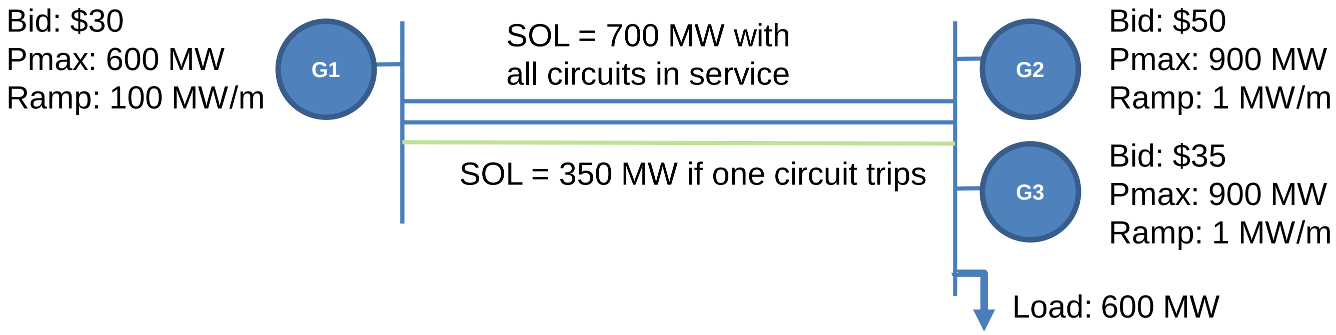
CRR Allocation Enhancements
CCRR Settlement Example

Allocation					
Holder	Flow k (A->B)	CRR MW Allocation	Flow kc (A->B)	α	CCRR MW Allocation
SC1	800	800 A->B	800	0.50	400 B->A
SC2	200	200 A->B	200	0.50	100 B->A
SC3	-300	300 B->A	-300	0.50	150 A->B
Total	700	700	700		350

Settlement			
Holder	CRR Payment	CCRR Payment	Total Payment
SC1	(800)($20)=$16,000	(-400)($15)=-$6,000	$10,000
SC2	(200)($20)=$4,000	(-100)($15)=-$1,500	$2,500
SC3	(-300)($20)=-$6,000	(150)($15)=$2,250	($3,750)
Total	$14,000	($5,250)	$8,750

CRR Allocation Enhancements

Example: isolate congestion to kc case



Weak-preventive model energy in base case					
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G3	210	$35	0	$0	$35

Corrective capacity in contingency kc=1					
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G1	-40	$5	1	-$5	$0
G2	20	$5	0	-$5	$5
G3	20	$5	0	-$5	$5

CRR Allocation Enhancements
Example: settlement w/ CRR & CCRR

DAM Market Settlement							
	Energy	LMP	Energy Revenue	Capacity	LMCP[1]	Capacity Revenues	Total Revenues
G1	390	$30	$11,700	-40	0	$0	$11,700
G2	0	$35	$0	20	$5	$100	$100
G3	210	$35	$7,350	20	$5	$100	$7,450
Total							$19,250
Load	600	$35					-$21,000
CRR Settlement							
	MW Allocated	$MCC_B^k - MCC_A^k + MCC_B^{kc} - MCC_A^{kc}$		$MCC_A^{kc} - MCC_B^{kc}$			Total Revenues
CRR_{AB}	600	$5					$3,000
$CCRR_{BA}$	250			-$5			-$1,250

CRR Allocation Enhancements

Extend example showing ownership interests

What if you owned G1 and the load at node B?

BigCorp

- Owns 600 MW G1 at node A.
- Owns 600 MW of load at node B.
- Is allocated 600 MW of CRR from A to B.

How does this settle?

Does BigCorp pay for corrective capacity more than once?

CRR Allocation Enhancements

Extend example showing ownership interests

DAM Market Settlement							
	Energy	LMP	Energy Revenue	Capacity	LMCP[1]	Capacity Revenues	Total Revenues
G1	390	$30	$11,700	-40	0	$0	$11,700
G2	0	$35	$0	20	$5	$100	$100
G3	210	$35	$7,350	20	$5	$100	$7,450
Load	600	$35					-$21,000
CRR Settlement							
	MW Allocated	$MCC_B^k - MCC_A^k + MCC_B^{kc} - MCC_A^{kc}$		$MCC_A^{kc} - MCC_B^{kc}$			Total Revenues
CRR_{AB}	600	$5					$3,000
$CCRR_{BA}$	250			-$5			-$1,250

BigCorp outflows = $21,000 for load
BigCorp in-flows = $11,700 for G1

-$9,300

CRR adjustments (in-flows) = $1,750

-$7,550 ← **net outflows; who receives this money?**

CRR Allocation Enhancements

Extend example showing ownership interests

BigCorp pays out net $7,550

G2 receives $100 for corrective capacity

G3 receives $7,350 for energy

G3 receives $100 for corrective capacity

Total = $7,550

BigCorp pays for energy at the node and corrective capacity at the node.

Corrective Capacity Settlement & No Pay Rules

Corrective Capacity Settlement & No Pay Rules

Settlement

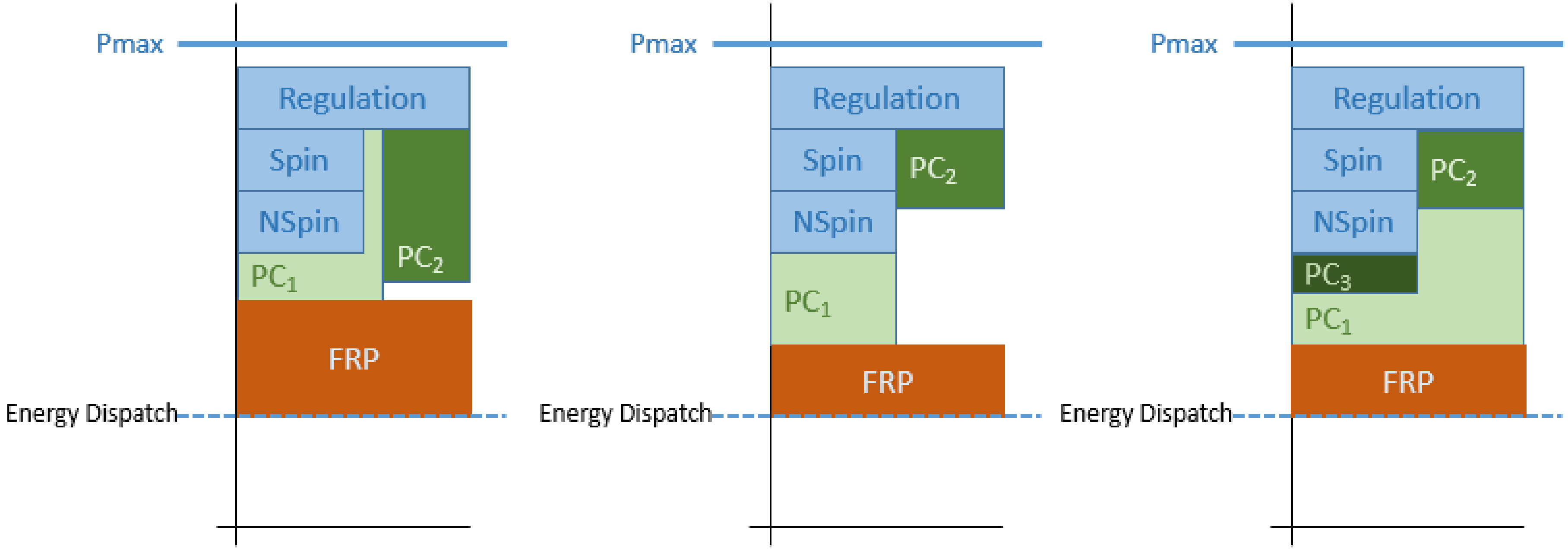
- Day-ahead market settled
- Fifteen minute market re-optimized (buy backs or more procurement)
- Five minute market re-optimized (buy backs or more procurement)

Awarded corrective capacity MW x LMCP

Corrective Capacity Settlement & No Pay Rules

Services procured

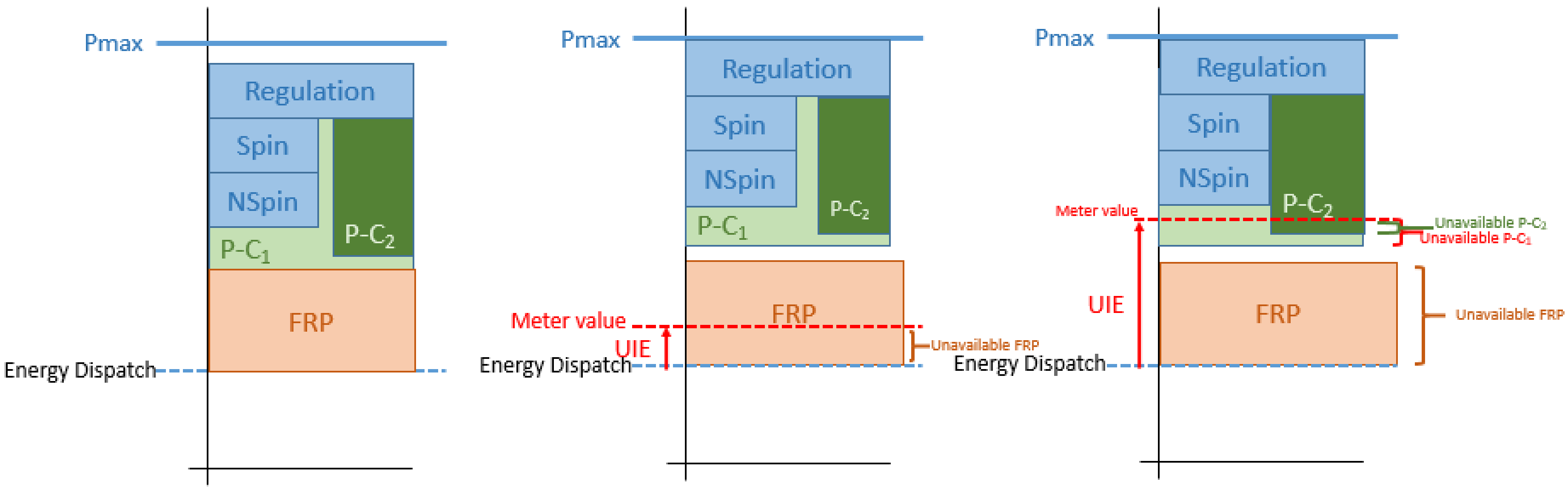
- Corrective capacity can overlap A/S
- Corrective capacity can be independent from A/S
- Corrective capacity does not overlap FRP



Corrective Capacity Settlement & No Pay Rules

No Pay

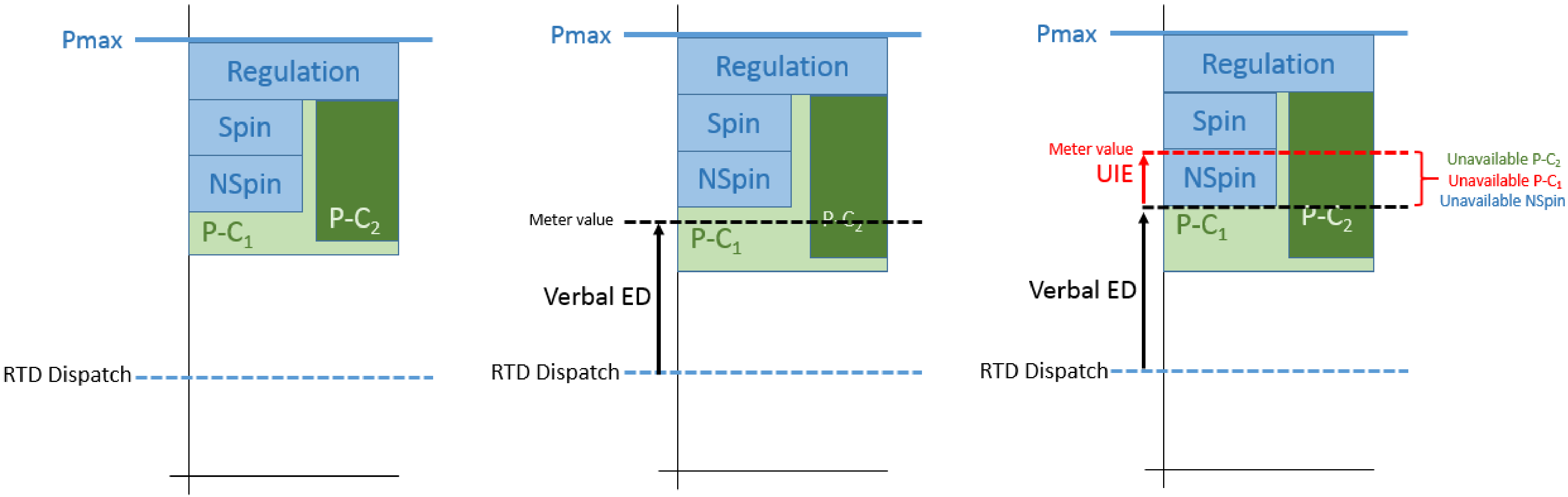
- If corrective capacity is unavailable because it is converted to Energy without Dispatch Instructions from CAISO, the Scheduling Coordinator shall pay back the unavailable capacity at the RTD LMCP.
- Uninstructed Deviations in real-time may cause corrective capacity to be unavailable.



Corrective Capacity Settlement & No Pay Rules

Corrective capacity deployment

- Automatically dispatched for real-time needs per re-optimization
- Operator can exceptionally dispatch for any reason
- If corrective capacity overlaps A/S, will be dispatched via RTCD



Next Steps

Next Steps

Item	Date
Third revised straw proposal	11/20/2015
Stakeholder Meeting	12/10/2015
Stakeholder comments due	12/22/2015
Prototype results	TBD
Draft final proposal	1/13/2016
Stakeholder call	1/20/2016
Stakeholder comments due	2/3/2016
Board meeting	3/24/2016-3/26/2016

Please submit comments to initiativecomments@caiso.com

Questions