California ISO
Your Link to Power
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MRTU Ancillary Service Pricing Under Deficiency Conditions

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Guideline for MRTU A/S Pricing Under Deficiency Conditions

- There is no ancillary service (A/S) Scarcity Pricing in MRTU

  - FERC accepted in concept the CAISO's initial limited scarcity proposal

  - FERC directed the CAISO to implement a more extensive Scarcity Pricing mechanism within 12 months after the startup of MRTU

MRTU A/S Pricing Under Deficiency Conditions

- In case of insufficient supply, minimum A/S requirement will be reduced.
  - Supply deficiency is identified in Scheduling Run
  - A/S requirement is reduced in Pricing Run to eliminate supply deficiency

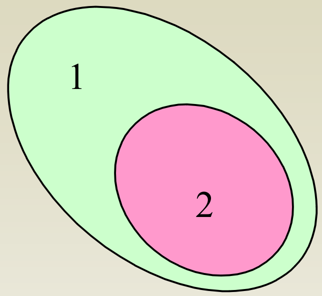
- Marginal economic A/S bid always sets A/S market clearing price (ASMP) with opportunity cost of providing energy

Additional MRTU A/S Pricing Rules

- A/S pricing under deficiency conditions also follows the following rules
  - Not to procure lower quality A/S to meet the requirement for a deficient higher quality A/S
  - To procure more the same or higher quality A/S from the outer Region to meet the requirement of an A/S deficient in a nested Sub-Region

General Assumptions of Examples

- Two nested regions
  - Region 2 – a Sub-Region within the CAISO system
  - Region 1 – the CAISO system excluding Region 2



- Energy and one A/S product
  - With fixed energy demand and minimum A/S requirement in each region
- Supply constraints for each of the four suppliers
  - Maximum bid-in A/S capacity
  - Maximum total bid-in capacity

Example 1 – No A/S Supply Deficiency

- There is no A/S supply deficiency

Input Assumptions

	Energy Offer		A/S Offer		Maximum Capacity (MW)	Demand (MW)
	Quantity (MW)	Price ($/MWh)	Quantity (MW)	Price ($/MWh)		
Region 1						
Energy Demand						4750
A/S Requirement						195
Supplier 1		25	45	6	4500	
Supplier 2		30	160	10	500	
Region 2						
Energy Demand						1500
A/S Requirement						90
Supplier 3		50	20	12	1500	
Supplier 4		150	80	18	100	

Example 1 – Scheduling Run Co-optimization Model

Objective Function:

$$\min(25 \cdot E_{1,1} + 30 \cdot E_{1,2} + 50 \cdot E_{2,3} + 150 \cdot E_{2,4} + 6 \cdot AS_{1,1} + 10 \cdot AS_{1,2}$$
$$+ 12 \cdot AS_{2,3} + 18 \cdot AS_{2,4} + 2000 \cdot SLK_{AS1} + 2000 \cdot SLK_{AS2})$$

Subject to:

Region 2:	$AS_{2,3} + AS_{2,4} + SLK_{SAS2} \geq 90$	α
	$E_{2,3} + E_{2,4} = 1500$	β
	$E_{2,3} + AS_{2,3} \leq 1500$	χ
	$E_{2,4} + AS_{2,4} \leq 100$	δ
Region 1 & 2:	$AS_{1,1} + AS_{1,2} + AS_{2,3} + AS_{2,4} + SLK_{AS1} \geq 285$	ε
Region 1:	$E_{1,1} + E_{1,2} = 4750$	ϕ
	$E_{1,1} + AS_{1,1} \leq 4500$	γ
	$E_{1,2} + AS_{1,2} \leq 500$	η
	$AS_{1,1} \leq 45, \quad AS_{1,2} \leq 160, \quad AS_{2,3} \leq 20, \quad AS_{2,4} \leq 80$	
Non-negative Value:	$AS_{i,j},\ E_{i,j},\ SLK_{ASi} \geq 0$	

$E_{i,j}, AS_{i,j}$ – Energy schedule and A/S procurements from supplier *j* in region i (MW)

SLK_{ASi} – Slack variables of A/S in region i (MW)

$\alpha, \beta, \chi, \delta, \varepsilon, \phi, \gamma, \eta$ – Shadow price of the constraints

Example 1 – Results of Scheduling Run and Pricing Run

Scheduling Run Results

Optimal Energy Dispatch and A/S Procurement (MW)									
AS_{11}	AS_{12}	$AS_{2,3}$	$AS_{2,4}$	E_{11}	E_{12}	$E_{2,3}$	$E_{2,4}$	SLK_{AS1}	SLK_{AS2}
35	160	10	80	4465	285	1490	10	0	0
Shadow Price ($/MWh)					Market Clearing Price ($/MWh)				
α	β	ε	ϕ		$P_{1,AS}$	$P_{2,AS}$	$P_{1,E}$	$P_{2,E}$	
101	150	11	30		11	112	30	150	

- Since there is no supply deficiency, energy prices are set by marginal economic bids.
- ASMPs include marginal A/S bids and opportunity costs
- Pricing Run has the same results

Example 2 – A/S Supply Deficiency in Region 2

- Based on Example 1, Supplier 3's bid-in A/S capacity is reduced to create a deficiency in Region 2

Input Assumptions

	Energy Offer		A/S Offer		Maximum Capacity (MW)	Demand (MW)
	Quantity (MW)	Price ($/MWh)	Quantity (MW)	Price ($/MWh)		
Region 1						
Energy Demand						4750
A/S Requirement						195
Supplier 1		25	45	6	4500	
Supplier 2		30	160	10	500	
Region 2						
Energy Demand						1500
A/S Requirement						90
Supplier 3		50	5	12	1500	
Supplier 4		150	80	18	100	

Example 2 – Scheduling Run Results

Scheduling Run Results

Optimal Energy Dispatch and A/S Procurement (MW)									
AS_{11}	AS_{12}	$AS_{2,3}$	$AS_{2,4}$	E_{11}	E_{12}	$E_{2,3}$	$E_{2,4}$	SLK_{AS1}	SLK_{AS2}
40	160	5	80	4460	290	1495	5	0	5
Shadow Price ($/MWh)					Market Clearing Price ($/MWh)				
α	β	ε	ϕ		$P_{1,AS}$	$P_{2,AS}$	$P_{1,E}$	$P_{2,E}$	
2000	150	11	30		11	2011	30	150	

- There is a 5 MW A/S supply deficiency in Region 2
- A/S minimum requirement of Region 2 will be reduced by 5 MW in Pricing Run

Example 2 – Pricing Run Co-optimization Model

Objective Function:

$$\min(25\cdot E_{1,1}+30\cdot E_{1,2}+50\cdot E_{2,3}+150\cdot E_{2,4}+6\cdot AS_{1,1}+10\cdot AS_{1,2}$$
$$+12\cdot AS_{2,3}+18\cdot AS_{2,4}+0.01\cdot SLK_{AS1}+0.01\cdot SLK_{AS2})$$

Subject to:

Region 2:	$AS_{2,3}+AS_{2,4}+SLK_{SAS2}\geq 85$	α
	$E_{2,3}+E_{2,4}=1500$	β
	$E_{2,3}+AS_{2,3}\leq 1500$	χ
	$E_{2,4}+AS_{2,4}\leq 100$	δ
Region 1 & 2:	$AS_{1,1}+AS_{1,2}+AS_{2,3}+AS_{2,4}+SLK_{AS1}\geq 285$	ε
Region 1:	$E_{1,1}+E_{1,2}=4750$	ϕ
	$E_{1,1}+AS_{1,1}\leq 4500$	γ
	$E_{1,2}+AS_{1,2}\leq 500$	η
	$AS_{1,1}\leq 45,\quad AS_{1,2}\leq 160,\quad AS_{2,3}\leq 5,\quad AS_{2,4}\leq 80$	
Upper Limits:	$SLK_{AS1}\leq 0.001,\quad SLK_{AS2}\leq 0.001$	
Non-negative Value:	$AS_{i,j},\ E_{i,j},\ SLK_{ASi}\geq 0$	

Example 2 – Pricing Run Results

Pricing Run Results

Optimal Energy Dispatch and A/S Procurement (MW)									
AS_{11}	AS_{12}	$AS_{2,3}$	$AS_{2,4}$	E_{11}	E_{12}	$E_{2,3}$	$E_{2,4}$	SLK_{AS1}	SLK_{AS2}
40	160	5	80	4460	290	1495	5	0	0
Shadow Price ($/MWh)					Market Clearing Price ($/MWh)				
α	β	ε	ϕ		$P_{1,AS}$	$P_{2,AS}$	$P_{1,E}$	$P_{2,E}$	
101	150	11	30		11	112	30	150	

- There is no more A/S supply deficiency in Pricing Run
- The ISO procures 5 MW more A/S in Region 1 to meet the total A/S requirement of Region 1 & 2
- Energy dispatch and A/S procurements are different than Example 1 (shown in red), but ASMPs are the same.

Example 3 – A/S Supply Deficiency in both Region 1 & 2

- Based on Example 2, Supplier 1's bid-in A/S capacity is reduced to create deficiencies in both Region 1 & 2

Input Assumptions

	Energy Offer		A/S Offer		Maximum Capacity (MW)	Demand (MW)
	Quantity (MW)	Price ($/MWh)	Quantity (MW)	Price ($/MWh)		
Region 1						
Energy Demand						4750
A/S Requirement						195
Supplier 1		25	38	6	4500	
Supplier 2		30	160	10	500	
Region 2						
Energy Demand						1500
A/S Requirement						90
Supplier 3		50	5	12	1500	
Supplier 4		150	80	18	100	

Example 3 – Scheduling Run Results

Scheduling Run Results

Optimal Energy Dispatch and A/S Procurement (MW)									
AS_{11}	AS_{12}	$AS_{2,3}$	$AS_{2,4}$	E_{11}	E_{12}	$E_{2,3}$	$E_{2,4}$	SLK_{AS1}	SLK_{AS2}
38	160	5	80	4462	288	1495	5	2	5
Shadow Price ($/MWh)					Market Clearing Price ($/MWh)				
α	β	ε	ϕ		$P_{1,AS}$	$P_{2,AS}$	$P_{1,E}$	$P_{2,E}$	
2000	150	2000	30		2000	4000	30	150	

- There is a 5 MW A/S supply deficiency in Region 2 and a 2 MW deficiency in the total of Region 1 & 2
- A/S minimum requirement of Region 2 and the total of Region 1 & 2 will be reduced in Pricing Run

Example 3 – Pricing Run Co-optimization Model

Objective Function:

$$\min(25\cdot E_{1,1}+30\cdot E_{1,2}+50\cdot E_{2,3}+150\cdot E_{2,4}+6\cdot AS_{1,1}+10\cdot AS_{1,2}$$
$$+12\cdot AS_{2,3}+18\cdot AS_{2,4}+0.01\cdot SLK_{AS1}+0.01\cdot SLK_{AS2})$$

Subject to:

Region 2:

$$AS_{2,3}+AS_{2,4}+SLK_{SAS2}\geq 85 \qquad \alpha$$

$$E_{2,3}+E_{2,4}=1500 \qquad \beta$$

$$E_{2,3}+AS_{2,3}\leq 1500 \qquad \chi$$

$$E_{2,4}+AS_{2,4}\leq 100 \qquad \delta$$

Region 1 & 2:

$$AS_{1,1}+AS_{1,2}+AS_{2,3}+AS_{2,4}+SLK_{AS1}\geq 283 \qquad \varepsilon$$

Region 1:

$$E_{1,1}+E_{1,2}=4750 \qquad \phi$$

$$E_{1,1}+AS_{1,1}\leq 4500 \qquad \gamma$$

$$E_{1,2}+AS_{1,2}\leq 450 \qquad \eta$$

$$AS_{1,1}\leq 38,\quad AS_{1,2}\leq 160,\quad AS_{2,3}\leq 5,\quad AS_{2,4}\leq 80$$

Upper Limits: $SLK_{AS1}\leq 0.001,\quad SLK_{AS2}\leq 0.001$

Non-negative Value: $AS_{i,j},\ E_{i,j},\ SLK_{ASi}\geq 0$

Example 3 – Pricing Run Results

Pricing Run Results

Optimal Energy Dispatch and A/S Procurement (MW)									
AS_{11}	AS_{12}	$AS_{2,3}$	$AS_{2,4}$	E_{11}	E_{12}	$E_{2,3}$	$E_{2,4}$	SLK_{AS1}	SLK_{AS2}
38	160	5	80	4462	288	1495	5	0	0
Shadow Price ($/MWh)					Market Clearing Price ($/MWh)				
α	β	ε	ϕ		$P_{1,AS}$	$P_{2,AS}$	$P_{1,E}$	$P_{2,E}$	
101	150	11	30		11	112	30	150	

- There is no more A/S supply deficiency in Pricing Run
- Energy dispatch and A/S procurements are different than Example 1 (shown in red), but ASMPs are the same.

Summary – No A/S Scarcity Pricing in MRTU

- A/S supply deficiency is eliminated in Pricing Run by reducing A/S requirement
  - Example 1 – no A/S supply deficiency
  - Example 2 – A/S requirement in Region 2 is reduced
  - Example 3 – A/S requirements in Region 2 and the total of Region 1 &2 are reduced
- MRTU A/S pricing mechanism follows the guideline:
  - No A/S Scarcity Pricing in MRTU
  - Marginal economic A/S bid always sets ASMP with opportunity cost of providing energy

Questions

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