Multi-Day Energy Security (MDES) Product

September 21, 2023

Agenda

- Review components and features of MDES design
  - LS Power's August 15, 2023 presentation
- Additional detail around MDES design components for discussion
- In-depth examples of market clearing outcomes and market efficiency

Recap of the Multi-Day Energy Security (MDES) Design Principles

- Address the net load forecast error across multiple weekend days, including holidays. Note: “net load” encompasses both system demand error and intermittent generation error.
- Create incentives for generators to procure incremental energy available to system operators
- Minimize costs to load and mitigate systemic risks to generators
- Non-discriminatory - open to all resource types capable of providing incremental energy reserves over the course of the designated weekend period.

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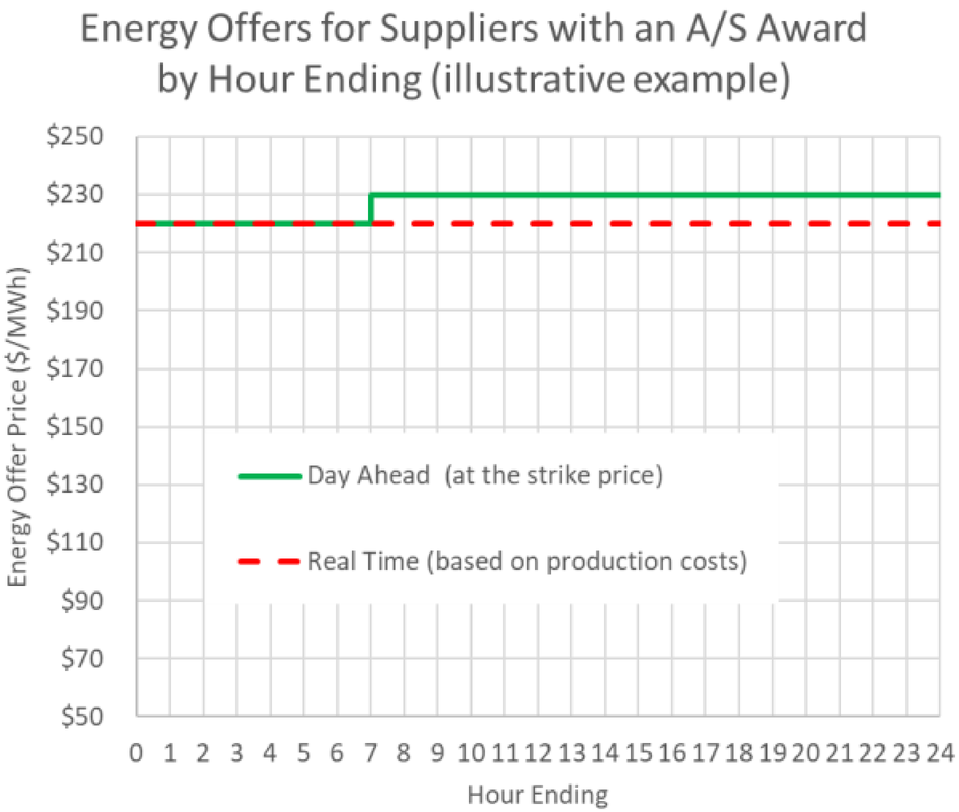
Recap of MDES Design Concepts

- MDES Suppliers receive a fixed payment in exchange for arranging for incremental energy for each day of a pre-determined (weekend) period and offering the energy at or above a pre-determined price.
- PJM determines the:
  - conditions when MDES auctions would be held based on number of days in the weekend and forecasted reserve margin throughout the weekend;
  - Daily quantity, denominated in MWh, to procure and informed by *net* load forecast error; and
  - strike price, set in $/MWh, equal to the highest forecasted LMP over the period.
- Suppliers submit $,MWh price pair offers by 9:00am, PJM clears MDES independently of the DAM, and announces MDES awards by 10:30am.
- MDES auction clears on a vertical demand curve with a cost cap informed by the substitutability of alternative resource types – e.g., slow starting resources, etc.
- MDES suppliers awarded an energy reserve obligation must submit evidence of fuel procurement by 3pm Friday and are assessed an administrative penalty if they don't.

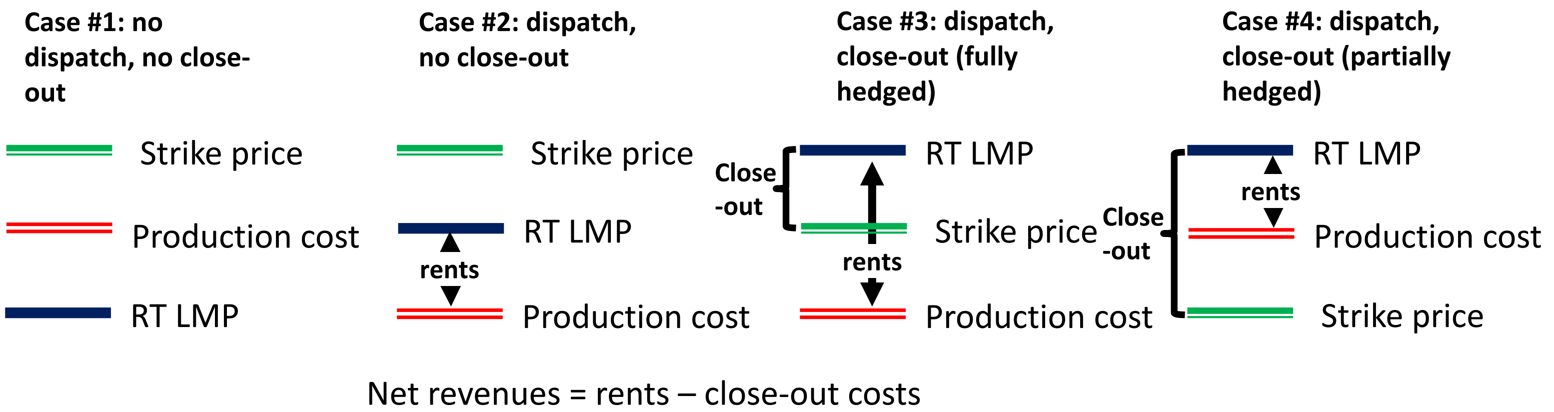
Restatement of Program Procedures (1 of 2)

- MDES suppliers must submit DA energy offers commencing Friday (for Saturday Operating Day) through the end of the pre-determined weekend period at no less than the MDES strike price for hours ending 07 through 23.
  - MDES RT energy offers are not constrained by MDES rules.



Restatement of Program Procedures (2 of 2)

- Financial close-out occurs during intervals when the RT LMP exceeds the MDES strike price after the unit parameters of the generator are taken into consideration and up to the MDES quantity awarded to the supplier; see slide 5 here.



- All other energy and capacity market rules and requirements remain in force.

Illustrative Examples and Conclusions

Scenario Inputs Definitions

- **RT LMP:** The actual Real Time LMP for the interval
- **Gas Day Ahead Price:** The delivered price at the delivery meter if gas is purchased and nominated during the timely cycle
- **ULSD Price:** The delivered replacement price of Ultra-Low Sulfur Diesel
- **Intraday Gas Price:** The delivered price at the delivery meter if gas is purchased and nominated after the timely cycle
- **Sellback price:** The price that the shipper receives if selling gas back after the timely cycle
- **Probability:** The likelihood of any outcome occurring. All outcomes sum to 100%.
- **Expected RT LMP:** The probability weighted RT LMP found by summing the product of the RT LMP and the outcome probability
- **Expected DA LMP:** User selected value close to the Expected RT LMP.
- **Strike Price:** Set equal to the Expected RT LMP

Representative Presentation of Values (Irrespective of Case)

Line	Item Description	Units	Field Calculation	Averages	Outcomes: High	Med	Low
A	RT LMP	$/MWh	User selections		$ 450	$ 275	$ 75
B	Gas Day Ahead Price	$/MMBtu	User selections		$ 26	$ 26	$ 26
C	ULSD Price	$/MMBtu	User selections		$ 25	$ 25	$ 25
D	Intraday gas price	$/MMBtu	User selections		$ 32	$ 30	$ 8
E	Sellback price	$/MMBtu	User selections		$ 20	$ 15	$ 4
F	Probability	%	User selections		1/3	1/3	1/3
G	Expected RT LMP	$/MWh	=sumproduct(A, F)	$ 267			
H	Expected DA LMP	$/MWh	~G	$ 267			
I	Strike Price	$/MWh	=G	$ 267			

Line	Item Description	Units	Field Calculation	Resource Types: NGCT	NGCC	Oil CT
J	Heat Rate	MMBtu/MWh	User selections	11	8	11

Offering an Analytical Framework

- In the successive slides, we'll step through an example case for a natural-gas combustion turbine (NGCT) when the strike price and the expected DA Energy LMP are equal
- In the example case, we calculate the risk-adjusted expected profit for: (i) the baseline case (No MDES supply – i.e., No A/S Case), and (ii) with the generator supplying MDES – i.e., A/S Case.
- We calculate the supplier's required minimum MDES clearing price by setting the generator's risk-adjusted profit in the "no A/S" case equal to the "A/S" case.
- We then summarize the cases for the NGCT, natural-gas combined cycle (NGCC), and fuel-oil combustion turbine (FOCT) toggling the relative position of gas day ahead price with ULSD price and modeling when the expected DA price is higher, lower, and equal to the strike price.

Baseline– no Ancillary Service Case for NGCT

Line Item	Description	Units	Field Calculation	Averages	Outcomes High	Outcomes Med	Outcomes Low
A	RT LMP	$/MWh	User selections		$ 450	$ 275	$ 75
B	Gas Day Ahead Price	$/MMBtu	User selections		$ 26	$ 26	$ 26
C	ULSD Price	$/MMBtu	User selections		$ 25	$ 25	$ 25
D	Intraday gas price	$/MMBtu	User selections		$ 32	$ 30	$ 8
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I	Strike Price	$/MWh	=G	$ 267			

				Resource Types		
				NGCT	NGCC	Oil CT
J	Heat Rate	MMBtu/MWh	User selections	11	8	11

- We calculate the risk-adjusted profit in the baseline for comparison against the test cases.

Natural-gas fired generator - simple cycle

Revenues Assuming no A/S Award

					High	Medium	Low
	Resource Inputs						
K		DA Energy offer	=B*J		$ 286.00	$ 286.00	$ 286.00
L		RT Energy offer	=C*J		$ 352.00	$ 330.00	$ 88.00
	Settlement						
M		A/S Credit	Zero for no A/S case		$ -	$ -	$ -
N		DA Energy credit	=if(H>=K, H, 0)		$ -	$ -	$ -
O		RT Energy credit	=if(and(A>=L, N=0), A, 0)		$ 450.00	$ -	$ -
P		A/S Closeout	Zero for no A/S case		$ -	$ -	$ -
Q		Total Settlement	=sum(M:P)		$ 450.00	$ -	$ -
	Fuel Cost and Revenues						
R		Fuel Costs	=-if(N<>0, K, if(O<>0, L, 0))		$ (352.00)	$ -	$ -
S		Sellback revenues	Set to zero		$ -	$ -	$ -
T		Net Fuel Revenues (Costs)	=sum(Q:R)		$ (352.00)	$ -	$ -
U	Net Revenues		=Q+T		$ 98.00	$ -	$ -
V	Expected Net Revenue	$/MWh	=sumproduct(F,U)	$ 32.67			
W	Standard Deviation	$/MWh	=stddev.p(F,U)	$ 46.20			
X	Risk-adjusted profit	$/MWh	=V/W	$ 0.71			

Ancillary Service Case for NGCT

Line Item	Description	Units	Field Calculation	Averages	High	Med	Low
A	RT LMP	$/MWh	User selections		$ 450	$ 275	$ 75
B	Gas Day Ahead Price	$/MMBtu	User selections		$ 26	$ 26	$ 26
C	ULSD Price	$/MMBtu	User selections		$ 25	$ 25	$ 25
D	Intraday gas price	$/MMBtu	User selections		$ 32	$ 30	$ 8
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H	Expected DA LMP	$/MWh	=G	$ 267			
I	Strike Price	$/MWh	=G	$ 267			

				Resource Types		
				NGCT	NGCC	Oil CT
J	Heat Rate	MMBtu/MWh	User selections	11	8	11

- DA Energy offer = strike price
- We set the risk-adjusted project equal for the no-A/S and A/S cases to solve for the minimum A/S clearing price.

Revenues Assuming A/S Award

Line Item	Section	Description	Units	Field Calculation	Average	High	Med	Low
	Resource Inputs							
Y		DA Energy offer		=I		$ 267.00	$ 267.00	$ 267.00
Z		RT Energy offer		=MIN(B, E)*J		$ 220.00	$ 165.00	$ 44.00
	Settlement							
AA		A/S Credit		**We are solving for this value**		$ -	$ -	$ -
AB		DA Energy credit		=IF(H>=Y, H, 0)		$ 267.00	$ 267.00	$ 267.00
AC		RT Energy Credit		=IF(AND(A>=Z, AB=0), A, 0)		$ -	$ -	$ -
AD		A/S Closeout		=IF(A>I, I-A, 0)		$ (183.00)	$ (8.00)	$ -
AE		Total Settlement		=sum(AA:AD)		$ 84.00	$ 259.00	$ 267.00
	Fuel Cost and Revenues							
AF		Fuel Costs		=-B*J		$ (286.00)	$ (286.00)	$ (286.00)
AG		Sellback revenues		=IF(OR(AB<>0, AC<>0), 0, E*J)		$ -	$ -	$ -
AH		Net Fuel Revenues (Costs)		=SUM(AF:AG)		$ (286.00)	$ (286.00)	$ (286.00)
AI	Net Revenues			=AE + AH		$ (202.00)	$ (27.00)	$ (19.00)
AJ	Expected Net Revenue		$/MWh	=SUMPRODUCT(F, AI)	$ (82.67)			
AK	Standard Deviation			=stddev.p(F, AI)	$ 84.44			
AL	Minimum A/S clearing price			=X*AK-AJ	$ 142.38			
AM	Expected A/S Closeout - net refund to load			=sumproduct(F, AD)	$ (63.67)			
AN	Expected Net A/S cost			=AL+AM	$ 78.71			
AO	Risk-adjusted profit		$/MWh	=(AJ + AL)/AK	$ 0.71			

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A/S and no-A/S Comparisons

- Utilizing the aforementioned methodology, we compared illustrative outcomes for a: (i) NGCT, (ii) NGCC, and (iii) FOCT.
- *Directional* observations:
  - NGCT required the lowest MDES clearing price in all cases.
  - NGCC required the highest MDES clearing price in all cases.
  - MDES-required clearing price for FOCT is sensitive to the relationship between strike price and DA LMP, critical when clearing an A/S for multiple days.

Case Description	Probabilities			RT LMP ($/MWh)				DA LMP	Price	Ahead Price	ULSD Price	Intraday Gas Price			Sellback Price			Heat Rates			Risk-adjusted Profit - No A/S			Min Required A/S clearing		
	H	M	L	H	M	L	E	($/MWh)	($/MWh)	($/MMBtu)	($/MMBtu)	H	M	L	H	M	L	NGCT	NGCC	FOCT	NGCT	NGCC	FOCT	NGCT	NGCC	FOCT
GDA price > ULSD, strike price = DA LMP	1/3	1/3	1/3	$ 525	$ 350	$ 85	$ 320	$ 320	$ 320	$ 30	25	$ 40	$ 35	$ 9	$ 40	$ 35	$ 9	11	8	11	$ 0.71	$ 80.00	$45.00	$ 152	$ 8,426	$6,686
GDA price > ULSD, strike price < DA LMP				$ 525	$ 350	$ 85	$ 320	$ 320	$ 270	$ 30		$ 40	$ 35	$ 9	$ 40	$ 35	$ 9				$ 0.71	$ 80.00	$45.00	$ 197	$ 9,920	$7,374
GDA price > ULSD, strike price > DA LMP				$ 525	$ 350	$ 85	$ 320	$ 320	$ 370	$ 30		$ 40	$ 35	$ 9	$ 40	$ 35	$ 9				$ 0.71	$ 80.00	$45.00	$ 39	$ 8,783	$6,543
GDA price < ULSD, strike price = DA LMP				$ 400	$ 195	$ 75	$ 223	$ 215	$ 215	$ 20		$ 35	$ 18	$ 7	$ 35	$ 18	$ 7				$ 0.71	$ 55.00	$ 0.71	$ 128	$ 7,295	$ 183
GDA price < ULSD, strike price < DA LMP				$ 400	$ 195	$ 75	$ 223	$ 215	$ 200	$ 20		$ 35	$ 18	$ 7	$ 35	$ 18	$ 7				$ 0.71	$ 55.00	$ 0.71	$ 138	$ 7,671	$ 193
GDA price < ULSD, strike price > DA LMP				$ 400	$ 195	$ 75	$ 223	$ 215	$ 230	$ 20		$ 35	$ 18	$ 7	$ 35	$ 18	$ 7				$ 0.71	$ 55.00	$ 0.71	$ 27	$ 4,926	$ 30

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A/S and no-A/S Comparisons

- Key takeaways:
  - The NGCC and FOCT have higher "costs" of participation in the MDES than the NGCT
  - Higher NGCC costs are due to the opportunity costs of offering into the DAM at the strike price, well above the unit's marginal costs (MC).
  - If the strike price is lower than the FOCT's MC, the FOCT may receive a DA energy award at a LMP below its MC, thus being forced to operate at a loss. This outcome cannot be ignored when offering/clearing A/S for multiple days.
- MDES price signals create incentives for generators that would not otherwise to procure additional energy available to the system operators.
- Next steps:
  - Continue modelling scenarios informed by historical data;
  - Model energy storage resources – e.g. pumped storage and batteries; and
  - Provide a paradigm to estimate MDES demand quantities.

Questions?

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