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MARKET CONSTRUCT
MISO Energy and Operating Reserve Products

10 Minute Response Time
Can be off-line or on-line

10 Minute Response Time
Must be on-line

5 Minute Response Time
Must be on-line
Automatic Generation Control Equipped (AGC)

Contingency Reserves

Operating Reserves Market

Regulating Reserves

Energy Market

SUPP
SPIN
REG
Price Formation at MISO

DA market
- Security constrained unit commitment/dispatch
- Financial market
- Co-optimization between Energy and AS products
- Sequential dispatch

Both DA committed units and cleared transaction will roll over to real time market as must run.

RAC (include both FRAC and IRAC)
- Minimize commitment cost, based on forecast load

Projected load, unit plan information

LAC
- All units which can start within LAC study time frame of 3 hours will participate in the commitment process.
- Dispatch results are not used

Study time interval: 15 30 45 60 75 90 105 120
150 180

Unit commitment information

RT SCED
- Real time Dispatch, single interval dispatch
- Final dispatch result
- Co-optimization between energy and AS products, ex-ante price will be calculated and posted for information only
- Dispatch target interval: 10
Market Clearing Price for Reserve Products

- Guarantees recovery of Operating Reserve Offer and Opportunity Cost of Energy re-dispatch for cleared Operating Reserves.
- Energy and Operating Reserves clear in a manner that maximizes revenue to the resources.

Market Clearing Price Basics

- For Operating Reserve products only
- Impacted by Energy and Operating Reserve offers
- Hourly MCPs posted for the Day-Ahead Market
- 5 minute MCP posted for the Real-Time Market
- One MCP calculated for each product, per Reserve Zone
**Scarcity Pricing**

**Why**
- Reserve shortages typically occur with sudden loss of a generator or other energy supply
- Pricing signal will indicate that MISO is anticipating reserve shortage while procuring the product at price the market is willing to pay

**What**
- A market outcome indicating clearing prices are based on administratively pre-determined values
- Impacts the price of the reserve that is scarce, other higher valued reserves and the energy component of the LMP

**How**
- SCED algorithm co-optimizes clearing between Energy and Operating Reserves
- Not clearing the full requirement of the product with demand curve based scarcity pricing
PRICING ENHANCEMENTS:
Extended LMP
Transmission Constraint Demand Curve
Pricing under Emergency Conditions
Challenges for Market Clearing Price

- Bid-based generator cost curves are non-convex since they are downward sloping over some range of output.
- Due to these non-convexities, there may not be an internally consistent set of prices that clears markets (i.e., that sets supply equal to demand).

Minimum Average Cost = $53/MWh

Average Cost at Minimum Output = $57.50/MWh

Average Cost at Maximum Output = $55/MWh

Minimum Average Cost = $53/MWh

Downward slope
Energy Pricing and Uplift

• Rules are utilized to determine energy market prices given the necessity of supplementing the principle of pure marginal cost pricing
  – In MISO, LMP is defined as the incremental offer cost in the dispatch of delivering the next unit of energy at each location.
  – In the NYISO, the pricing algorithm assumes (among other things) that block-loaded GTs can be flexibly dispatched between 0 MW and EconMax.

• Uplifts provide incentive to follow dispatch
  – Uplift is required to compensate generators for the gap between the market price and the average cost of energy for the generator’s scheduled level of output.
  – These are also called make-whole payments
Holistic market pricing with ELMP

• Electricity markets will function most efficiently when prices are consistent with the underlying commitment and dispatch cost structure
  – Generators in the RTO are permitted to make offers for start-up costs, minimum generation (no load) costs, ramp rates (up and down), and minimum and maximum run times, among other things.

• ELMP provides an analytically grounded and internally consistent pricing methodology that incorporates both commitment and dispatch cost
  – Extend LMPs in order to include the effects of startup costs, no-load costs and costs of operating any resources dispatched at minimum.
Extended LMP Design

- Revise price calculation without changing the generator commitment and dispatch
- Planned ELMP implementation will provide improved pricing on single interval basis built upon current dispatch software
- Allows reflection of true cost of energy from fast start units defined as
  - Notification time plus start up time less than or equal to 10 minutes and
  - Minimum run time less than or equal to 1 hour
- Emergency Demand Response called on by MISO can participate in ELMP
Generation Production Costs and ELMP

- For Fast Start Resources, true cost of energy is reflected through total generation offer cost curves that include start-up and no-load cost.
- Total cost curve are convexified by establishing a tangent to the curve from the origin.
- Minimum limits are relaxed in the dispatch for pricing purposes.

![Diagram](image)
## Participation of Offer Costs in Real Time Price Setting

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<tr>
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<th>ELMP</th>
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<tr>
<td><strong>No Scarcity</strong></td>
<td>* Energy Offer Costs of Online Units over Dispatchable Range</td>
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<tr>
<td></td>
<td></td>
<td>* Energy Offer Costs of Online Faststart Units over Range below Min Limit</td>
</tr>
<tr>
<td></td>
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<td>* Startup and Noload Costs of Online Faststart Units</td>
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<tr>
<td><strong>Transmission and/or Ancillary Service Scarcity</strong></td>
<td>* Transmission or A/S Demand Curves</td>
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<tr>
<td></td>
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<td>* Energy Offer Costs of Offline Units over Dispatchable Range</td>
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Comparison of LMP and ELMP on a Peak Load Day: July 6, 2012

SMP data

[Graph showing comparison of SMP ELMP and SMP LMPC on July 6, 2012]
ELMP Implementation Timeline

Dec, 2011
Tariff filing with FERC

March, 2014
Software Implementation

May, 2014
Start of Parallel Operations

July, 2012
FERC approval

October 1, 2014
Production Operation
PRICING ENHANCEMENTS:

Extended LMP
Transmission Constraint Demand Curve
Pricing under Emergency Conditions
Transmission Constraint Demand Curve (TCDC)

• Goal is to manage transmission security in an economic way
  – Avoid over-price for transmission constraint violation
  – Reduce transient price spikes

• Pricing of small violations in transmission limit at full penalty value (known as Marginal Value Limit) may not be efficient
  – Could be caused by external factors
  – May not affect reliability

• Transmission constraint demand curve improves real-time pricing and reduces congestion cost
  – Scarcity prices reflect the degree of violation
Design of TCDC

- Multi-step demand curves catering to different violation level for transmission constraint
- Applied to both Day ahead and Real time Markets
- For simplicity, two-step demand curves will be used
  - Lower demand curve block for relatively small violations
  - Higher demand curve block for larger violations
Design of TCDC

• Solution – Demand Curve by different voltage level

- **SOL constraints (69kV#)**
  - Violation Percentage Beyond the Limit
    - (0,2] 400
    - >2 500

- **SOL constraints (115kV-138kV#)**
  - Violation Percentage Beyond the Limit
    - (0,2] 700
    - >2 1000

- **Special group**
  - Violation Percentage Beyond the Limit
    - (0,2] 1,000
    - >2 2,000

- **SOL Constraints>=161kV**
  - Violation Percentage Beyond the Limit
    - (0,2] 1,000
    - >2 2,000

- **IROL Constraints**
  - Violation Percentage Beyond the Limit
    - >0 3,000

• Implemented in October 2013
PRICING ENHANCEMENTS:

Extended LMP
Transmission Constraint Demand Curve

Pricing under Emergency Conditions
Accessing Planned Resources

- It is necessary for MISO to progress through its Maximum Generation Emergency Procedure to gain access to certain resources.
The probability of MISO entering emergency procedure in summer 2014
Price depression phenomenon

- Load Modifying Resources (LMR) are deployed in step 2 of the Maximum Generation Event
- Since deployment of the LMRs simply shifts the vertical demand curve, prices would drop from the top of the supply curve to the new intersection point
Potential Solution

- Goal is to at least maintain the high price where the supply stack meets high demand before Maximum Emergency Event is invoked and LMRs are deployed.
- An approach is to adjust the LMR offer price to “match up” with marginal offer prior to deployment:
  - No change in the LMR deployment process.

![Diagram showing LMP and LMR price relationship](image-url)
Adjusted Offer Price for each Generator’s dispatch range between Economic Maximum and Emergency Maximum and/or emergency committed unit is the \textbf{sum of}

- Generator’s offer cost for the applicable capacity block
- Max of (Average generator’s ELMPs within the emergency declared areas of 12 intervals immediately prior to the declaration of the max gen event - lowest price segment emergency capacity released, 0)
Maximum Generation Events – Offer Price adjustment for LMRs* in Step 2b

Default Offer Price for LMR called on by MISO is the sum of

- LMR’s offer cost for the applicable capacity block (will be 0 if LMR doesn’t have offer)
- Max of (Average generator’s ELMPs within the emergency declared areas of 12 intervals immediately prior to the declaration of the max gen event - lowest price segment emergency capacity released, 0)

* LMR: Load Modifying Resources such as behind-the-meter-generation and voluntary load management
Minimum Generation Events – Offer Price adjustment for Generators

Default Offer Price for each Generator’s dispatch range between Economic Minimum and Emergency Minimum is

- Generator’s offer cost for the applicable capacity block minus
- Max(highest price segment of emergency capacity released for the min gen event – the average of (all generator’s ELMPs within the emergency declared areas of 12 intervals immediately prior to the declaration of the min gen event), 0)
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Market Development, MISO