A Focus on Improving Performance of the Day-Ahead Market: A Market Participant Perspective

Staff Technical Conference

Federal Energy Regulatory Commission

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San Francisco, CA

June 28, 2011

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Outline

- State of the art modeling and methodologies for clearing the Day Ahead Market
- Next Generation of Algorithms for Improving Efficiency
- Renewable Energy Sources Participation in the Market
- Demand Response Modeling Issues
- Market Participant Simulation Processes, Requirements and Data Issues
- Summary

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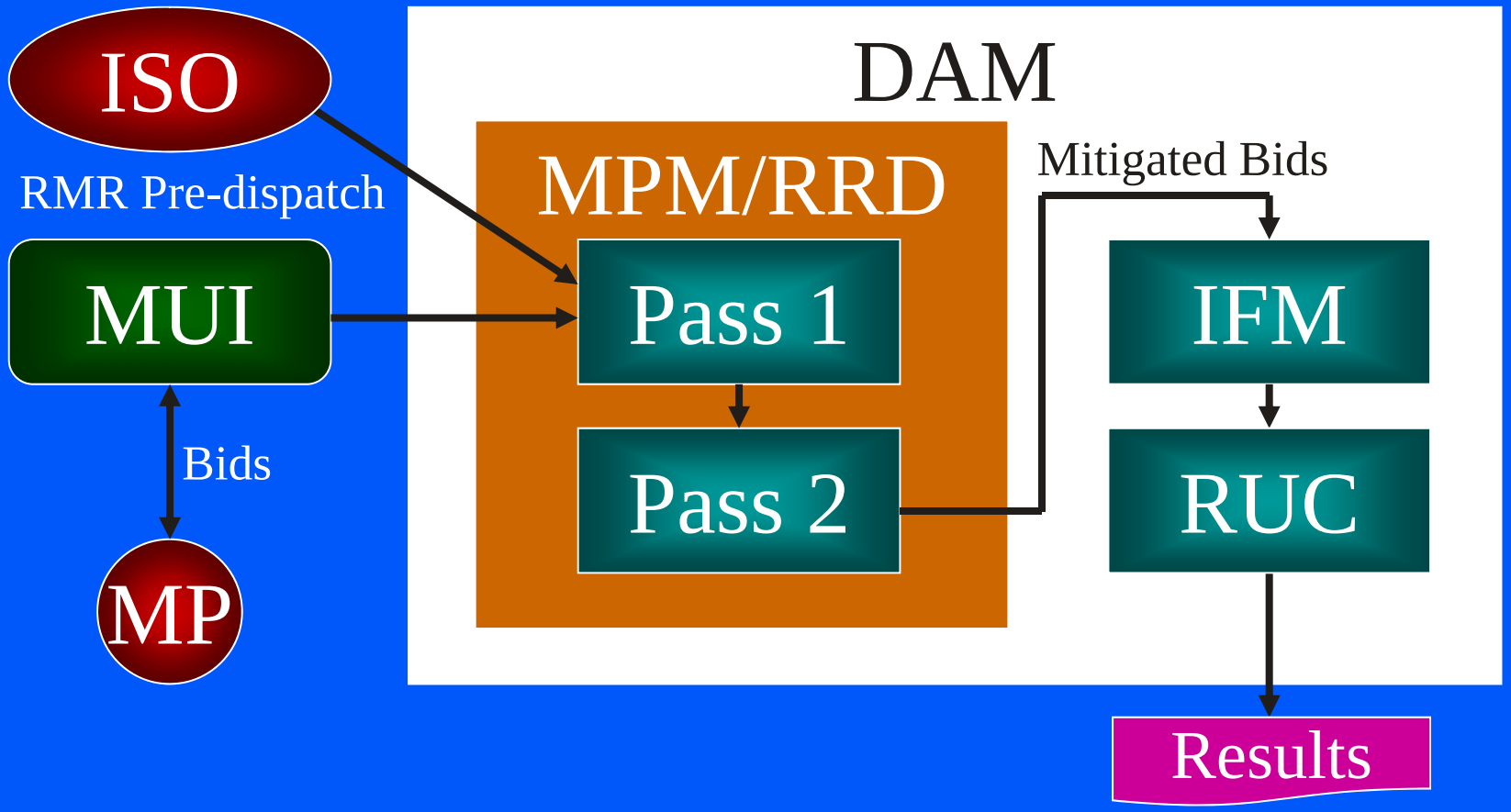
Day-Ahead Market Structure



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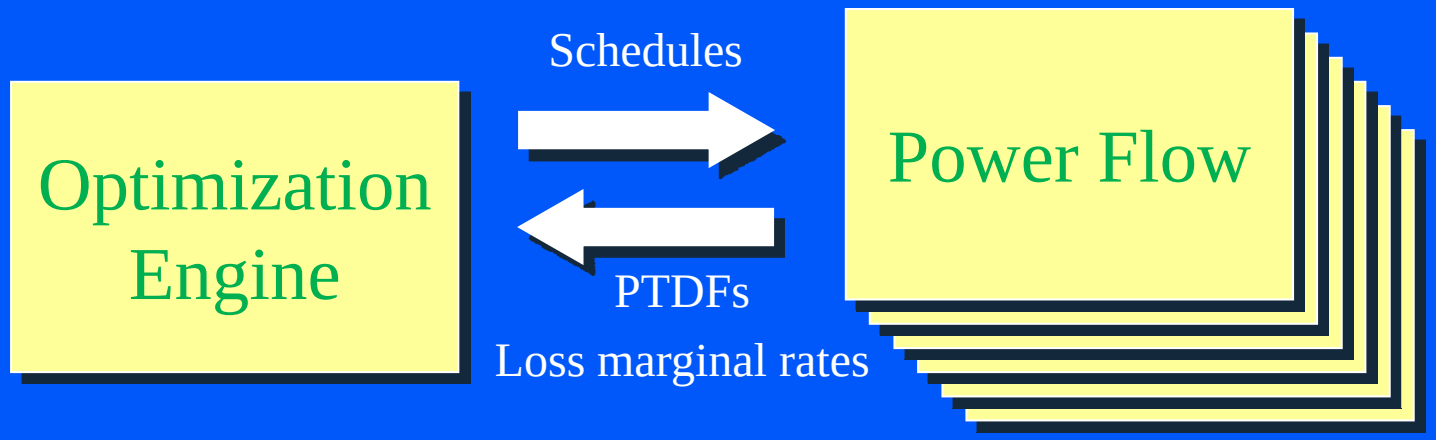
SCUC Solution Method

- Mixed Integer Linear Programming (MILP)
  - Separate power flows for each time interval
  - Iterate with optimization engine that has a single power balance constraint and the active inequality constraints for each time interval



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LMPs & Ancillary Services Prices

- When the market clears it produces along with the LMPs the Ancillary Services Marginal Prices for each region (RASMPs) and for each service
- Energy and energy are coupled through the resource's Capacity limit constraints
- If these constraints are binding the LMPs are impacted
- The RASMPs for each service is the shadow cost of the AS constraint for the service at the optimal solution
- All resources in the region are paid the same regional price (ASMP)
- Units that belong in more than one region are paid the summation of the RASMPs of the over-lapping regions

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Benefits of Energy-AS Co-optimization

- Efficient Unit Commitment and Energy/AS schedule
  - Lower overall cost
- Efficient allocation of inter-tie transmission capacity
- Accurate representation of opportunity cost in LMP and AS Marginal Price (ASMP)
- ASMP ≥ AS Bid + Opportunity Cost (OC)

  Opportunity Cost = |LMP – Energy Bid|
- If LMP < Energy Bid ⟶ OC = 0
- If a resource has not submitted an energy bid and is not under an obligation to offer energy, then OC = 0

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State of the Art Modeling

- Start Up Cost & Unit Start Up Time Functions
- Forbidden Regions & Ramp Rate Functions
- Inter-temporal Constraints (Minimum Up/Down Constraints, Start-Up Time, Maximum number of Daily Start-Ups, Daily Energy Limit, etc.)
- Various types of network constraints (Full AC Power Flow Solution, Transmission Constraints, Inter-Tie Energy/AS Constraints, Nomograms, Contingency Constraints, etc.)

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MILP versus ALR Comparison

Capability	MILP	ALR
Flexibility for adding new constraints and models	Yes	No
Flexibility of modeling a large number of coupling constraints	Yes	No
Dynamic ramp rates & Forbidden regions with crossing rules	Yes	No
Advanced infeasibility detection		
Heuristics to achieve a feasible solution	No	Yes
Block dispatchable transactions	Yes	No
Optimal automatic discrete relaxation of infeasible constraints	Yes	No
Lower bound on the optimal solution	Yes	No
Performance	fast enough	fast

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Next Generation of Algorithms for Improving Efficiency

- Develop Multi-Day Unit Commitment (issues: bid replication, performance)
- Co-optimize Energy/AS/FTRs in the DAM to hedge congestion in RTM
- Implement Nodal Pricing for Loads (issues: economic hardship on entities located in load pockets)
- Co-optimize generation dispatch for congestion management and network reconfiguration, i.e., transmission switching (issue: network reconfiguration solution does not ensure revenue adequacy in the FTR market)
- Develop market mechanisms to manage high penetration of Renewable Energy Sources (RES)
- Co-optimize Markets and Reliability (Co-optimize Energy, AS, Transmission & RUC products)

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DAM-RUC Co-Optimization

- One integrated approach
  - Two power balance constraints
    - Generation Schedule = Load Schedule
    - Generation Schedule + RUC Capacity = Demand Forecast

Pros

- Only one pass
- Maximum efficiency
- Effective mitigation
- Better manage over-generation conditions

Cons

- May be difficult to isolate RUC commitment cost
- Congestion costs from RUC capacity
- More complex to implement

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DAM-RUC Co-Optimization

- Minimize
  - Start-Up Cost
  - Minimum Load Cost
  - Energy Schedule Cost
  - Ancillary Services Procurement Cost
  - RUC Capacity Procurement Cost
- All other constraints similar to DAM and RUC
  - Inter-temporal constraints
    - MUT, MDT, MDS, ramp rates, energy limits
  - Forbidden operating regions
  - AS regional constraints
  - Inter-tie Energy/AS/RUC Capacity constraints

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RES Participation in Forward Markets

- Managing renewables today
- Grid Rule Changes
- Day Ahead Market Rules
- Additional Forward Markets
- Additional Congestion Hedging Mechanisms

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Managing Renewables Today

- Renewable participation in Day-Ahead Markets is not consistent throughout US markets
  - Renewables may not participate due to forecast uncertainties and unfavorable market rules
  - This may lead to renewables “showing up” in real-time markets, causing inconsistencies from the Day-Ahead market
- Simulations can be adjusted to account for renewable characteristics
  - Forecast uncertainty can be modeled with Monte Carlo and other probabilistic techniques
  - Long-term simulations must include realistic variability in hourly, daily, and seasonal weather patterns

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Grid Rules for Renewables

- Ensure that RES provide valuable Ancillary Services
- Ensure that grid rules require these capabilities from new RES
- Promote electricity storage; Pumped-storage and others (compressed air)
- A/S products could include: Black Start, Voltage Support, Primary Governor Response, Load Following, Regulation Reserves, and Spinning Reserves
  - Providing A/S instead of energy sometimes requires the “dumping” of energy
  - This may make economic sense during periods of high renewable resource production levels

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Day-Ahead Market Rules for Renewables

- Day-ahead market rules should not be prejudiced against (or biased towards) any particular resource category; provide economic bids; minimize administrative measures
- The market products and rules should support grid reliability and overall economic efficiency of the grid
- Production tax credits & other incentives should not adversely impact operation of markets
  - For example, wind generation often continues to produce at negative prices (e.g. -$30/MWh) because of external incentives
  - These prices do not reflect the "true" costs of operation (e.g. fuel, maintenance, …)
  - This behavior can have negative impacts on other resources in the grid
- Participation in Day-Ahead Market by renewables is subject to additional uncertainty, due to wind/solar forecasting errors
  - Additional hedging mechanisms may be useful

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Day-Ahead Market Rules for Renewables

- Provide incentives for increased dispatch capability (especially downward dispatchability) such as disallowing netting of deviations
- Substantially reduce energy bid floors to enable LMPs to go lower, thus incenting resources to submit decremental bids and capturing the RES opportunity costs
- Implement market rules to increase operational flexibility, such as Performance-based Regulation, load following, etc.
- Provide incentives to reduce the amount of self-schedules
- Achieve flexible thermal generation

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Additional Forward Markets (e.g. Hour Ahead Market)

- Significant forecasting errors exist in the Day-Ahead for renewable resources
- An additional forward market (e.g. 4-hours into the future) could be very beneficial
  - Renewable resource forecasts become significantly better when the timeframe becomes shorter
  - Provide a scheduling opportunity to RES to establish a schedule as the basis for measuring real-time deviations
  - There is still time for other non-renewable resources (e.g. combined-cycle plants) to respond to changes in RES (and load) forecasts

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Additional Congestion Hedging Mechanisms

- Power Markets typically offer Financial Transmission Rights to allow hedging against congestion uncertainty
  - Purchased months/years ahead and settled in the Day-Ahead
- Renewable resources have significant uncertainty even after the close of the Day-Ahead Market
  - Additional hedging mechanisms would allow for hedging of congestion in the 4-Hour Ahead and Real-Time Markets

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Demand Response

- Typically we have two types of DR products, a) Price DR Products and b) Reliability (emergency) DR Products
- Generally, Price DR products are activated when energy procurement prices are high or system resources are constrained; an example is the CAISO's Proxy Demand Resource (PDR) product
- Reliability DR Products are activated programs to respond to severe resource constraints or grid emergencies; an example is the CAISO's Reliability Demand Response Product (RDRP)
- DR markets include, a) Capacity Market, b) Reserves & Regulation Market and c) Energy Markets

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DR Bidding Modeling

- Participating Load (PL) submits a three-part bid that includes the following: a) Load Curtailment Cost, b) Minimum Load Reduction Cost and c) Load Energy Bid
- Aggregate PLs are modeled as aggregate controls in the optimization with a fixed distribution to the underlying nodes using relevant Custom LDFs
- The Base Load is a Price Taker, i.e., it is charged the relevant aggregate LMP as any non-Participating Load
- When the Participating Load is curtailed from the Base Load, it is eligible for recovering its Load Curtailment Cost and its hourly Minimum Load Reduction Cost
- When the Participating Load is dispatched it is paid (in addition to the Base Load charge) its LMP for the load reduction

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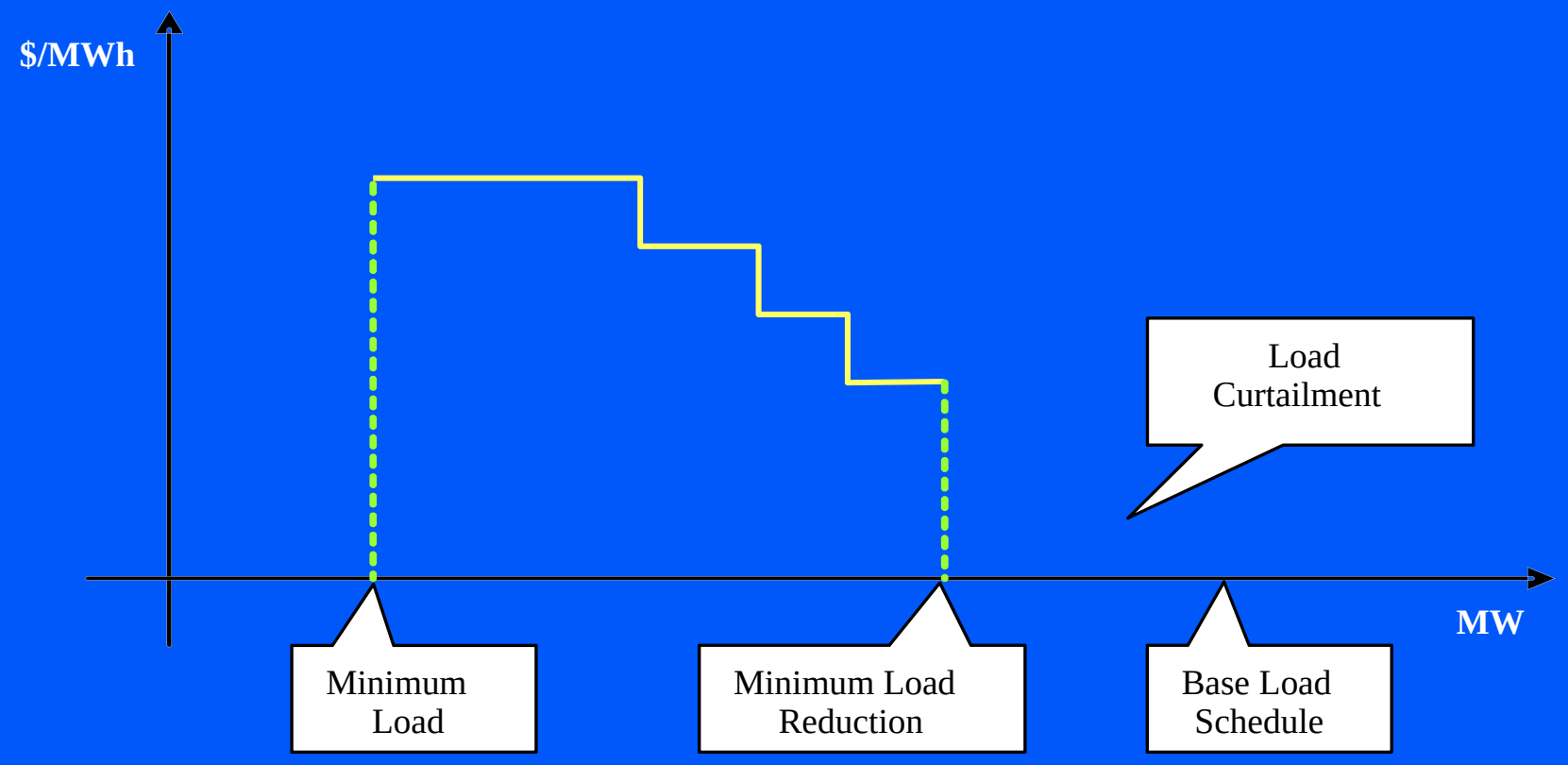
DR Bidding Modeling



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DR Modeling Improvement

- DR resources can arbitrage low Zonal prices and higher nodal prices; the potential "money pump" in which DR resources can exaggerate the load reduction is substantial
- This strategy is likely to be profitable in locations and at times when the LMP is anticipated to be higher than the Zonal price
- Define and implement much smaller Zones within which LMPs are fairly uniform
- Require that DRs purchase their baseline at the nodal prices where the reductions are to occur
- Limit DR participation via administrative rules and default no-pay demand reduction percentage relative to the customer's actual consumption

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DR Market Barriers (In addition to the Zonal/Nodal Arbitrage)

- Energy prices are insufficient to encourage DR so capacity and AS payments will be of primary importance; This argues for the development of centralized capacity markets that do not bias for or against particular resources (generation vs. non-generation)
- Customers may not like transitioning from emergency DR currently managed by IOUs to 'earlier', more frequent or Price DR products cleared in wholesale markets
- Retail Rate Policies and Metering Infrastructure have limited Real Time Price signals, so customers cannot see price signals and have no incentive to reduce consumption
- Demand response can't be fully active in retail markets until retail customers see prices and a linkage exists between retail and wholesale markets

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DR Other Barriers

- Regulatory pressures from cities which are in load pockets make it difficult to implement nodal pricing for retail pricing applications; this make difficult to align pricing for generation, load and DR resources
- Need to resolve federal and state DR policy differences
- Customer behavior very difficult to change
- Customer perceive market products difficult to understand and accept
- Communication infrastructure and data exchange linkages between parties can be a barrier (slow penetration to distribution customers)

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Market Participant Perspective: Simulate Co-optimization of Energy & AS in same manner as the ISOs

- Simulate Co-optimization of Energy and Ancillary Services in same manner as the ISOs
  - MILP representation
  - Multi-step simulation
  - Inter-temporal constraints, minimum up/down times, etc.
  - Startup and shutdown costs included
  - Ramp constraints
  - Iterating with full AC power flow where transmission constraints are added to MILP formulation using PTDFs
  - Infeasibilities enforced with penalties with post solution pricing run

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Model the Network

- Full AC solution
  - Check line and branch group flows
  - Constraints over 85% of limit added to MIP dispatch so that they may be enforced
  - Linear PTDFs used to enforce constraints in MILP
- Monitored/Enforced Constraints(s)
  - Data from ISO related to;
    - All constraints including contingency(s)
    - Formulation associated with multi-dimensional constraints
    - Timely release of new Network models BEFORE they are put into production
    - Outage details of transmission network are often not provided

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Model the Network

- Critical information continued……
- MISO, ISO-NE, NYISO, PJM all provide data on monitored constraints, as well as the associated contingencies, in the event that a constraint becomes binding under contingency conditions
- CAISO provides the shadow price and identifies the binding constraint but <u>does not provide the cause</u> why a constraint is binding or a description of the associated contingency where applicable
- CAISO does not provide details of nomogram constraints enforced
- Details of operational de-rating of constraints is often not provided

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Model Various Generator Types

- Model various Generator types,
  - Restrictions or Limitations, such as;
    - Thermal
    - Hydro,
    - Emissions
- Multi-Stage Generator Modelling
  - E.g. combined cycle 2 identical Gas Turbines (GT1 and GT2) and 1 Steam Turbine (ST); the feasible configurations are:
    - a. Configuration 1: (GT1 and ST) or (GT2 and ST)
    - b. Configuration 2: GT1 and GT2 and ST
  - Transition matrix of feasibility and costs between configurations

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Bid Data

- Modeling bid data is a very complex undertaking
  - Best source of bid data are publicly posted on ISOs OASIS historic Bid data
  - ISOs does not provide resource names of bids
  - Start Up costs and No Load costs and aggregate unit distribution factors are not provided to market participants
  - Similarly convergence bid pnodes are not provided
  - Formats vary and are NOT consistent across all ISOs
    - For example,
      - MISO gives all the cleared bids/offers, but not the actual MP name
      - Some ISOs only give the aggregated bids/offers that were cleared

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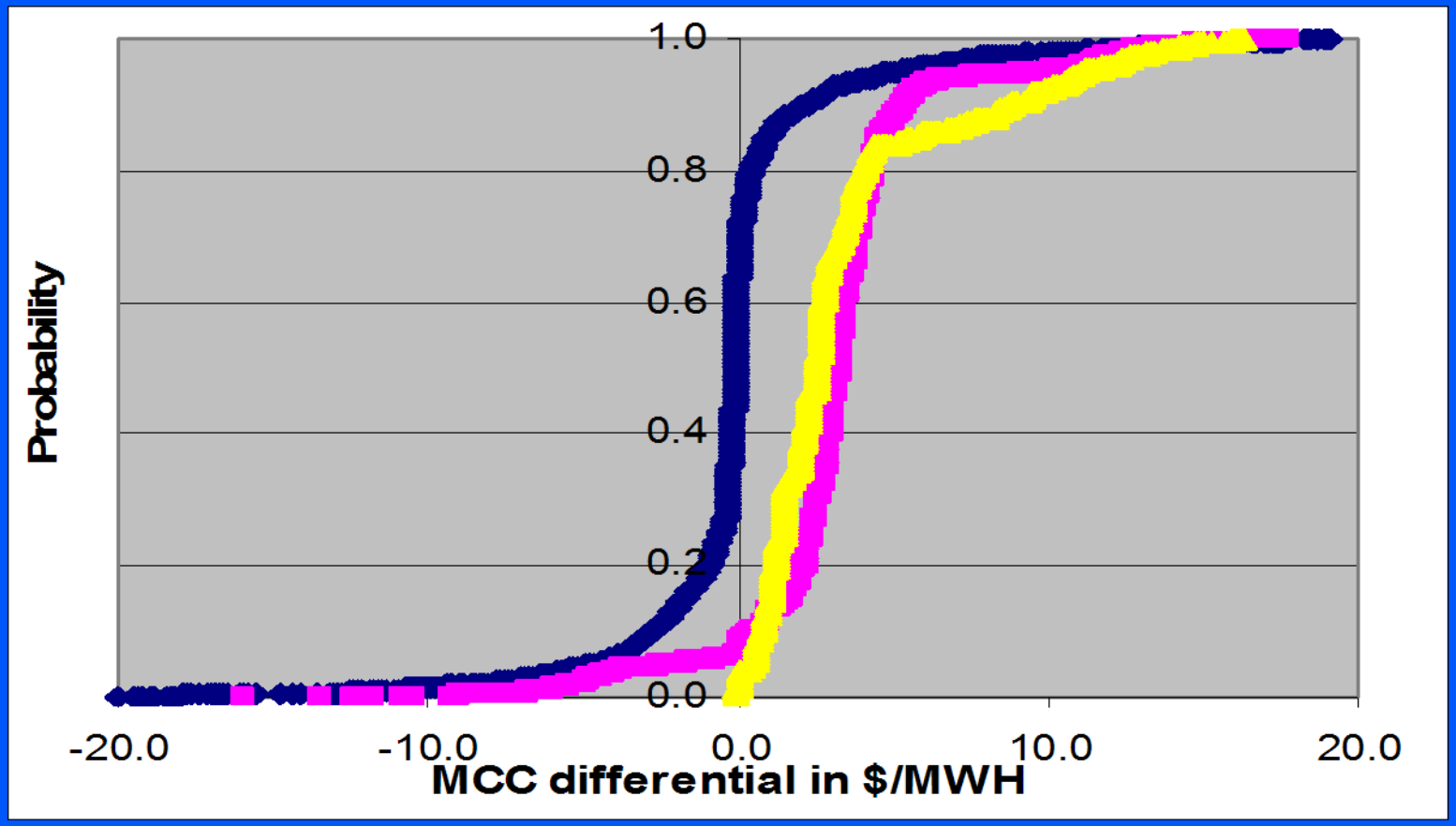
Illustration ofFTR Valuation Results



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Summary

- State of the art methodologies are currently deployed to clear the DAM
- However, high penetration of Renewable Energy Sources poses significant operational and market challenges
- Similarly, to maximize the benefits of Demand Response substantial changes are required in the clearing and settlements of the wholesale markets
- Substantial progress has been made in accurately simulating energy markets to support Market Participants in various applications such as FTR analysis and bidding strategies
- However, the market data required for accurate simulations are not consistent across markets and in some cases are not available

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