Day-Ahead Market Enhancements Phase II Working Group

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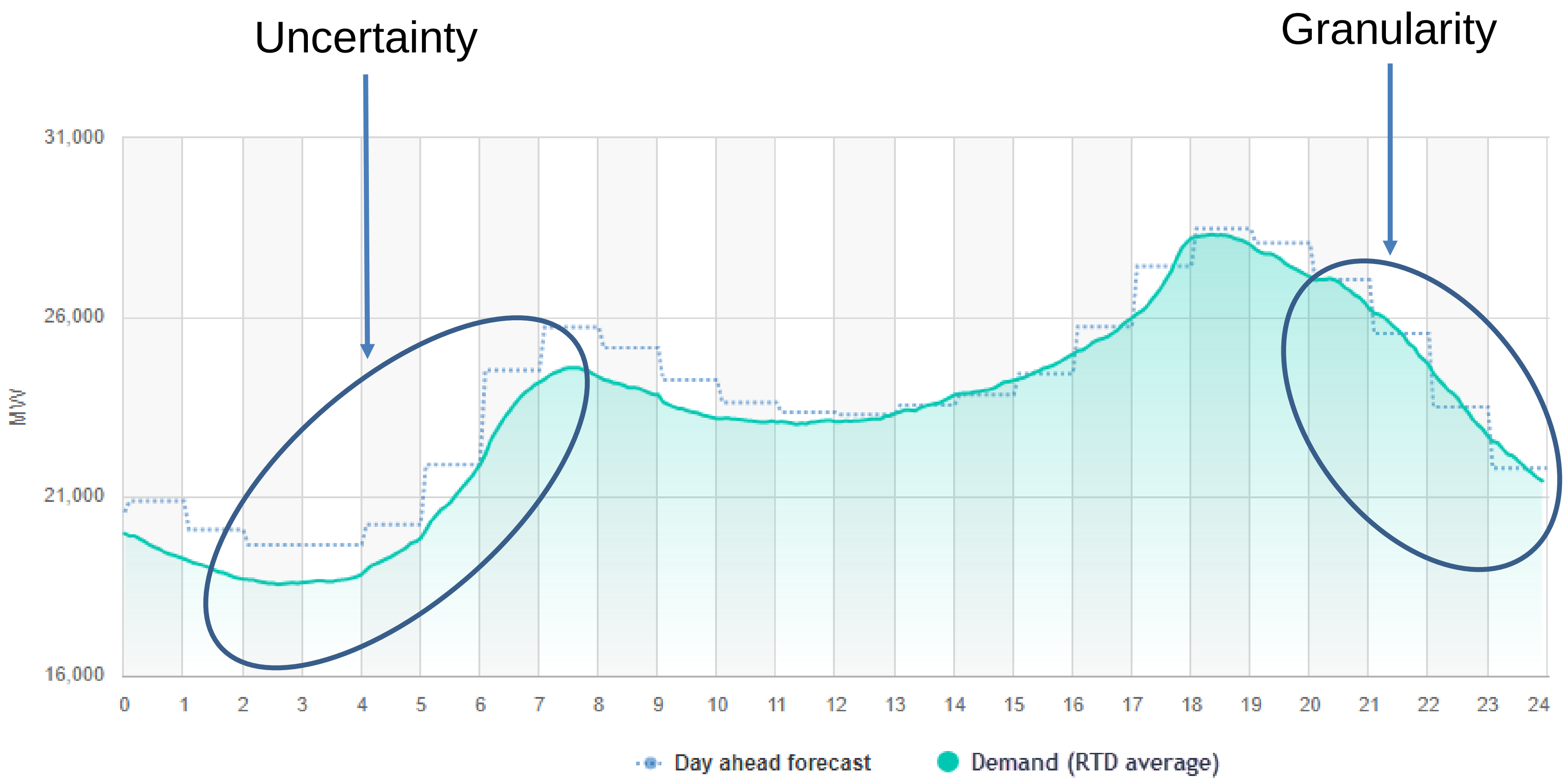
Agenda

Time	Item	Presenter
10:00 – 10:10	Welcome	Kristina Osborne
10:00 – 12:00	Day-Ahead Market Optimization: Alternative #1 & #2	George Angelidis and Megan Poage
12:00 – 1:00	LUNCH	
1:00PM – 2:30	Mathematical Formulations and Settlements	George Angelidis
2:30 – 2:45	Next Steps	Shami Davis

Day-ahead market enhancements position the fleet to better respond to real-time imbalances



In response to stakeholder comments, day-ahead market enhancement initiative split into two phases

- Phase 1: 15-Minute Granularity
  - 15-minute scheduling
  - 15-minute bidding
  - Implementation Fall 2020
- Phase 2: Day-Ahead Flexible Ramping Product (FRP)
  - Market formulation of FRP consistent between day-ahead and real-time market
  - Improve deliverability of FRP and ancillary services (AS)
  - Re-optimization of AS in real-time 15-minute market
  - Implementation Fall 2021

Key Objectives of DAME Phase 2

- Increased efficiency
  - Co-optimizing all market commodities
- Increased reliability
  - Commit/schedule resources to meet demand forecast and uncertainty
- Maintain existing financial market tools
  - Virtual and load bids for taking financial positions
  - Congestion Revenue Rights for hedging congestion
- Reasonable performance

Previous Proposal: Combine IFM and RUC into a Single Optimization Problem

- Co-optimize financial and reliability targets for best overall outcome
- Developed mathematical formulation and Excel prototype, and worked out settlement examples
- Failed!
  - Strong coupling between the financial and physical markets undermined existing financial instruments
  - Different prices for physical, virtual, and load schedules with potentially significant market uplifts

Current Proposal: Keep Financial (IFM) and Reliability (RUC) Markets Separate

- Alternative 1 (conservative)
  - Keep current DAM application sequence
    - MPM/IFM – RUC
    - Add FRU/FRD procurement in IFM
    - Additional unit commitment and fixed AS/FRU/FRD in RUC
- Alternative 2 (aggressive)
  - Change current DAM application sequence
    - MPM/RUC – MPM/IFM
    - Co-optimize Energy/AS/FRU/FRD in RUC
    - Fixed unit commitment and AS/FRU/FRD in IFM

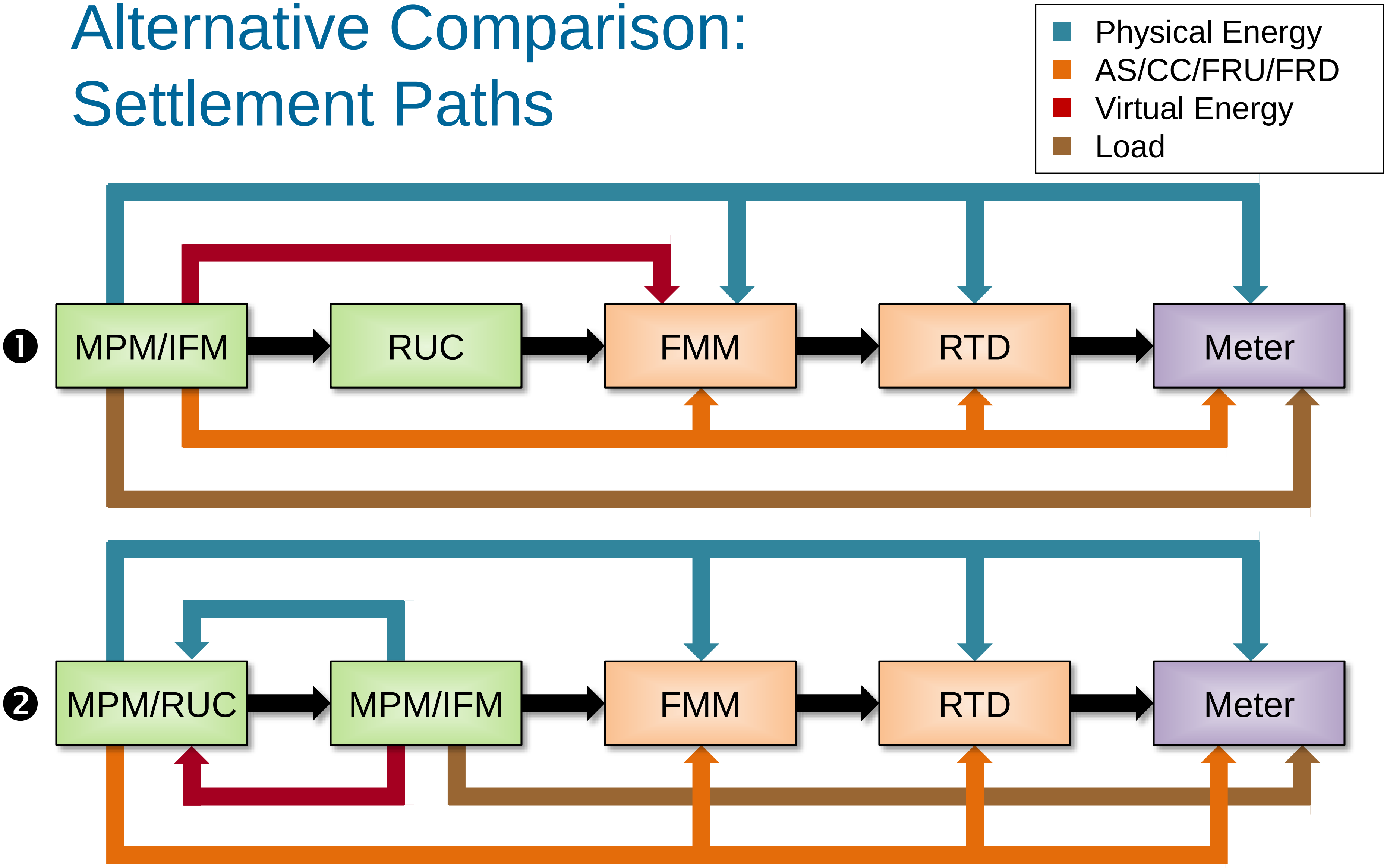
Alternative 1 Details

- Co-optimize Energy/AS/FRU/FRD in IFM
  - Full unit commitment
  - Clear physical supply with virtual and load bids
- Minimal change in RUC
  - Additional unit commitment (no de-commitment)
  - Use availability bids (non-zero for RA Resources, after EDAM) to procure RUC Capacity to meet demand forecast
  - Fixed AS/FRU/FRD awards from IFM
- No changes to deviation settlement except for FRU/FRD/Corrective Capacity (CC)

Alternative 2 Details

- Reliability Unit Commitment (RUC)
  - Full unit commitment
  - Co-optimize Reliability Energy/AS/FRU/FRD to meet demand forecast
  - Use energy bids, no need for RUC availability bids
- Independent Forward Market (IFM)
  - Forward Energy physical/virtual/load schedules
  - Fixed unit commitment and AS/FRU/FRD from RUC
- Settle Forward Energy in IFM, deviation in RUC

Alternative Comparison: Settlement Paths



Alternative 1 Pros

- Lower regulatory risk (closer to status quo)
- Easier implementation (small changes)
- Virtual schedules are liquidated in FMM providing hedge for demand/VER forecast errors and outages from DAM to RTM

Alternative 1 Cons

- Inefficient unit commitment
  - Influenced by virtual/load bids
  - Additional unit commitment in RUC with no de-commitment
- Inefficient RUC Capacity
  - Energy bids are ignored
  - FMM deviations even without change in conditions/bids
- AS/FRU/FRD awards consistent with ramp capability at IFM schedules, not load forecast

Alternative 2 Pros

- Efficient unit commitment
  - Single shot, not influenced from virtual/load bids
- Efficient RUC Energy/AS/FRU/FRD schedules
  - No FMM deviations without change in conditions/bids
- AS/FRU/FRD awards consistent with ramp capability at RUC schedules meeting demand
- RUC prices reflect real-time conditions
- Simplified Bid Cost Recovery (one cost allocation)
- Overall lower performance requirements for DAM

Alternative 2 Cons

- Virtual schedules are liquidated in RUC providing hedge for demand/VER forecast in RUC, not FMM
  - FRU/FRD awards can hedge for that uncertainty
  - RUC prices would be closer to FMM prices
- VER deviation in RUC introduces a cost for ISO's VER forecast error in DAM
  - ISO can use SC's VER forecast, if historically more accurate

Proposed DAME phase 2 schedule:

Milestone	Date
WORKING GROUP MEETING	
Stakeholder workshop	November 30, 2018
Stakeholder comments due	December 21, 2018
2ND REVISED STRAW PROPOSAL & WORKING GROUP MEETING	
Stakeholder meeting	January 17, 2019
Stakeholder comments due	January 31, 2019
3RD REVISED STRAW PROPOSAL	
Stakeholder call	February 28, 2019
Stakeholder comments due	March 14, 2019
DRAFT FINAL PROPOSAL	
Stakeholder call	April 2, 2019
Stakeholder comments due	April 9, 2019
EIM GOVERNING BODY MEETING – May 1, 2019	
ISO BOARD OF GOVERNORS MEETING – May 15-16, 2019	

Appendix

Alternative 2

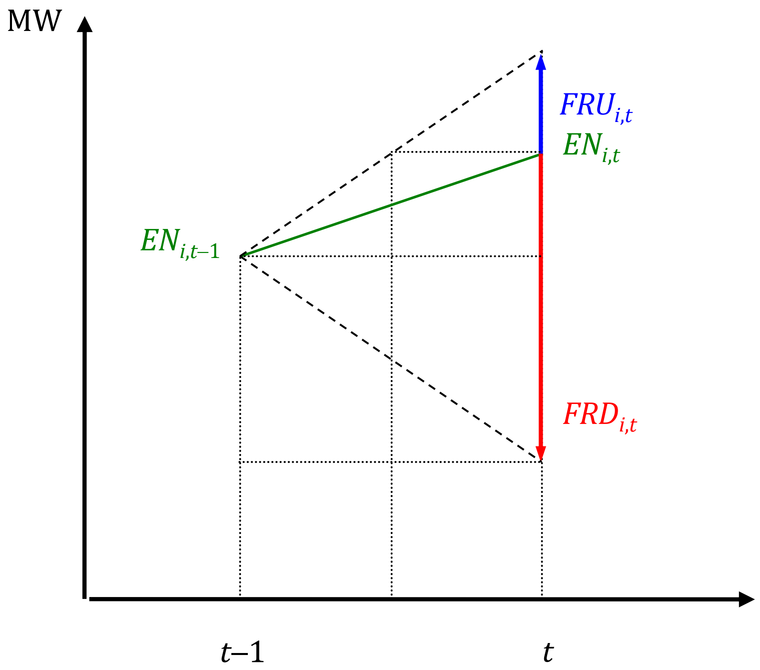
Mathematical Formulation

and

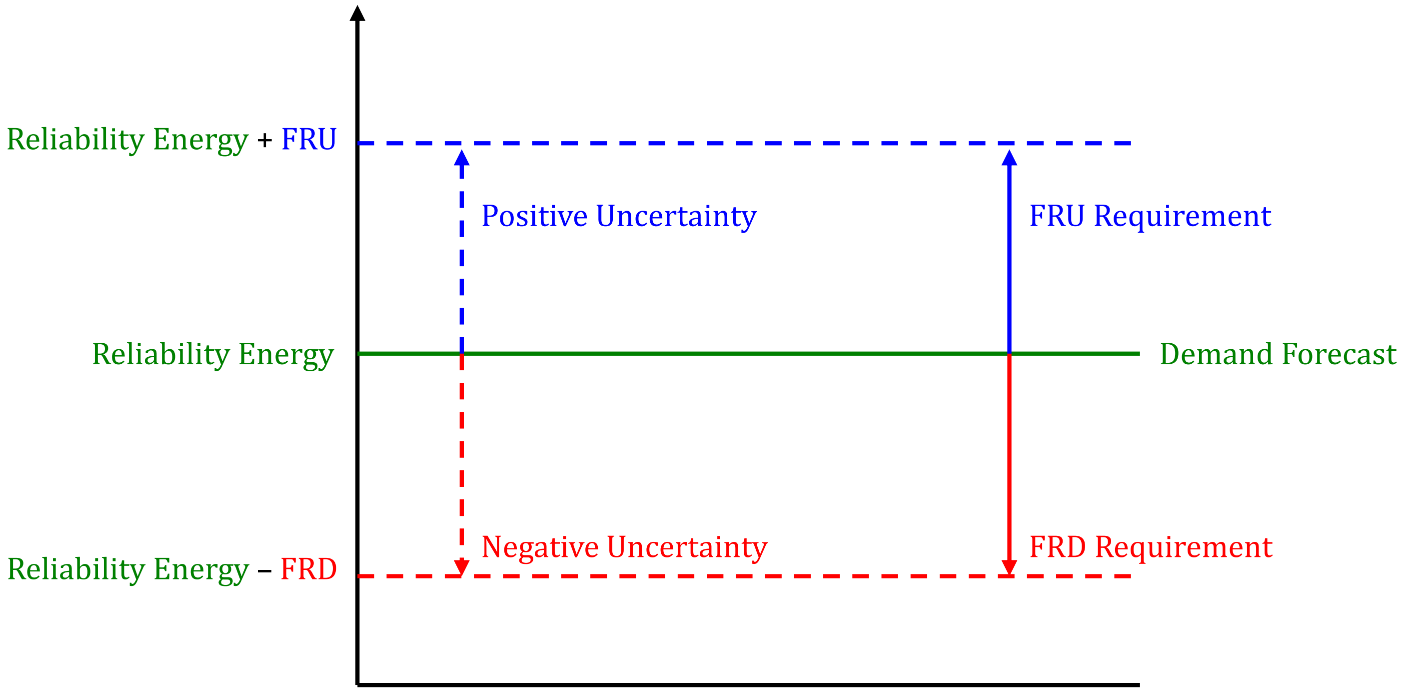
Settlements

What is Reliability Energy and Flexible Ramp?

- Reliability Energy
  - The physical supply that meets the demand forecast
- Flexible Ramp
  - Reserved up/down ramping capacity at t–1 to be dispatched at t to meet up/down uncertainty



Reliability Unit Commitment Targets



Power Balance and Flexible Ramp Procurement Constraints in RUC

$$\sum_i EN_{i,t}^{(RUC)} = D_t^{(RUC)} \qquad \lambda_t^{(RUC)}$$

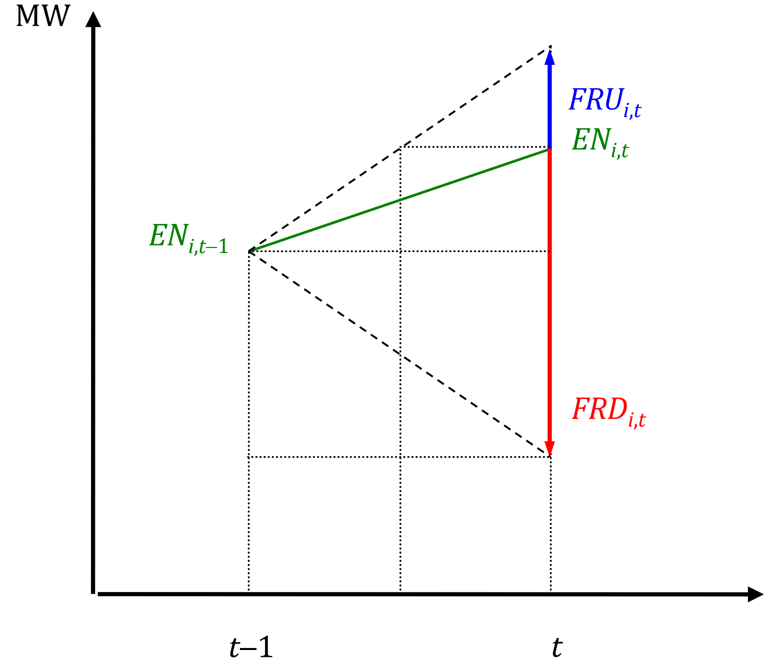
$$\sum_i FRU_{i,t}^{(RUC)} \geq FRUR_t^{(RUC)} \qquad \rho_t^{(RUC)}$$

$$\sum_i FRD_{i,t}^{(RUC)} \geq FRDR_t^{(RUC)} \qquad \sigma_t^{(RUC)}$$

Energy and Flexible Ramp Capacity and Ramping Constraints in RUC

- Capacity Constraints

$$EN_{i,t} + FRU_{i,t} \leq UEL_{i,t}$$
$$EN_{i,t} - FRD_{i,t} \geq LEL_{i,t}$$



- Ramping constraints

$$EN_{i,t} + FRU_{i,t} \leq EN_{i,t-1} + RRU_i\left(EN_{i,t-1}\right)$$
$$EN_{i,t} - FRD_{i,t} \geq EN_{i,t-1} - RRD_i\left(EN_{i,t-1}\right)$$

Power Balance Constraint in Independent Forward Market

$$\sum_i \left(EN_{i,t}^{(IFM)} + VS_{i,t}\right) = \sum_i \left(L_{i,t}^{(IFM)} + VD_{i,t}\right) + Loss_t \quad \lambda_t^{(IFM)}$$

Independent Forward Market Settlement No Change

- Physical Supply
  - $-EN_{i,t}^{(IFM)}\ \lambda_t^{(IFM)}, t = 1,2,\ldots,T$
- Virtual Supply
  - $-VS_{i,t}\ \lambda_t^{(IFM)}, t = 1,2,\ldots,T$
- Virtual Demand
  - $+VD_{i,t}\ \lambda_t^{(IFM)}, t = 1,2,\ldots,T$
- Load
  - $+L_{i,t}^{(IFM)}\ \lambda_t^{(IFM)}, t = 1,2,\ldots,T$
- Marginal loss over-collection (to measured demand)
- Congestion revenue (to CRRs)

Reliability Unit Commitment Settlement

- Physical Supply
  - $-\left(EN_{i,t}^{(RUC)} - EN_{i,t}^{(IFM)}\right) \lambda_t^{(RUC)}, t = 1,2, \dots, T$
  - $-FRU_{i,t}^{(RUC)} \rho_t^{(RUC)}, t = 1,2, \dots, T$
  - $-FRD_{i,t}^{(RUC)} \sigma_t^{(RUC)}, t = 1,2, \dots, T$
- Virtual Supply
  - $+VS_{i,t} \lambda_t^{(RUC)}, t = 1,2, \dots, T$
- Virtual Demand
  - $-VD_{i,t} \lambda_t^{(RUC)}, t = 1,2, \dots, T$

Fifteen Minute Market Settlement

- Energy schedule
  - $-\left(EN_{i,b}^{(FMM)} - EN_{i,b}^{(RUC)}\right)\lambda_b^{(FMM)}$
- Flexible Ramp Up/Down awards
  - $-\left(FRU_{i,b}^{(FMM)} - FRU_{i,b}^{(RUC)}\right)\rho_b^{(FMM)}$
  - $-\left(FRD_{i,b}^{(FMM)} - FRD_{i,b}^{(RUC)}\right)\sigma_b^{(FMM)}$
- Forecasted Movement
  - $FM_{i,b}^{(FMM)} = EN_{i,a}^{(FMM)} - EN_{i,b}^{(FMM)}$
  - $-FM_{i,b}^{(FMM)}\left(\rho_b^{(FMM)} - \sigma_b^{(FMM)}\right)$

Real Time Dispatch Settlement No Change

- Energy schedule
  - $-\left(EN_{i,b}^{(RTD)} - EN_{i,b}^{(FMM)}\right)\ \lambda_b^{(RTD)}$
- Flexible Ramp Up/Down awards
  - $-\left(FRU_{i,b}^{(RTD)} - FRU_{i,b}^{(FMM)}\right)\ \rho_b^{(RTD)}$
  - $-\left(FRD_{i,b}^{(RTD)} - FRD_{i,b}^{(FMM)}\right)\ \sigma_b^{(RTD)}$
- Forecasted Movement
  - $FM_{i,b}^{(RTD)} = EN_{i,a}^{(RTD)} - EN_{i,b}^{(RTD)}$
  - $-\left(FM_{i,b}^{(RTD)} - FM_{i,b}^{(FMM)}\right)\left(\rho_b^{(RTD)} - \sigma_b^{(RTD)}\right)$

Uninstructed Deviation Settlement No Change

- Physical Supply
  - Uninstructed Imbalance Energy
    - $UD_{i,t} = EN_{i,t}^{(M)} - EN_{i,t}^{(RTD)}$
    - $-UD_{i,t}\ \lambda_t^{(RTD)}$
  - Flexible Ramping Product No Pay
    - $\min\left(\max\left(0, UD_{i,t}\right), FRU_{i,t}^{(RTD)}\right)\ \rho_t^{(RTD)} -$
      $\max\left(\min\left(0, UD_{i,t}\right), -FRD_{i,t}^{(RTD)}\right)\ \sigma_t^{(RTD)} +$
      $\min\left(\max\left(0, UD_{i,t} - FRU_{i,t}^{(RTD)}\right), \max\left(0, FM_{i,t}^{(RTD)}\right)\right)\ \left(\rho_t^{(RTD)} - \sigma_t^{(RTD)}\right) -$
      $\max\left(\min\left(0, UD_{i,t} + FRD_{i,t}^{(RTD)}\right), \min\left(0, FM_{i,t}^{(RTD)}\right)\right)\ \left(\rho_t^{(RTD)} - \sigma_t^{(RTD)}\right)$

Load Settlement

- Load Imbalance
  - $L_{i,t}^{(M)} - L_{i,t}^{(IFM)}\ \lambda_t^{(M)}$
  - Using a weighted average price:
    - $\lambda_t^{(M)} = \frac{\left(D_t^{(RUC)} - \sum_i L_{i,t}^{(IFM)}\right)\lambda_t^{(RUC)} + \left(D_t^{(FMM)} - D_t^{(RUC)}\right)\lambda_t^{(FMM)} + \sum_{\tau\in t}\left(D_\tau^{(RTD)} - D_t^{(FMM)}\right)\lambda_\tau^{(RTD)}}{\sum_{\tau\in t} D_t^{(RTD)} - \sum_i L_{i,t}^{(IFM)}}$
  - Switching to absolute-value weights when
    - $\lambda_t^{(M)} > \max\left(\lambda_t^{(RUC)}, \lambda_t^{(FMM)}, \left\{\lambda_\tau^{(RTD)}\right\}_{\tau\in t}\right)$
    - $\lambda_t^{(M)} < \min\left(\lambda_t^{(RUC)}, \lambda_t^{(FMM)}, \left\{\lambda_\tau^{(RTD)}\right\}_{\tau\in t}\right)$
  - Switching to a simple average when the denominator is zero

Uncertainty Cost Allocation

- Upward Uncertainty Cost
  - $\sum_i FRU_{i,t}^{(RUC)}\ \rho_t^{(RUC)} + \sum_i \left(FRU_{i,t}^{(FMM)} - FRU_{i,t}^{(RUC)}\right)\ \rho_t^{(FMM)} +$
    $\sum_i \left(FRU_{i,t}^{(RTD)} - FRU_{i,t}^{(FMM)}\right)\ \rho_t^{(RTD)} - \sum_i \min\left(\max(0, UD_{i,t}), FRU_{i,t}^{(RTD)}\right)\ \rho_t^{(RTD)}$
  - Allocated to upward uncertainty movement and positive UIE per category in each BAA using existing FRU cost allocation
- Downward Uncertainty Cost
  - $\sum_i FRD_{i,t}^{(RUC)}\ \sigma_t^{(RUC)} + \sum_i \left(FRD_{i,t}^{(FMM)} - FRD_{i,t}^{(RUC)}\right)\ \sigma_t^{(FMM)} +$
    $\sum_i \left(FRD_{i,t}^{(RTD)} - FRD_{i,t}^{(FMM)}\right)\ \sigma_t^{(RTD)} + \sum_i \max\left(\min(0, UD_{i,t}), -FRD_{i,t}^{(RTD)}\right)\ \sigma_t^{(RTD)}$
  - Allocated to downward uncertainty movement and negative UIE per category in each BAA using existing FRD cost allocation

Forecasted Movement Cost Allocation

- Forecasted Movement Cost
  - $\sum_i FM_{i,t}^{(FMM)}\left(\rho_t^{(FMM)} - \sigma_t^{(FMM)}\right) +$
    $\sum_i \left(FM_{i,b}^{(RTD)} - FM_{i,b}^{(FMM)}\right)\left(\rho_t^{(RTD)} - \sigma_t^{(RTD)}\right) -$
    $\sum_i \min\left(\max\left(0, UD_{i,t} - FRU_{i,t}^{(RTD)}\right), \max\left(0, FM_{i,t}^{(RTD)}\right)\right)\left(\rho_t^{(RTD)} - \sigma_t^{(RTD)}\right) +$
    $\sum_i \max\left(\min\left(0, UD_{i,t} + FRD_{i,t}^{(RTD)}\right), \min\left(0, FM_{i,t}^{(RTD)}\right)\right)\left(\rho_t^{(RTD)} - \sigma_t^{(RTD)}\right)$
  - Allocated pro rata to BAA metered demand

Real-Time Imbalance Offset Allocation

- Real-Time Imbalance Energy Offset
  - $\sum_i \left(EN_{i,t}^{(RUC)} - EN_{i,t}^{(IFM)}\right) \lambda_t^{(RUC)} -$
    $\sum_i (VS_{i,t} - VD_{i,t}) \lambda_t^{(RUC)} +$
    $\sum_i \left(EN_{i,t}^{(FMM)} - EN_{i,t}^{(RUC)}\right) \lambda_t^{(FMM)} +$
    $\sum_i \left(EN_{i,t}^{(RTD)} - EN_{i,t}^{(FMM)}\right) \lambda_t^{(RTD)} +$
    $\sum_i \left(EN_{i,t}^{(M)} - EN_{i,t}^{(RTD)}\right) \lambda_t^{(RTD)} - \sum_i \left(L_{i,t}^{(M)} - L_{i,t}^{(IFM)}\right) \lambda_t^{(M)} +$
    $UFE_t + GHG_t$
  - Allocated to each BAA and distributed according to their OATT