Co-optimization of Congestion Revenue Rights in ERCOT Day-Ahead Market
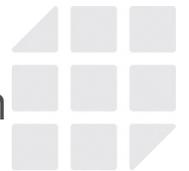
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FERC Conference on increasing real-time and day-ahead market efficiency through improved software - June 24-26, 2013

Agenda

- ERCOT Day Ahead Market (DAM) Overview

- Congestion Revenue Rights (CRRs) in DAM
  - Co-optimization
  - Benefits
  - Challenges

- ERCOT Experiences
  - Dead Bus Issue
  - Virtual Power Divergence
  - Evaluating CRR Options in Contingency Analysis
  - CRR Option Modeling Reform in DAM

- Summary

ERCOT Overview

- Transformed from zonal to nodal market structure in December 2010

- ERCOT market covers 85% of Texas' overall power usage

- Record peak demand of 68,305 MW (occurred on August 3, 2011)

- 550 generating units including 60 combined-cycle generation plants

- More than 10,000 MW wind generation capacity installed – the most in US

- Record wind net power output of 9,674 MW (occurred on May 2, 2013)
    - Wind was supplying 28.05% of the 36.164 MW load

- Market size about $34 billion

ERCOT Day Ahead Market

- DAM is a voluntary and financially binding market which co-optimizes
  - Supply side:
    - Energy offers (3 part offers)
    - Ancillary Service offers (Reg-up, Reg-down, Responsive Reserve, Non-Spin)
    - Energy-only offers (virtual)
    - CRR offers (subset of CRR options held by Non-Opt-In-Entities via CRR allocation and auction process)
  - Demand side:
    - Energy-only bids (virtual)
    - CRR bids (referred to in ERCOT DAM terminology as PTP obligation bids)
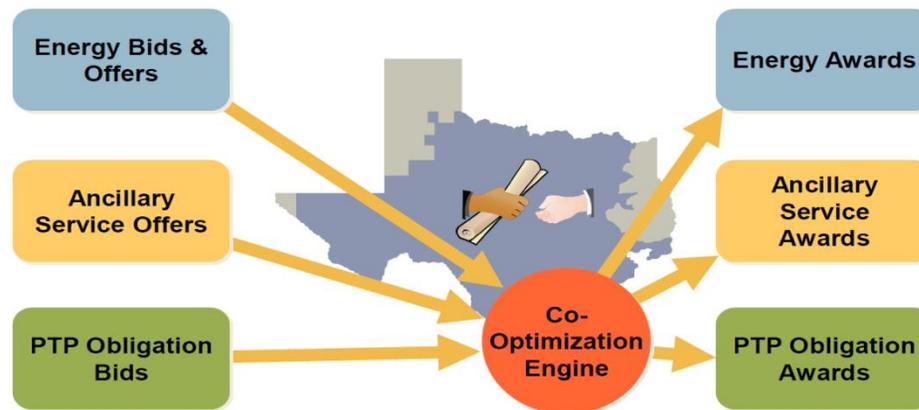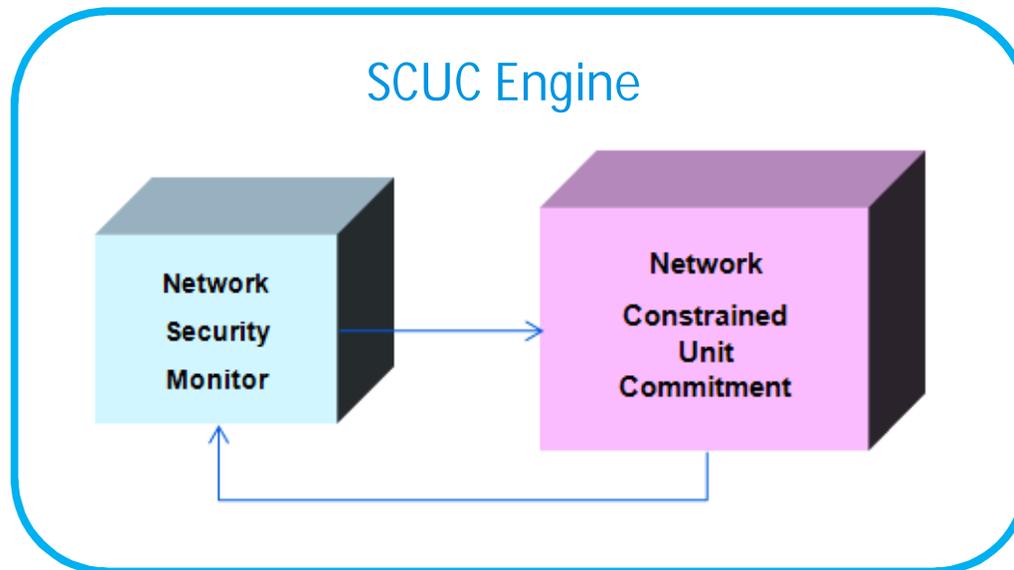
ERCOT Day Ahead Market

- DAM network security constraints include

- 6000 buses

- 4000+ contingencies

- Enforce thermal limits ≥ 60 KV transmission lines

- Enforce generic constraints

- Automatic optimize phase shifter tap positions to relieve congestions

- Model Special Protection Scheme (SPS) Triggering

- Simulate load rollover schemes
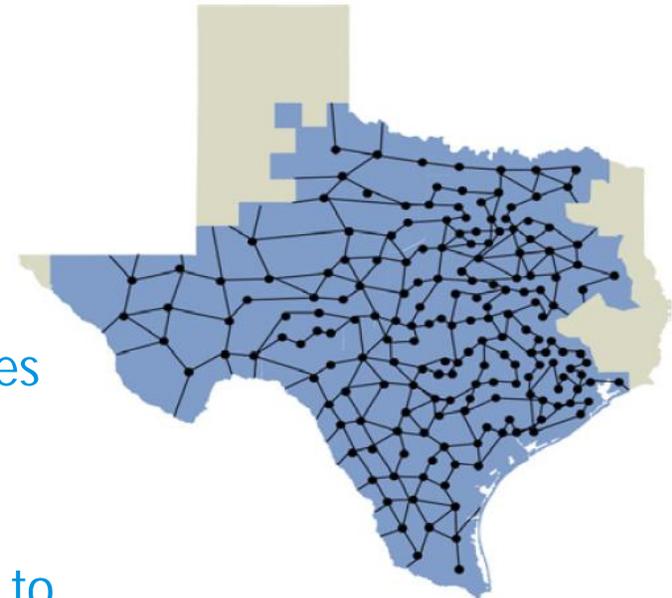
DAM Solution Engine

- Security Constrained Unit Commitment (SCUC) market clearing engine utilizing:
  - Network Security Monitor (NSM)
  - Network Constrained Unit Commitment (NCUC)

- Two modules iterate until the optimal solution is reached
  - normally takes 6 to 7 iterations

SCUC Engine

Network Security Monitor

Network Constrained Unit Commitment

CRRs Markets in ERCOT

- In ERCOT, CRRs can be acquired in two market places:
  - CRR Auction and/or allocation
    - Allocation of CRR to only a subset of market participants (Non-Opt-In-Entities)
  - Day-Ahead Market

- In ERCOT, CRRs are Point to Point (PTP) financial rights designated between any two Settlement Points (source and sink). There are 500+ Settlement Points in ERCOT grid
  - Resource nodes
  - Load zones
  - Hubs
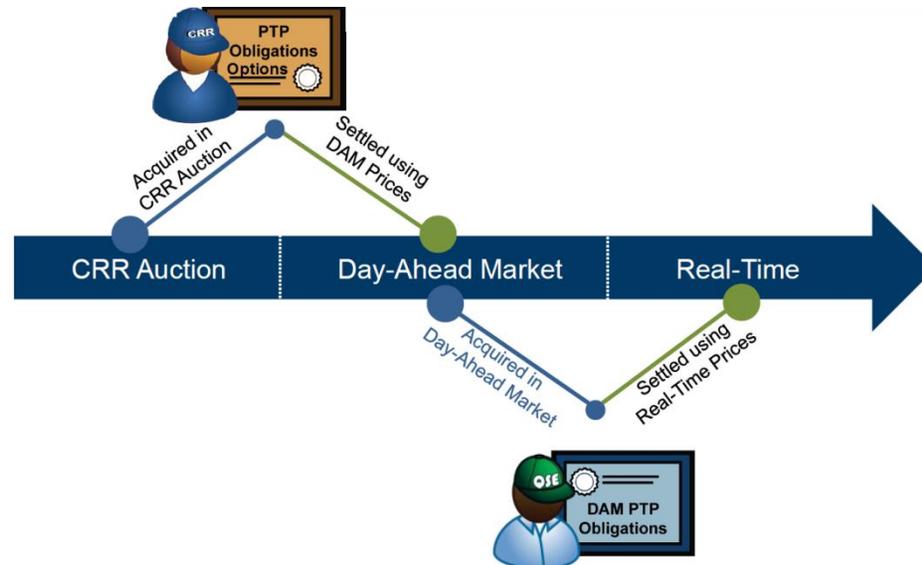
CRRs in Day Ahead Market

- Payment or charge to CRR owners when transmission grid is congested
  - Purchased at DAM price spread
  - Settled at Real-Time price spread

- Tie-breaking rules applied to CRR bids with same prices – unique optimal solution


$5/MWh

$10/MWh

Sink B

Source A
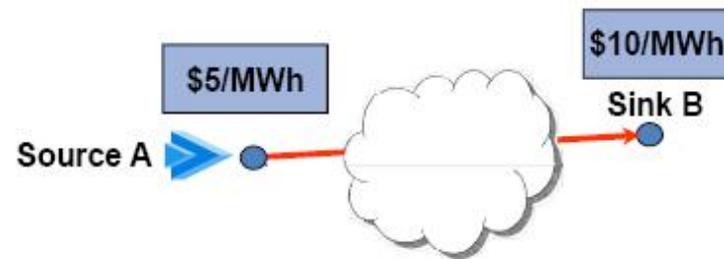
- Two instruments:
  - Point to point obligations
  - Point to point options*

  (* Only a subset of market participants have the ability to have CRR Options that are settled in Real-time. Prior to February 2013, Point to point options were modeled in the DAM SCUC process as unidirectional flows – i.e. no counter flow. From February 2013, Point to point options are modeled as obligations but settled as options)

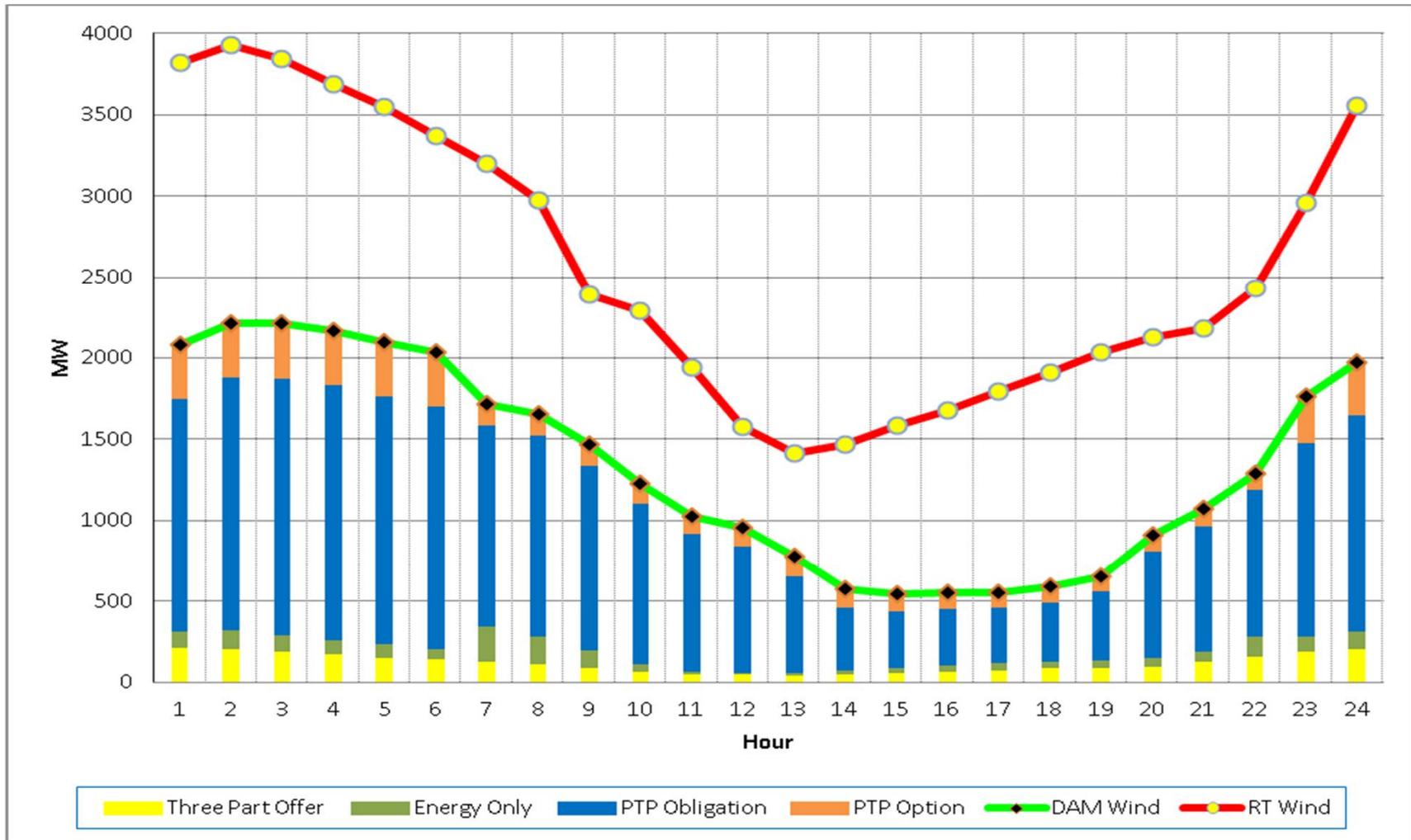VENTYX
AN ABB COMPANY

Who are buying CRR in DAM

- **Bilateral Contract Owners – Financial Hedge**
  - Locking in the price of congestion at the cost of purchasing for price certainty

- **Speculators – Financial Investment**
  - Purchased as a financial tool to speculate if congestion rent in real-time is higher than purchase price
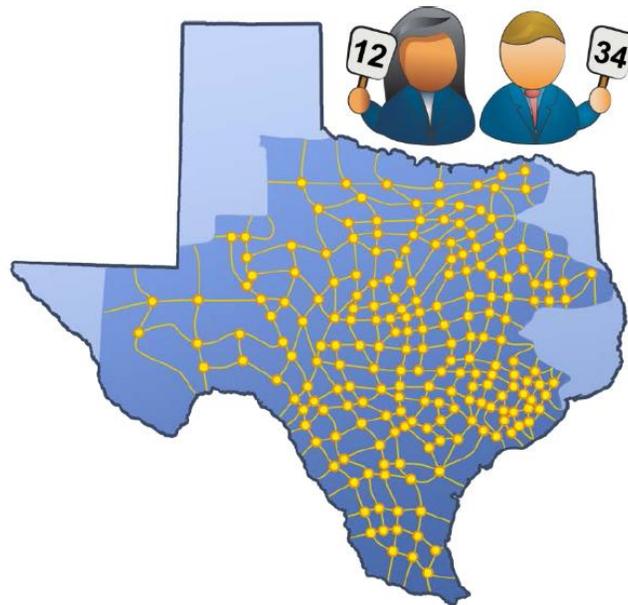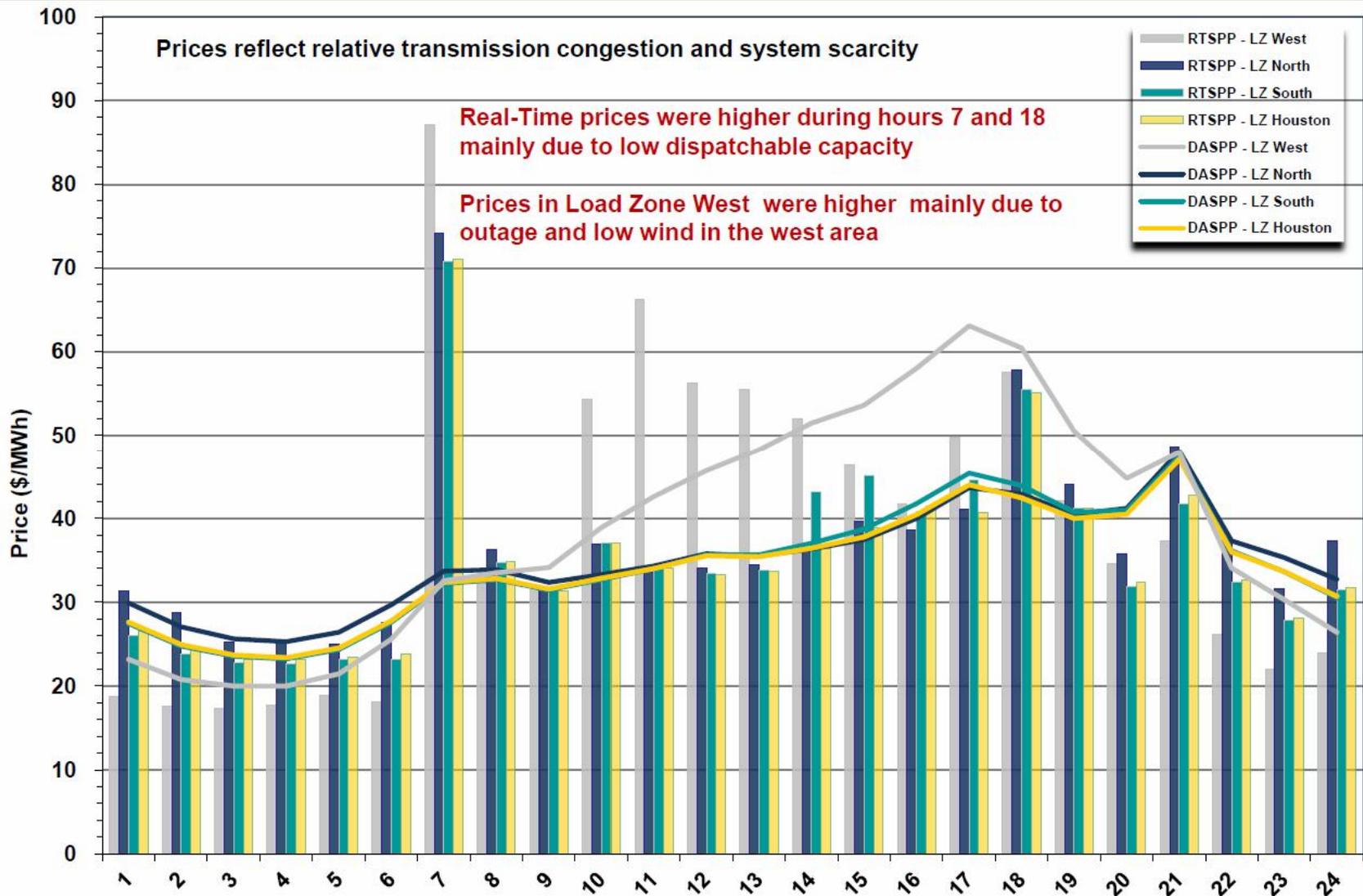
Benefit of CRR Co-optimization in DAM

- Market participants:
  - More flexibilities comparing to long-term CRR auctions
  - Adjusting hedging strategies based on expecting system condition changes
  - Adjusting investment portfolios based on changing market opportunities

- ISOs:
  - Reflecting effects of bilateral contracts outside DAM
  - Reflecting effects of non-participating generations and loads
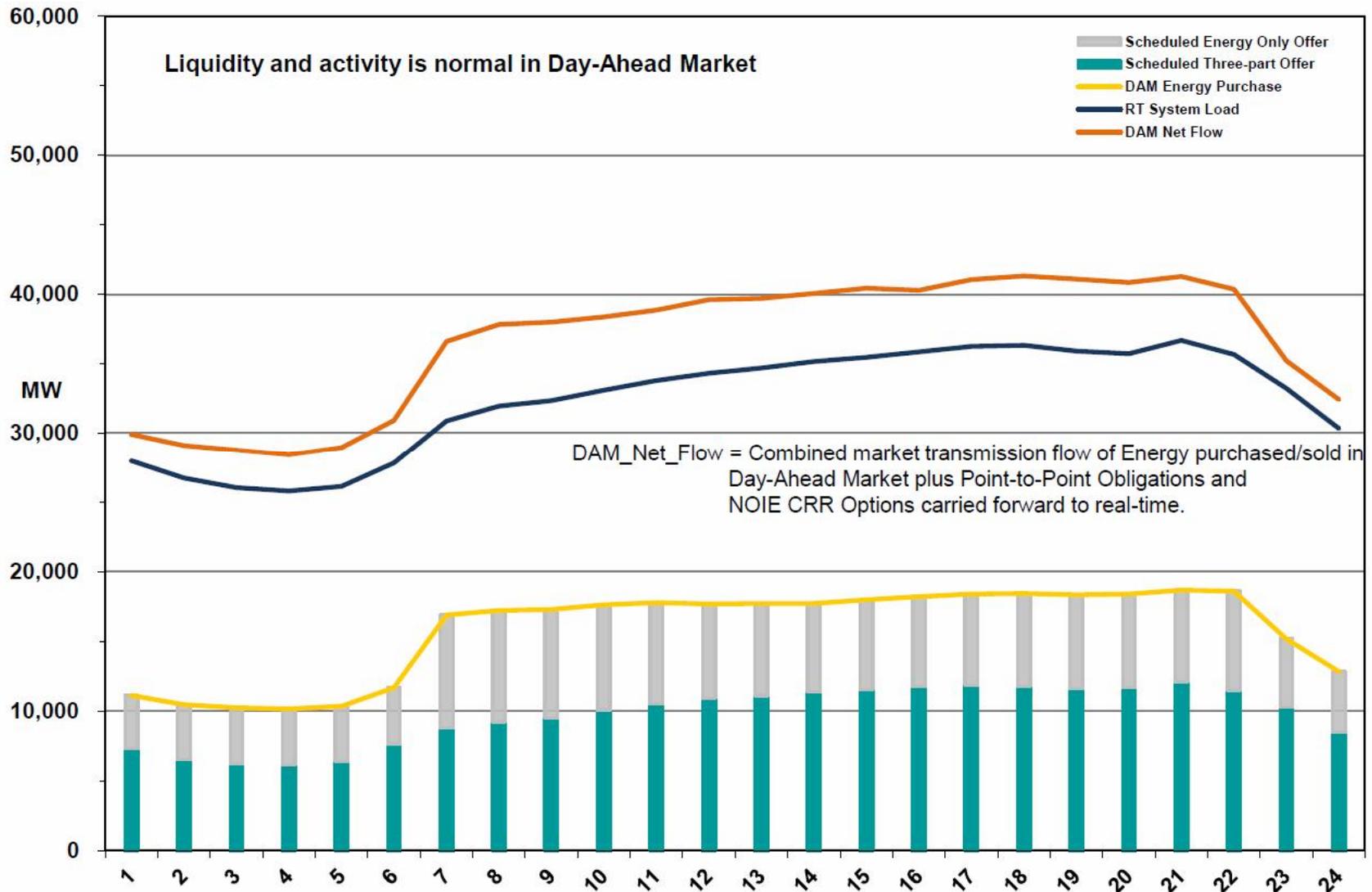 - Improving Day-Ahead and Real-Time market convergence

Wind Generation in DAM

Day-Ahead vs Real-Time Prices – April 2013

Day-Ahead Awards – April 2013

Liquidity and activity is normal in Day-Ahead Market

Legend:
- Scheduled Energy Only Offer
- Scheduled Three-part Offer
- DAM Energy Purchase
- RT System Load
- DAM Net Flow

DAM_Net_Flow = Combined market transmission flow of Energy purchased/sold in Day-Ahead Market plus Point-to-Point Obligations and NOIE CRR Options carried forward to real-time.

Challenges of CRR Co-optimization in DAM

- Large bid volumes – more decision variables

- Large combinations of sources and sinks – more transmission constraints

- Bus splitting contingencies – need to keep tracking bid locations

- Block CRR bids – more integer variables added to Mixed Integer Programming (MIP) problems

- Numerical complexities for CRR option evaluations

- ERCOT Experiences:
  - Dead bus issue
  - Virtual power flow divergence
  - Evaluating CRR options in contingency analysis
  - CRR option modeling reform in DAM

Dead Bus Issue

- ERCOT pricing rules for de-energized resource nodes:

- Use average LMP for Electrical Buses within the same station having the same voltage level as the de-energized Electrical Bus, if any exist

- Use average LMP for all Electrical Buses within the same station, if any exist.

- Use system lambda

- When breaker status changes cause some buses de-energized in real-time, artificial LMP spreads are created.

Dead Bus Example

- In Day Ahead, B1, B2, B3 closed, B4 open

- PTP obligations from R1 to R2 are $0
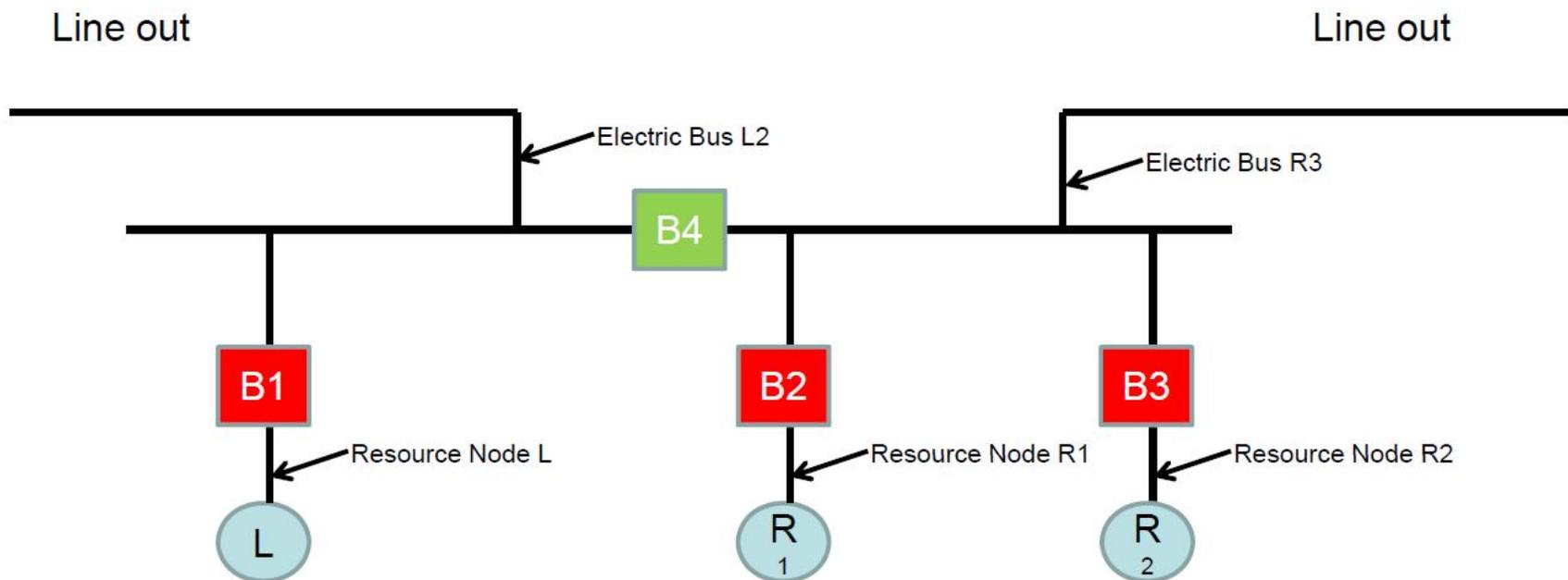
Dead Bus Example

- In Real-Time, B1, B2 closed, B3, B4 open

- R2 LMP = AVG (LMP_L, LMP_{R1}, LMP_{L2}. LMP_{R3})

- PTP Obligations from R1 to R2 have non-zero value
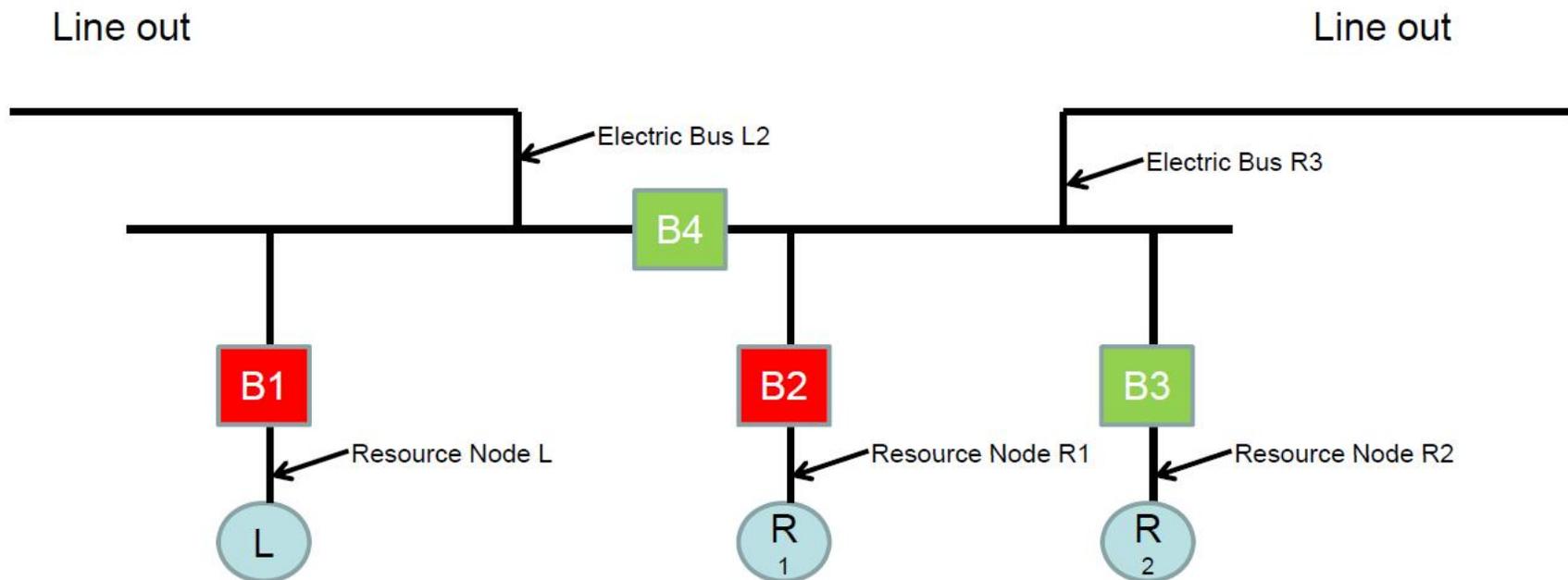
Solutions to Dead Bus Issue

- **Immediate remedies**
  - Adding Electrical Buses: Adding 609 Electrical Buses to 140 Stations
  - Heuristic Substation Rules: Using LMP from a predefined candidate list to replace LMP of the dead bus

- **Permanent solution: Electrical Similar Settlement Point (ESSP) Feature**
  - DAM treats two settlement points as Electrical Similar Settlement Points (ESSPs) if
    - Settlement points mapped to same power flow bus
    - Impedance between two settlement points is less than 0.0005 pu and rating greater than 9000 MVA
  - At 5:00 AM, DAM determines and posts a set of advisory ESSP pairs
  - At 10:00 AM, DAM determines the final ESSP pairs to be used in DAM clearing
  - SCUC clear engine will not award any CRR bids placed between ESSP pairs
  - Final ESSP pairs are posted after DAM cleared

Virtual Power Flow Divergence

Virtual Power Flow Divergence

- What happened on June 24, 25 and 26,
  - Market Participants over-reacted to the news causing extremely high volumes of CRR bids in all locations
  - Power flow failed to converge for all peak hours
  - Most of transmission facilities were overloaded

- Key features for DAM SCUC to survive under such stress conditions
  - Watch-list constraints
  - Power flow security limit constraints
  - Intelligent critical constraint set management

- DAM SCUC took ~20 iterations and eventually reached optimal solution

Evaluating CRR Options in Contingency Analysis

- In order to maintain revenue adequacy, while evaluating CRR options in power flow analysis, only negative congestion impacts are considered, i.e., unidirectional flows

- Super-position law does not hold; options need to be evaluated one-by-one
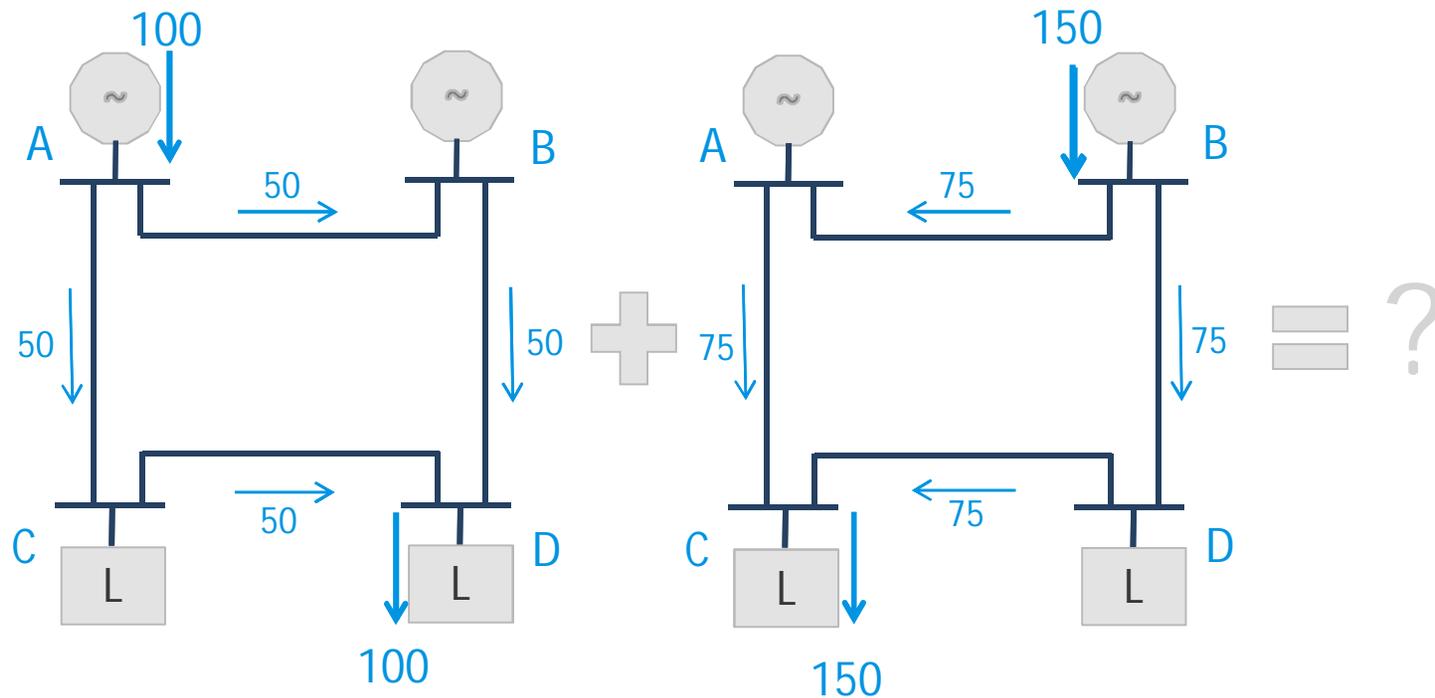
Evaluating CRR Options in Contingency Analysis

- Base Case Power Flow
  - Solve [B'][Θ]=[P] for all CRR options
  - Only add negative impacts to a specific flow direction and ignore counter flows

- How about contingency analysis?
  - Assuming 100 CRR options, 2,500 contingencies, 24 hours

- Need to perform fast forward/backward matrix operations 6 million times
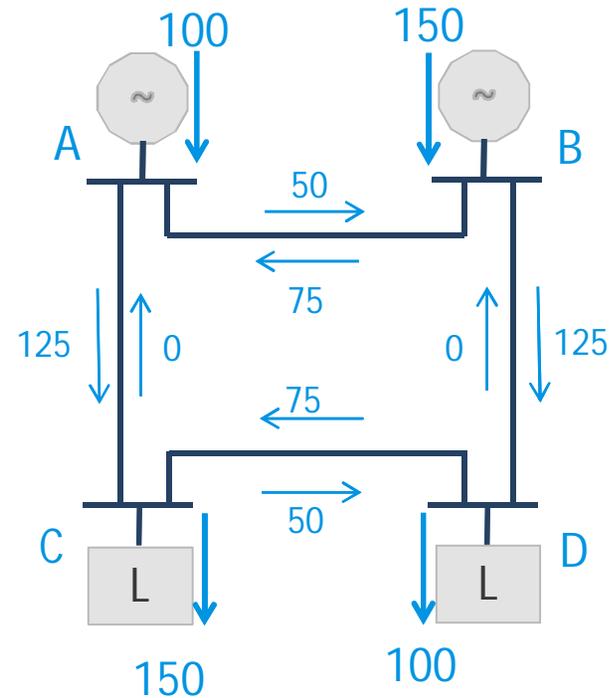
Evaluating CRR Options in Contingency Analysis
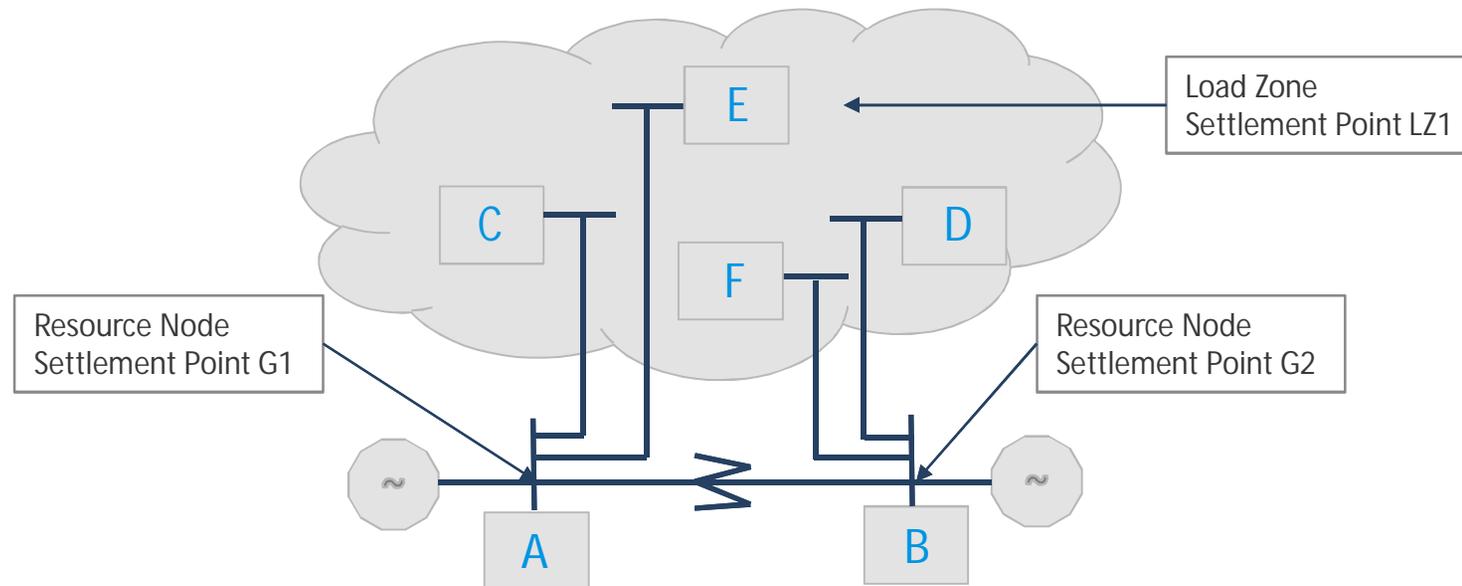
- Perform incremental contingency analysis

- Apply modern parallel computation technologies

$+P_{ct}$ $-P_{ct}$
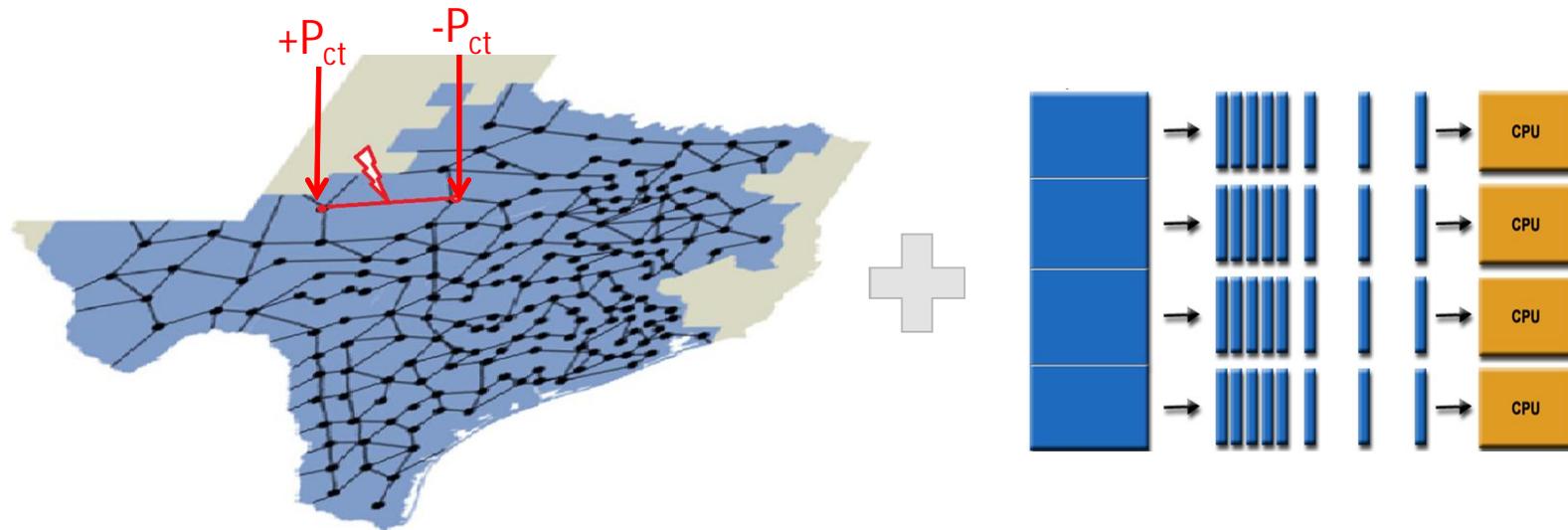
- Network Security Monitor (NSM) performance improved from 1+ minutes to 5 seconds per study interval

CRR Option Modeling Reform in DAM

- Unexpected issue of a transformer flow binding in both directions for two different contingencies due to option modeling (no counter-flow).

Load Zone Settlement Point LZ1

Resource Node Settlement Point G1

Resource Node Settlement Point G2

- After stakeholder discussions, it was decided to model options as obligations (i.e. provide counter-flow) but settle them in real-time as options

Summary

- Co-optimizing CRR in DAM is good for both Market Participants and ISOs
  - Providing market participants a flexible hedge/investment tool
  - Helping Day-Ahead and Read-Time market convergence

- Lots of technical and operational challenges but improving overall market efficiency significantly

- ERCOT experiences can be useful to other ISOs

Thank You