OE Visualization and Controls Peer Review

Market Monitoring Tools

Bernie Lesieutre – LBNL

Bob Thomas - Cornell

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Market Monitoring Tools: Overview

Approach: Use dispatch, profit, revenue/offer price, withholding sensitivities to identify opportunities for local advantage that give some participants market power potential.

2006 Technical Work:

Extend prior results to large, RTO-scale systems.

Initiate large-scale analysis with RTO (PJM).

Evaluate reactive power effects on energy markets.

Publication and presentation of results.

Market Power: Substitutability

Market power boils down to the issue of *substitutability*

Locational Advantage: “Load Pockets”

- Physical network constraints limit supply to certain loads, so that the incremental demand can only be supplied by a few suppliers.

- These suppliers can raise prices without changing dispatch because their supply is not substitutable.

Market Power Screens

- Automatic screens are based on concentration measures:
  - HHI
  - Pivotal Supplier
  - Residual Supplier Index
  - Market Share Analysis

  These may be applied to capacity, uncommitted capacity, dispatch, fuel type, geography, etc.
- Other screens are based on historical behavior (conduct)

  These are useful screens.

  Limitation: They do not use a physical model to explicitly account for network effects and real-time operation.

Sensitivity Approach

Dispatch, Profit, Revenue/Offer-price, withholding sensitivity

- We calculate and analyze sensitivities to identify load pockets and market participants with market power potential.
- This approach relies on an explicit representation of the physical electric network.
- The use of a physical model distinguishes this approach from concentration measures (HHI, etc.) and analysis of historical data (AMP conduct and impact tests).

Sensitivity Approach

Our approach to Market Power Monitoring uses sensitivity matrices:

- Dispatch Sensitivities

$$\Delta g = M\Delta\lambda$$

- Revenue Sensitivities

$$\Delta r = N\Delta\lambda$$

where

$$N = diag(g) + diag(\lambda)M$$

Sensitivity Analysis

Technical Challenges for Large Systems

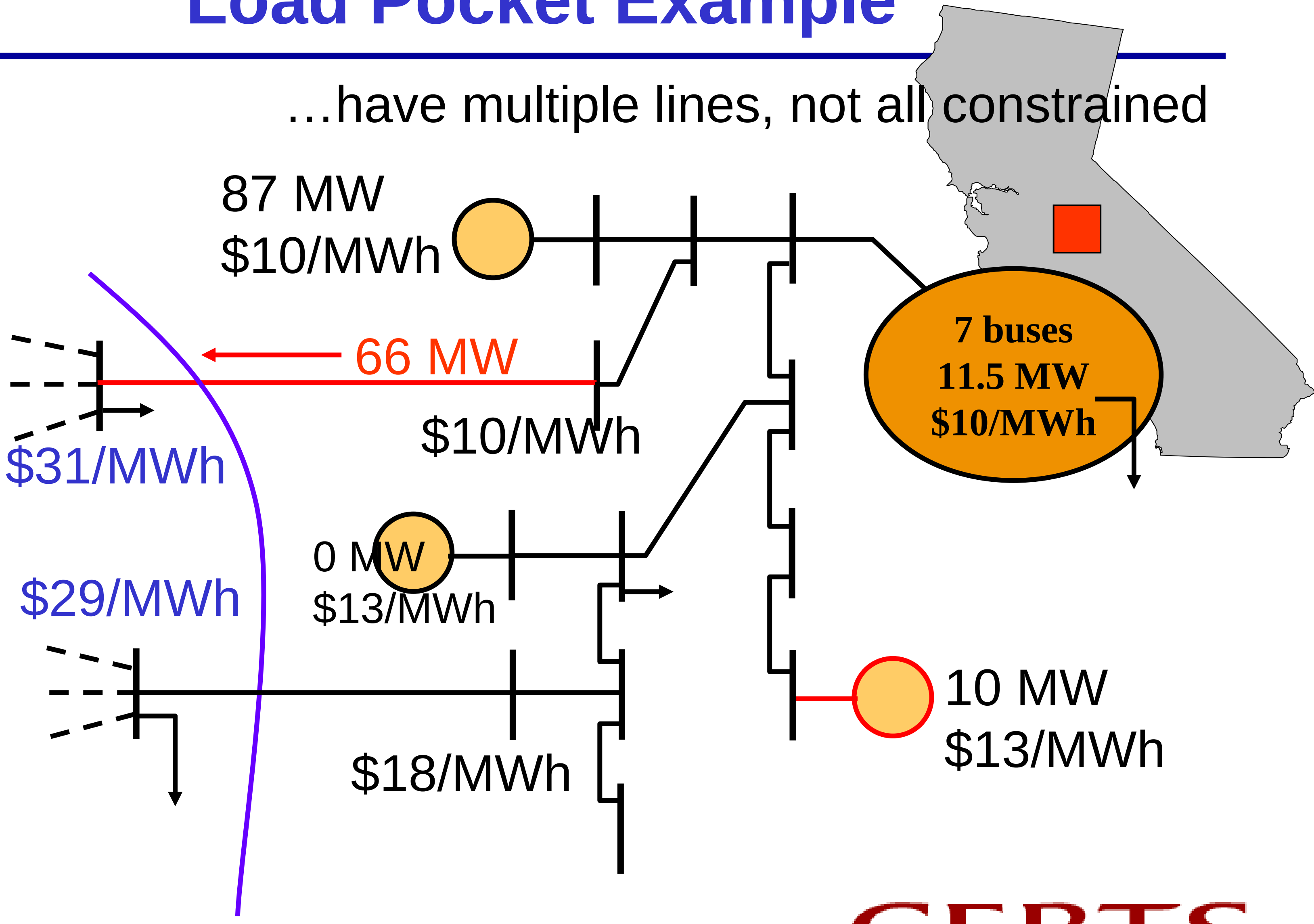
- Computation of Sensitivity Matrices
  - Commercial power flow solvers do not provide this information … yet. Approximation developed.
- Evaluation of Sensitivity Matrices
  - Algorithm based on clustering highly correlated rows in null space basis.
- Theoretical Justification for our Approach
  - Why are the *rows* of the null space basis correlated?

Application

- Western grid (representative model)
- PJM (upcoming analysis)

Load Pocket Example

…have multiple lines, not all constrained



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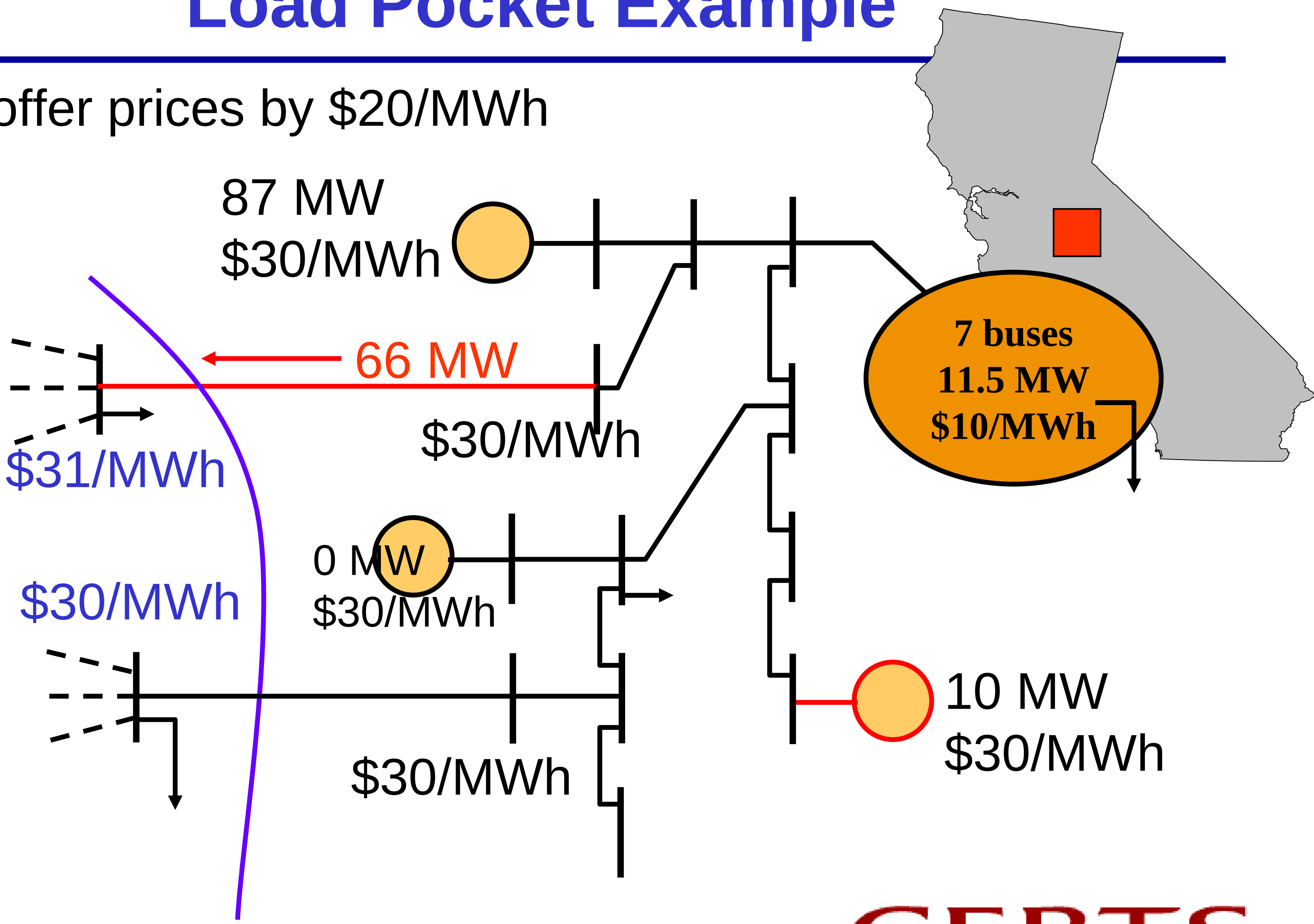
Load Pocket Example

Raise offer prices by $20/MWh



Application - PJM

We are in discussion with PJM about applying our sensitivity-based studies to their system.

Step 1. NDA.

Step 2. Understand their models.

Step 3. Adapt our methods to their specific models.

Step 4. Apply our techniques to identify participants with market power potential, using snapshots they provide.

Step 5. Compare with their analyses.

Step 6. Determine next steps.

Reactive Market Power

- The focus of the deregulation is mainly active power adequacy
- No financial reward for reactive power
- Reactive power dispatch to preserve system operational reliability
- Change in the payment policy might affect market power structure

Reactive Power Pricing

- Optimization problem to minimize the active power cost
- Reactive power dispatch is part of constraints
- Price of reactive power
- If not binding, free
- If binding, LMP

- Dispatch Sensitivity matrix

$$\begin{pmatrix} \Delta g \\ \Delta q \end{pmatrix} = \begin{bmatrix} M_{gg} & M_{gq} \\ M_{qg} & M_{qq} \end{bmatrix} \begin{pmatrix} \Delta \lambda \\ \Delta \lambda_q \end{pmatrix}$$

→ Only λ is accessible

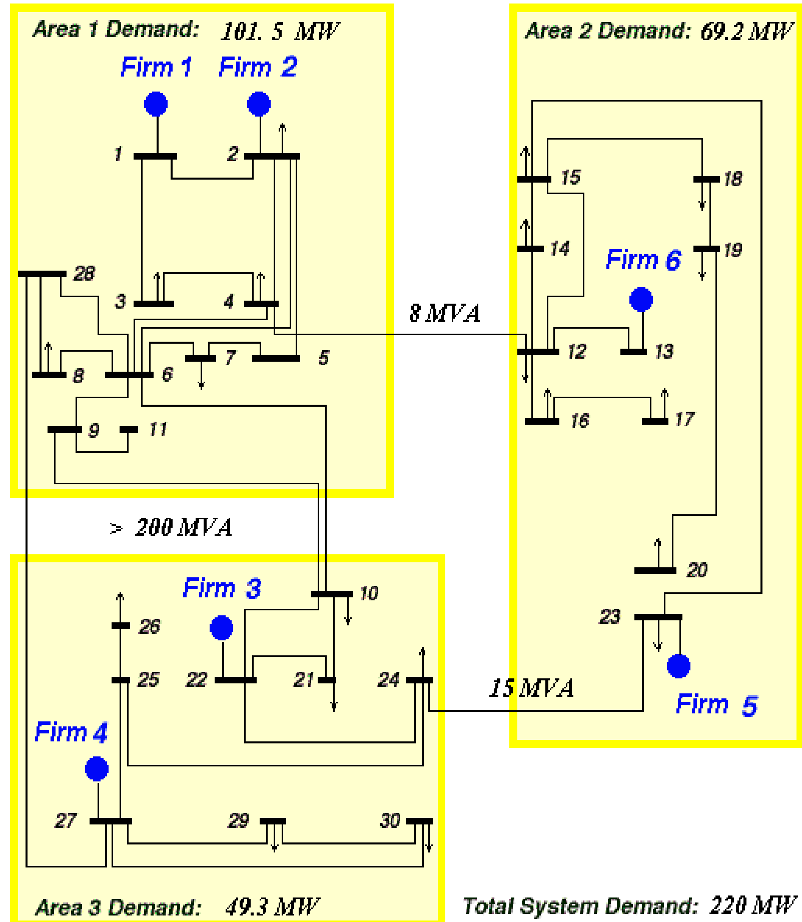
- More convenient formula

$$\begin{pmatrix} \Delta g \\ \Delta q \end{pmatrix} = \begin{bmatrix} M_{gg} + M_{gq} R \\ M_{qg} + M_{qq} R \end{bmatrix} \Delta \lambda = \begin{pmatrix} M_g \\ M_q \end{pmatrix} \Delta \lambda$$

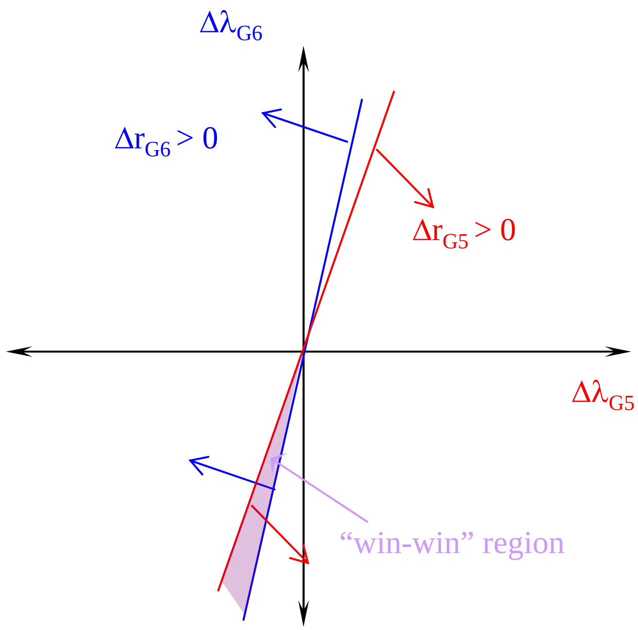
$$where \quad \Delta \lambda_q = R \Delta \lambda$$

Simulation Environment

- Modified IEEE-30 bus system →
- Two lines connecting Area1-2 and Area 3-2 have small capacities
- High Q-demands around Firm 2 and 6
- Offers
  - Cheap Firm 3,4
  - Intermediate Firm 1,2
  - Expensive Firm 5,6

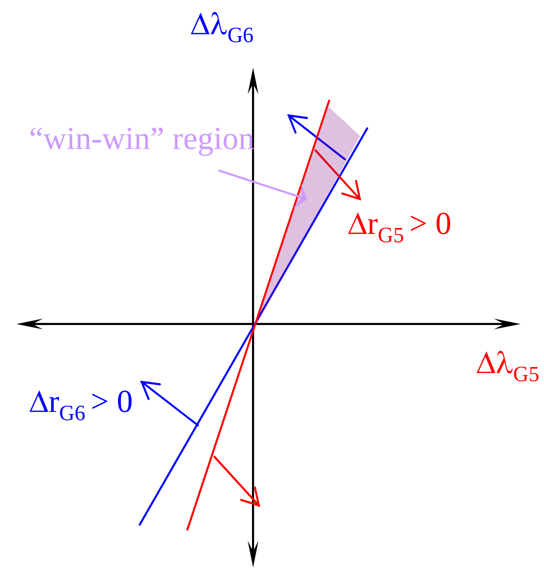


Case Study I



No reward for reactive power

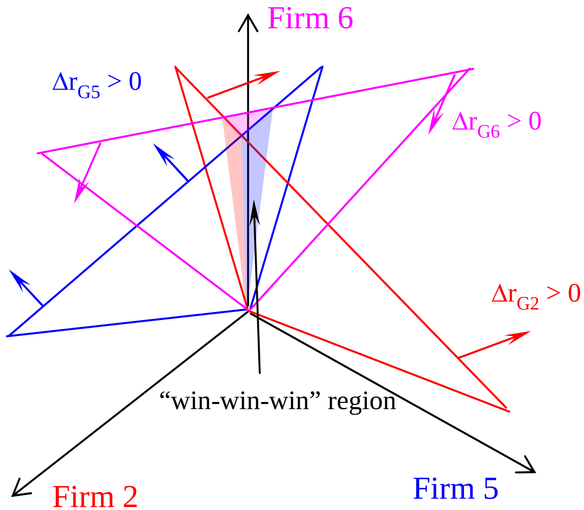
Competitive energy market

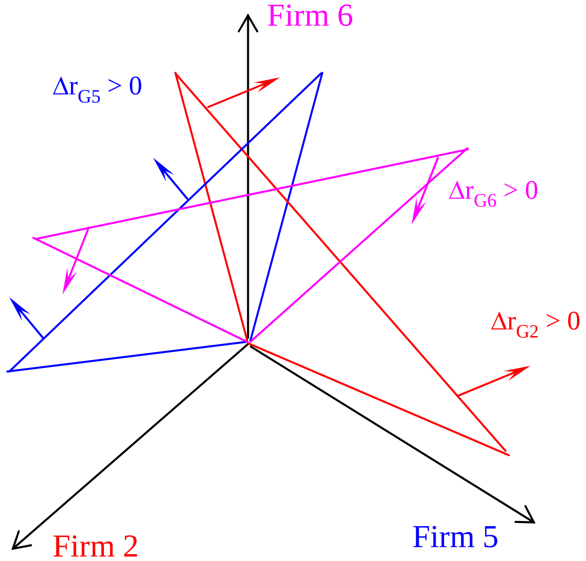


Reactive power payments

Market power in energy market

Case Study II





No financial reward for reactive power.

Market power potential for three firms

Reactive power payments.

Competitive Energy Market

Reactive Market Power Summary

- Market power structure depends on the payment policy
- The relationship between the changes in active and reactive prices is a key to estimate the change in market power
- A new method to measure dependence of change in reactive power price on that in real power price has been developed and tested

Sensitivity Analyses and Transmission Bottlenecks

Modeling Issues:

- AC vs DC power flow models
- Use of proxy limits, i.e. voltage limits expressed as line constraints.

Usage:

- Aid in evaluating transmission bottlenecks
- Aid in expansion planning to support market functions
- Resolve relation between proxy limits and LMP
- Partial bottleneck metric