Overview of Restructured Electricity Markets: Locational Marginal Pricing

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Course materials available from:

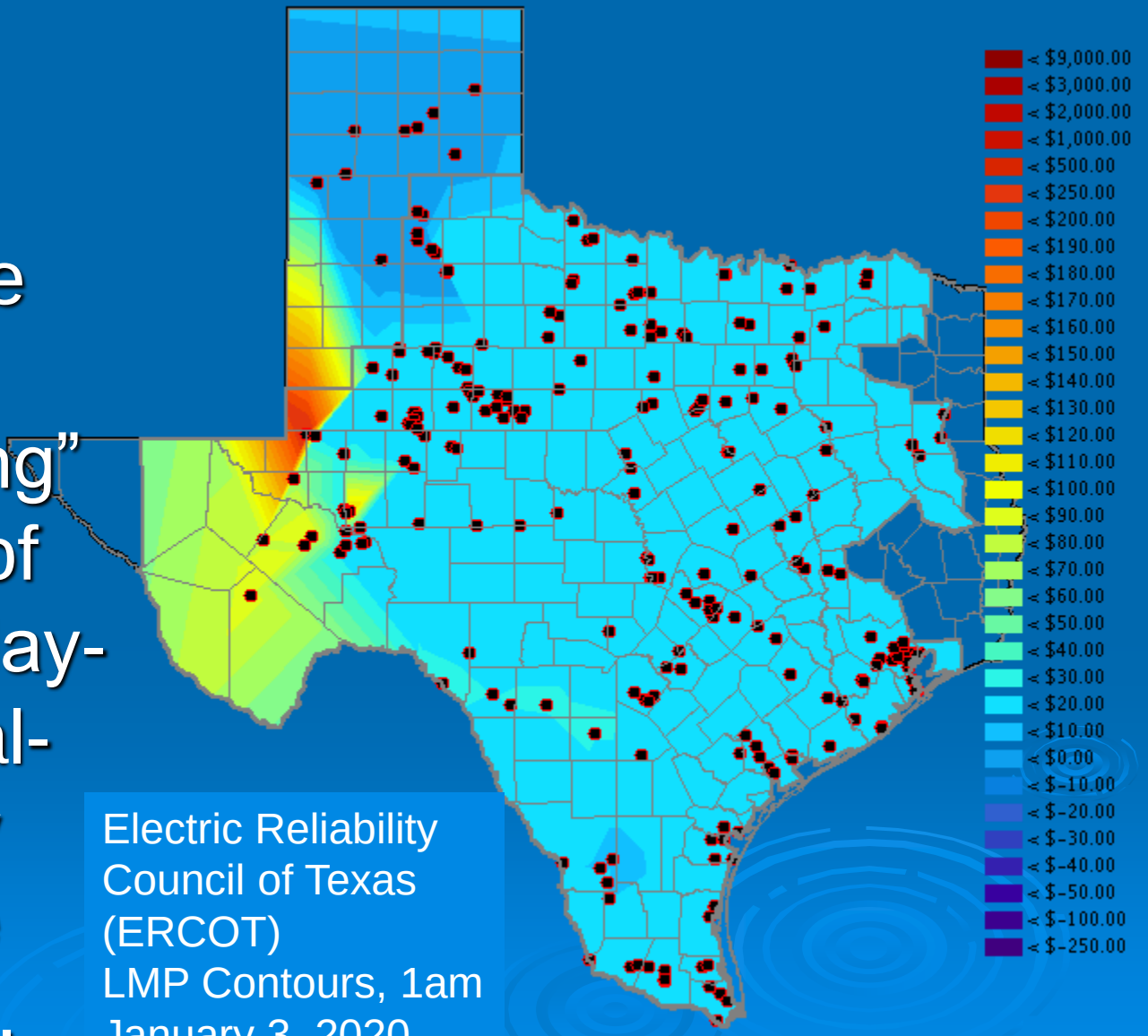
www.ece.utexas.edu/~baldick/classes/394V/EE394V.html

Outline

- Focus of class
- Challenges
- Importance
- Approach
- Main topics
- Teaching this class

Focus of class

- Rigorously develop and understand the "locational marginal pricing" (LMP) model of "centralized" day-ahead and real-time electricity markets at the graduate level.



Electric Reliability Council of Texas (ERCOT)
LMP Contours, 1am
January 3, 2020

Focus of class

- LMP used in Eastern and Midcontinent United States, California, Southwest Power Pool, ERCOT, Mexico, New Zealand, Russia.

Focus of class

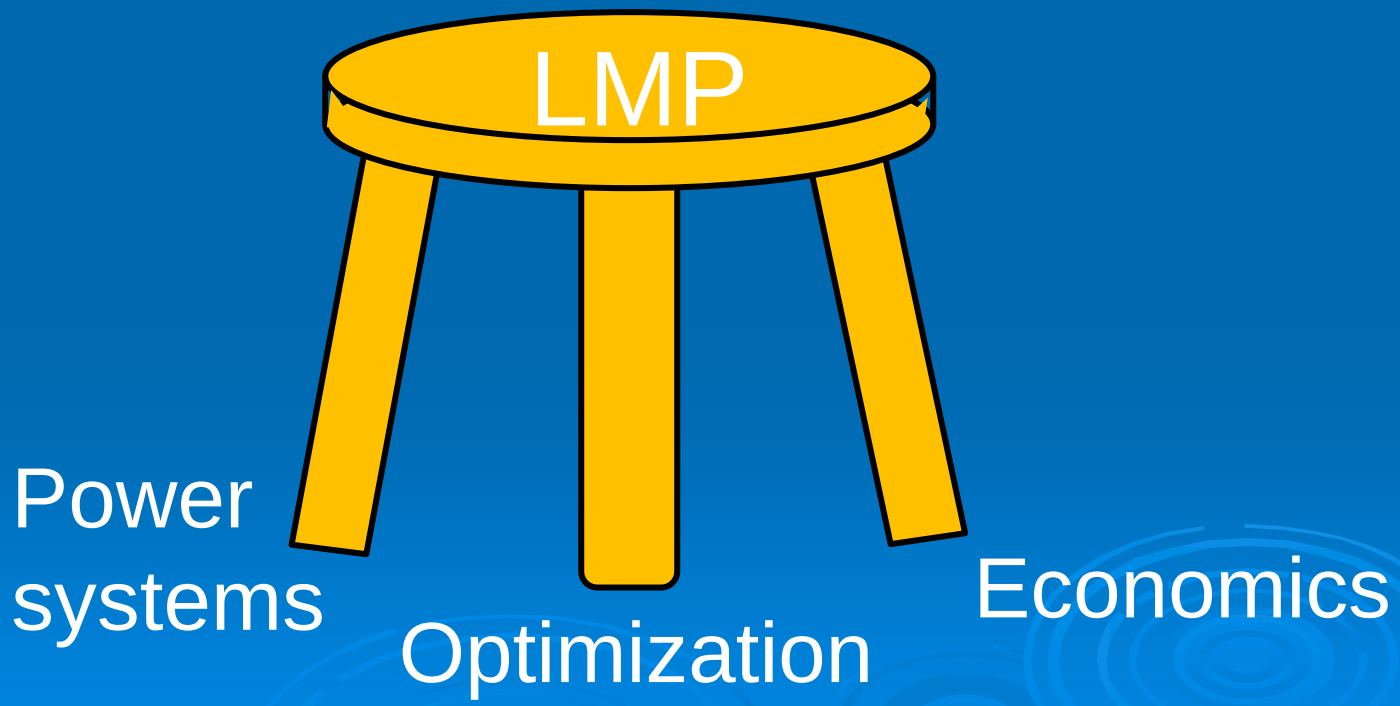
- ERCOT used as main example of LMP markets, but
- Features of other markets, such as capacity markets, also discussed, so that class is relevant nationally and internationally.

Focus of class

- Class also covers other key aspects of electricity markets:
  - Power flow,
  - Economic dispatch,
  - Unit commitment,
  - Pricing rules and incentives,
  - Hedging of energy and transmission price risk.

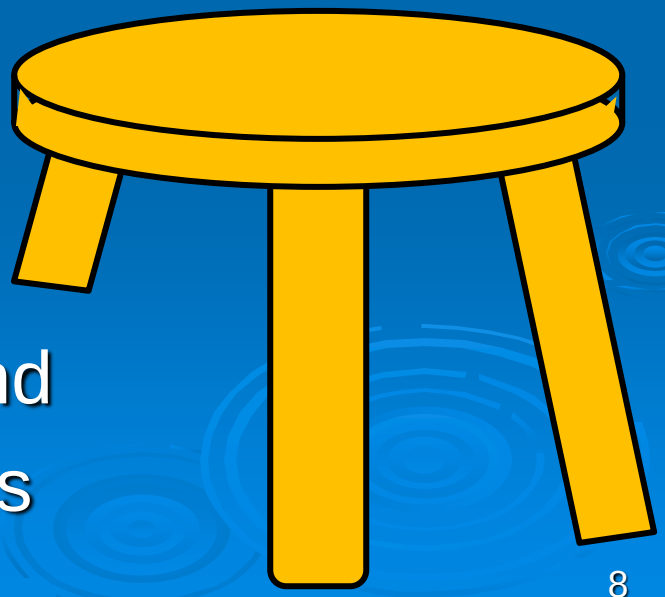
Challenges

- LMP class synthesizes and depends on material from power systems, optimization, and economics:



Challenges

- Typical students (engineering, economics, policy) do not have background in all three areas of power systems, optimization, and economics :
  - First third to half of semester is rapid review of background material in these areas,
  - Students assumed to have undergraduate background in at least two areas, with expectation that they will spend additional time outside of class reviewing other area.



Importance

- Operation of organized electricity markets has significant economic implications and requires technical understanding across several disciplines,
- Personnel at Independent System Operators (ISOs) and market participants need understanding of *purpose* and *principles* of operation of organized markets,
- No direct counterpart of organized market in other industries and no single textbook covers all relevant material.

Approach in one semester class

- Review background,
- Discuss pricing in organized electricity markets in the absence of transmission constraints.
- Then introduce transmission constraints and their implications.
- Also discuss a number of other topics including ancillary services, unit commitment, energy and transmission price risk hedging, network models, and capacity adequacy.

Background topics

- History of restructuring in Texas:
  - Instructors from other regions should substitute,
- Power flow:
  - Solution of non-linear simultaneous equations,
  - Power flow,
- Optimization:
  - Optimization,
  - Economic dispatch,
- Economics:
  - Microeconomics,
  - Economic decision-making.

Main topics

- Offer-based economic dispatch without transmission constraints:
  - Surplus, Feasible production set, Need for centralized coordination, Optimization formulation, Generation offers, Demand specification, Demand bids, Dispatch calculation, Pricing rule, Incentives, Value of lost load and implications for pricing and incentives, Generalizations: Ancillary services (reserves and regulation); non-linear system constraints, representation of constraints, operating reserve demand curve, capacity markets.

Main topics

- Locational marginal pricing:
  - Optimal power flow, DC optimal power flow, Offer-based optimal power flow, Examples, Properties of locational marginal prices, Congestion rent (merchandising surplus) and congestion cost, Contingency (or security) constraints, Reactive power and losses, Decomposition and linearization.

Main topics

- Unit commitment:
  - Temporal issues, Formulation, Mixed integer programming, Make-whole payments, Lagrangian relaxation, Duality gaps, Role of prices and implications for investment decisions, Transmission constraints, Robust, stochastic, and reliability unit commitment.

Main topics

- Hedging of energy and transmission price risk:
  - Volatility of energy prices, Forward markets,Day-ahead and real-time markets, Contracts for differences, Relationship to capital formation, Transmission prices, Financial transmission rights, Revenue adequacy, Hedging real-time prices.

Teaching this class

- Detailed slides, including in-class review questions and homework exercises are available at: http://users.ece.utexas.edu/~baldick/classes/394V/EE394V.html
- Video recording of class material is available on the CUSP website: https://cusp.umn.edu/power-systems/electricity-markets
- Solutions to homework exercises will be made available to instructors on request.

Summary

- Class presents rigorous derivation of locational marginal pricing model of electricity markets, together with related concepts such as unit commitment,
- Purpose and principles are emphasized in class material,
- Background material accommodates students from engineering, optimization, and economics.