Valuation of Transmission Assets and Projects

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Transmission Investment: Opportunities in Asset Sales, Recapitalization and Enhancements

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Presentation Outline

- Transmission Assets
  - Transmission Companies
  - Merchant Transmission Investments
  - Financial Transmission Rights
- Estimating the Value of Each Asset
  - Regulated returns
  - Market-based returns
- Tools
  - Production Cost Models with Volatility Analysis
  - Statistical /Knowledge-Based Models
  - Stochastic Models
- Volatility Analysis

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Valuing Transmission Assets

- Valuing Transmission Companies
  - Example ITC
- Valuing Merchant Transmission Investments
  - Example DC link between LI and CT
- Valuing Financial Transmission Rights
  - Example: FTRs in PJM and TCCs in NY

Valuing Transmission Companies

Key Components

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Owning Transmission Companies

- Physical ownership of assets, includes operating and managing these assets
- Regulated by FERC and State Agencies
- Regulated returns with some performance-based, or incentive-based rate of return on investment
- Responsibility to maintain, upgrade and operate these assets in a reliable manner
- Coordinate Operation with affiliated RTO
- Interconnection Agreements with Generation and load

Regulated Revenues

- FERC approved rate of return
- Forecasted demand
- Forecasted Transmission service revenue (in, through and out service)
- Investment could be effectively high return

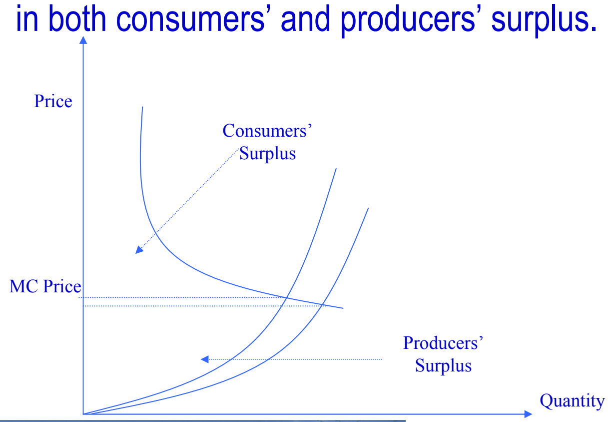
Measuring the Value of Transmission Upgrade

- There several major metrics to measure the value of transmission upgrades:
  - Production cost savings (Fuel and variable Operating & Maintenance costs)
  - Societal welfare increase (consumers' and producers' surplus)
  - Market value from the use of the asset on a commercial basis

The next slides illustrate the value of transmission upgrades in terms of these metrics.

Producer and Consumer Surplus

As the supply curve shifts right due to more economic dispatch of generation resources, there is a net increase in both consumers' and producers' surplus.



Production Cost Savings

Eliminating transmission congestion increases the economic efficiency of dispatching generation resources to meet demand at lowest cost, and thus lowers the total cost of producing electricity (by eliminating congestion and potentially reducing transmission losses).

- In the case of transmission congestion, the supply and demand curves become locational and differ by location.
- For example, during peak hours, high-price areas could buy available steam gas-fired generation in other areas instead of starting a peaker. This peaker appears more economical due to the presence of transmission congestion, although it is much less inefficient than a steam gas-fired unit or a combined-cycle unit

Increased Social Welfare

Eliminating transmission congestion increases market prices in some areas and decreases prices in other areas. Producers benefit in increased-price areas, while consumers lose, and vice versa for areas with lower prices

- Thus consumers' surplus increases in areas where prices go down and producers' surplus increases in areas where prices increase. The net benefit to both consumers and producers in all areas is the social welfare.
- Exporting areas will realize a net benefit even though prices are going up, since generation is higher than demand.

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Increased Market Competitiveness

- Could eliminate a local reliability problem or increase Available Transmission Capacity
- Mainly due to the elimination of the Capacity Benefit Margin and Transmission Reserve Margin.
- Due to better scheduling of transmission lines maintenance (a mechanism for sharing benefits and costs should be established).
- Due to standardized approaches to defining path ratings and transfer capabilities.
- Eliminating contract path contracts and scheduling limits increases the utilization of the transmission system, reduces total production cost, reduces transmission congestion cost, and lowers locational prices.

Production Cost Savings or Social Welfare

- If demand is inelastic, a system-wide change in social welfare is exactly equal to a system-wide change in production costs
- However, the social welfare metrics is much more informative, because
  - It fully captures the geographical impact of a transmission project
  - It is comprehensive as it measures the impact on producers and consumers
- Production cost savings is a metric that is meaningful on a system-wide basis only

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Market Value of Commercial Transmission Projects

- For a single line, an "intuitive" value of a line is driven by the price spread at two ends of that line
- However, even for a single line this intuitive value is uncertain: should we measure it before the line is built or after it is built?
- If we measure it after the line is built, what if there is no price spread? Does this mean that the new line has no value?

Richard Schuler's Paradox

- If we invest in a new road and decide to recoup the investment using congestion pricing, then…
- If there is no traffic jam, everyone drives for free;
- If there is a traffic jam, motorists should pay for slowing down; and
- The more time you spend in the jam, the more you pay…
- Solution: put a toll booth

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How to Recoup Your Investment in Transmission?

- Regulatory approach – add the project to the rate base in exchange for regulated rate of return. The right metrics of project value – change in social welfare. That would justify the project for regulators
- Market approach – hold an open season and pre-sell the project before committing to invest. The right metrics – buyers' willingness to pay for the project. The value is driven by price spreads before – and after the project is built
- In both cases, measuring the value of the project requires an extensive analytical effort

Valuing Merchant Transmission Investments

Key Components

Value of Transmission Investment

- When a transmission constraint is relieved there are usually winners and losers (in perfectly competitive markets) .
- The winners are:
  - The Generation in the constrained down area benefit by increased access to higher price markets.
  - The load in the constrained up area benefit by increased access to low cost generation.
- The losers are:
  - The load in the constrained down area loses because of higher energy prices.
  - The generation in the constrained up area loses because of increased competition for lower cost suppliers.
- This set of winners and losers change in the presence of market power and other market imperfections.

Difficulty in Capturing Rent Value

- The biggest difficulty facing a new transmission investment is capturing the value of the line, after it is built. For example, if a line were to completely remove congestion between a low cost area and a high cost area, the price differential would be zero, although the differential could have been very high before building the line.
- Thus, there will be a need for long term contracts before building the line, similar to the open season that Transenergie had for the cross sound cable.
- The parties most interested in building the line are the beneficiaries from building the line (for example, the party valuing the cross sound cable is LIPA, since it is the winner)

Valuing Merchant Transmission Investments

- Transmission congestion value
  - Congestion cost
  - Capacity Credit
  - Ancillary services?
- Temporal and locational arbitrage
- Deterministic approach Plus Volatility analysis
  - Marginal Cost bidding and strategic bidding

Deterministic Approach

- Forecast Locational energy and ancillary services prices in each market or location using best guess of futures market conditions
- Use a market simulation model
- Use a volatility analysis tool to value the optionality of the asset

Expected Market Conditions

- Generation is competing with transmission, thus it is important to analyze the following conditions in each market or submarket:
- Supply
  - New Entry
  - Retirements
  - Type of marginal capacity and fuel
  - Fuel prices
- Demand
  - Load growth
  - Load shape
- Interconnection between hydro and dominantly thermal generation systems
- Transmission and operating constraints

Regulatory Conditions

- For transmission projects linking two markets the regulatory risks include:
  - The elimination of wheeling charges
  - Type of allocated rights for the investment: either entitled to the difference in locational prices between the two connected buses times the capacity of the link (financial), or can schedule energy in either direction without incurring congestion cost or wheeling charges (physical).
- The convergence of the two markets (under one RTO).

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Impact of Imperfect markets

- In the presence of market power the value of transmission asset could be lower or higher than under competitive conditions.
- The value of the link depends on the owner.

Strategic Bidding Simulation

- Instead of using short-run marginal costs as bids, strategic bids could be used based on theoretical bidding strategy that can be adopted by generation companies in an imperfect market (I.e., workably competitive market).
- A bidding strategy could assume that generators reach a Nash-type equilibrium where each generation company maximizes its profits given the supply of all other generation companies in the market.
- The generation units are dispatched in least–cost security constrained manner using.

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Volatility Analysis

- The optionality value of transmission investments is determined by the uncertainties in the future. For example, uncertainty in new entry and retirements of generation units and load growth. The optionality value of the link is the expected value of the link under all possible outcomes, or the sum of the probability of each event times the value of the link if the event were to materialize.
- The difficulty is in assigning probabilities to these events and to identify all possible events and simulate them to determine the value of the link.
- Instead we resort to option theory to see if it is possible to determine the optionality values without going through all possible events.
- The use of spread options to value a transmission right in the presence of energy storage is truly a research project

Volatility Types and Correlations Captured in our Analysis

- Volatility Types
  - Day-to-day volatility of fuel prices;
  - Day-to-day volatility in electricity load due to small weather fluctuations and other factors;
  - Plant outages;
  - Bidding behavior.
- Correlations Embedded in the MAPS output
  - Correlated movements in fuel prices on the monthly and annual basis;
  - Correlated weather in New England and New York.
- Correlations Modeled via Monte-Carlo Simulations
  - Trading;
  - Correlated movements in weather;
  - Correlated movements in daily prices.

Proposed Approach to Market Volatility Analysis

- Our approach to value transmission lines connecting two markets.
  - The forecasted market clearing prices calculated by deterministic market simulation tools (such as DAYZER) reflect expected value of future prices in any given hour. The future hourly prices can be considered random variables with these prices as their means.
  - Thus, it is important to develop a distribution of the hourly prices to be able to capture the complete behavior of prices in each market and the value of transmission links.
  - Use historical distribution of hourly prices in each market as a proxy for future distribution of hourly prices.
  - Use forecasted price as average prices and use historical distributions to fully characterize the hourly price random variables.

Description of Market Volatility Analysis

1. Collect historical hourly prices in the each market
2. Calculate historical Means and Standard Deviations for each hour-type, and generate a distribution of normalized price changes for each market.
3. Calculate correlation parameters between the prices in the two markets.
4. Adjust historical data based on your expectation of future market volatility and correlation levels
5. Draw random numbers from historical distribution of normalized price changes and add it DAYZER hourly prices (*after adjusting for that hour type*).
6. Do step 5 for each market using correlation factors

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Description of Market Volatility Analysis

7. Simulate price trajectories (assuming mean reversion) for the two markets connected by the transmission link.
8. The value of the link is the sum of the absolute value of the hourly differences (assuming option-type, directional transmission rights).
9. Go to Step 6 and repeat for a large number of simulations (more than 200 simulations)
10. Calculate an expected value and plot a histogram of the value of the link.

Valuing Financial Transmission Rights

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Transmission Property Rights

- Financial rights
  - Guarantees the holder the financial equivalent of using the transmission right, but not the physical certainty.
  - The value is independent of actual power flow, and depends on congestion on the system.
  - Could be from point to point (NY, PJM and NE) or Flowgate –based (ERCOT)
- Physical rights
  - The right to inject a certain amount of power at point A and take it out at point B.
  - The holders are guaranteed the scheduling certainty for their rights.
  - Use it or lose it type of rights to prevent hoarding.

Valuation of Financial Transmission Property Rights

- Obligation type rights
  - The value of the right is equal to the LMP at receiving point minus the LMP at the sending point, times the quantity of the right.
  - The holders are responsible for negative payments
- Option type rights
  - Same as obligation type rights except that the holders are NOT responsible for negative payments
- Currently NY ISO offers only obligation-type TCCs while PJM offers both types of FTRs

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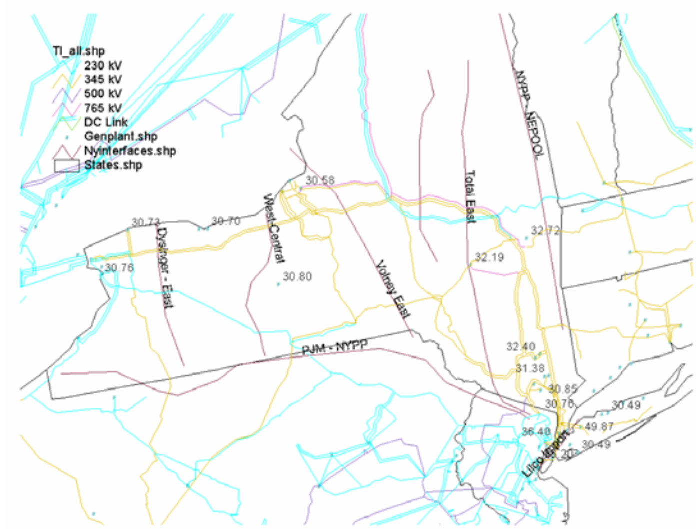
Value of Financial Transmission Rights

- The value of a financial transmission right is
  - For point-to-point:: the congestion component of the LMP at the receiving node minus the congestion component at the sending point.
  - For flowgate-based: the shadow price or the congestion cost of the flow gate
- Note that the financial transmission rights currently used provide financial hedge against congestion only, not against the cost of marginal transmission losses op the system. Thus, the value is not equal to the difference in LMPs but the difference in the congestion component of the LMPs.
- Transmission rights are settled in the Day-ahead Market

Illustrative Prices [$/MWh]



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Valuation Issues

- Transmission outages
- Generation Unit outages
- Transmission upgrades
- Change in Operation Procedures

FTRs Allocation & Bidding Strategies

- Transmission rights are either allocated directly or the auction revenues are allocated to native load
- The bidding for FTRs in the auction depends on the level of the Auction Revenue Rights (ARRs) and load requirements for each bidder.

Estimating the Value of Transmission Assets

LMP Markets

- Generators bid their willingness to supply at a node
- Consumers bid to purchase at a node
  - Reality: Demand is forecasted
- In real time the system operator dispatches units so as to minimize cost (including transmission) given bids
- LMP calculated for each bus
- Pay the generators; Charge the loads
- Multiple Clearing times / markets
  - Day ahead market that corresponds to the scheduling commitment time frame
  - Real-time market ahead market that corresponds to the dispatch time frame

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Unit Commitment and Day-Ahead Markets

- Transmission rights are settled in the DAM
- Day Ahead market involves a unit commitment and hourly dispatch algorithm
- Unit Commitment minimize the total production cost (DAM bids) over 24 hour period, given constraints on:
  - Generation units MUT, MDT, Ramping
  - Forecasted load, generation units and line availability
  - Operating reserves and second contingency

Locational Price Forecasting

- Nodal Marginal Pricing - Theory
- Types of Price Forecasting Models
  - Production Cost Models
  - Statistical/Knowledge-Based Models
  - Stochastic Models
- Input Assumptions
- Importance of Sensitivity Analysis

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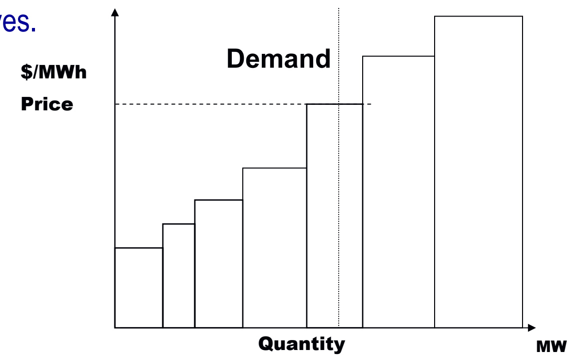
Nodal Marginal Pricing - Theory

- The market clearing price is the marginal cost of the marginal unit in the absence of transmission constraints. In economics terms, the market clearing price is the point of intersection of supply and demand curves.



Nodal Marginal Pricing - Theory

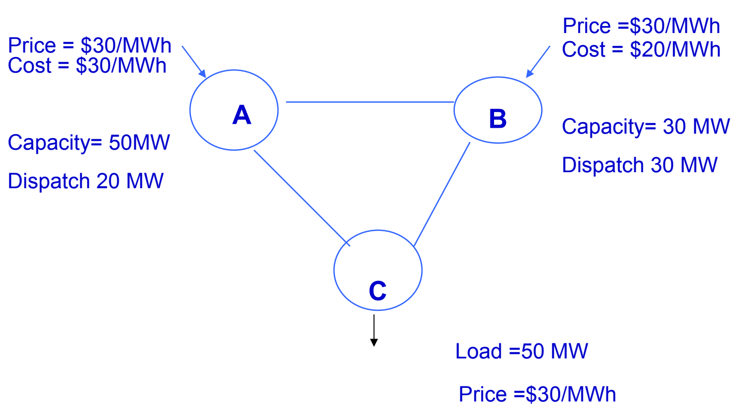
- In the presence of transmission constraints, the costs of energy production, and thus prices, vary by location.
- Nodal pricing applies Spatial Spot Pricing theory on a real time basis to derive a bus by bus Locational Marginal Price (LMP)
- Calculations are based on Security Constrained Dispatch model
- All transactions on the grid *ARE CHARGED or CREDITED* at the LMP
- Generators are paid this price and consumers are charged this price

Nodal Marginal Pricing - Theory

- Nodal prices are not necessarily capped by the marginal costs of marginal units - they can be higher than the most expensive unit, or negative.
  - Nodal prices can be higher than the marginal cost of the most expensive unit running.
  - Nodal prices at constrained out areas can be negative.

Nodal Marginal Pricing - Theory

Example of nodal prices without constraints.



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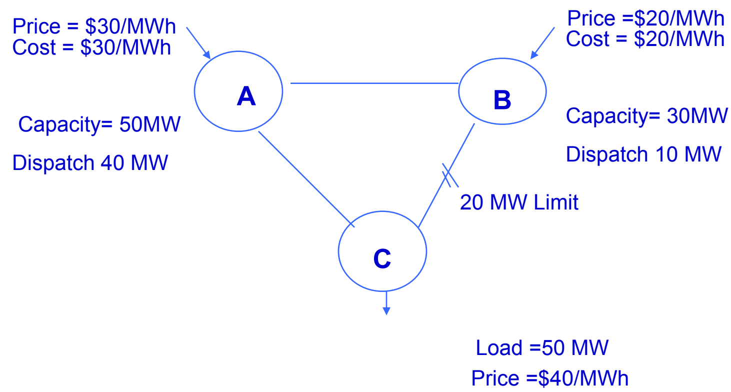
Nodal Marginal Pricing - Theory

Example of nodal prices *with* constraints. Note that prices can exceed the highest marginal cost unit.



Nodal Pricing - The Mathematical Model

The model can be mathematically described as follows:

$$\text{Minimize Total Cost} = \sum_{i \in I} GenCost_i * Gen_i$$

Subject to:

$$(1) \qquad Gen_i \leq MaxCap_i \qquad \forall i \in I$$

$$(2) \qquad \sum_{i \in I} Gen_i = \sum_{a \in A} Load_a + Spin\,\mathrm{Re}\,ser_{Pool}$$

$$(3) \qquad PowerFlows_l \leq MaxFlows_l \qquad \forall l \in L$$

$$(4) \qquad PowerFlows_l \geq MinFlows_l \qquad \forall l \in L$$

Price Forecasting Models

- There are three possible approaches to price forecasting:
  - Production Cost Models: Build a Market Model with specified assumptions
    - Can be complicated
    - Results accuracy depends on accuracy of input assumptions
  - Stochastic Models: Run a large number of Monte Carlo simulations
    - Require large number of simulations
    - Require knowledge of the distribution of the input variables
  - Statistical/ Knowledge-Based Systems: Try to learn the market by observing prices and relating these to events
    - Need to learn all possible events
    - Price accuracy depends on the training

Market Model

- The market model can be either one of the following:
  - Competitive: Generators bid Marginal (incremental) cost
  - Oligpolostic:
    - Most realistic but difficult to model
    - Many possible equilibria (Nash type equilbira)
  - Monopolistic: Unlikely `

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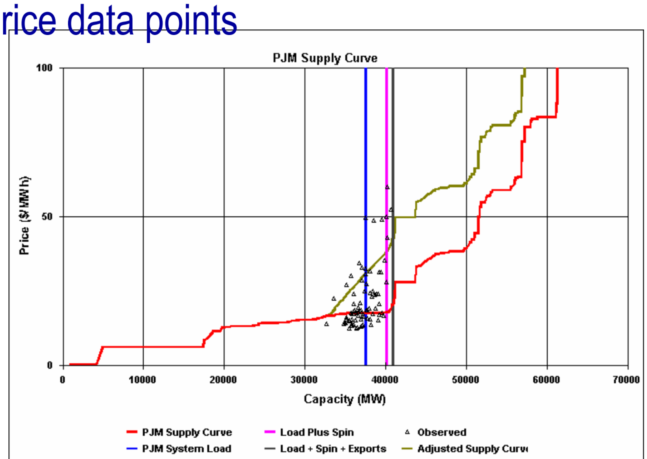
Market Equilibria

- Nash: A player maximizing its own payoff given the strategies followed by all opposing players (General equilibrium)
  - Cournot: Set of outputs for which each firm maximizes profit given the *outputs* of the remaining firms
  - Bertrand: Set of outputs for which each firm maximizes profit given the *prices* of the remaining firms
  - Supply Function: Set of outputs for which each firm maximizes profit given the *supply curves* of the remaining firms

Knowledge-Based Systems

- The model learns the market given observed load,price data points



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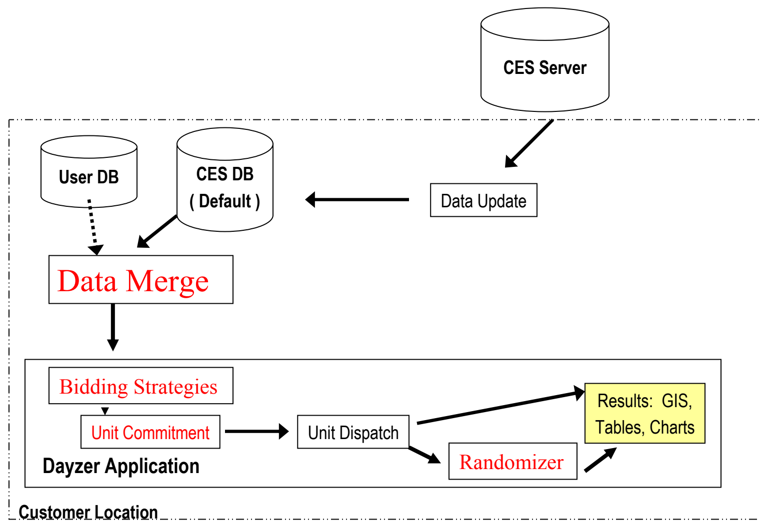
Market Simulation Models: DAYZER



Randomizer

- Uses Dayzer hourly prices as inputs to generate the hourly trajectories using the above volatility analysis approach.

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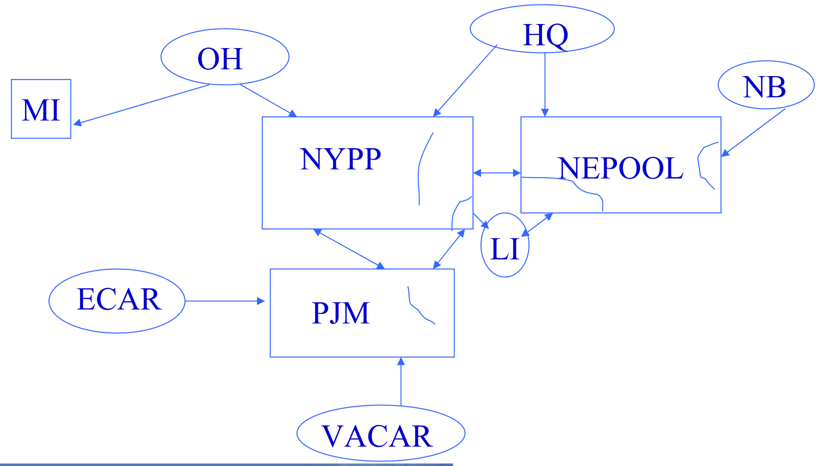
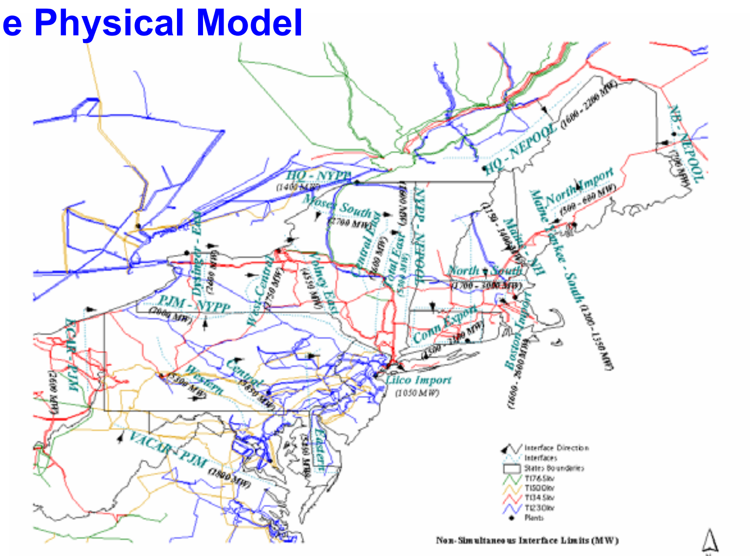
A Simplified Geographic Model of the Northeast Markets



The Physical Model



Important Input Assumptions

Thermal Characteristics

- Units Summer and Winter capacities
- Units heat rates, fuel types & outages
- Units variable operation and maintenance cost by unit type and size

Hydro Unit Characteristics

- Hydro and pump storage generation levels

Fuel Prices

- Fuel prices for each geographic area

Transmission System Representation

- Transmission constraints

External Supply Curves

- Imports and exports from outside the Northeast system

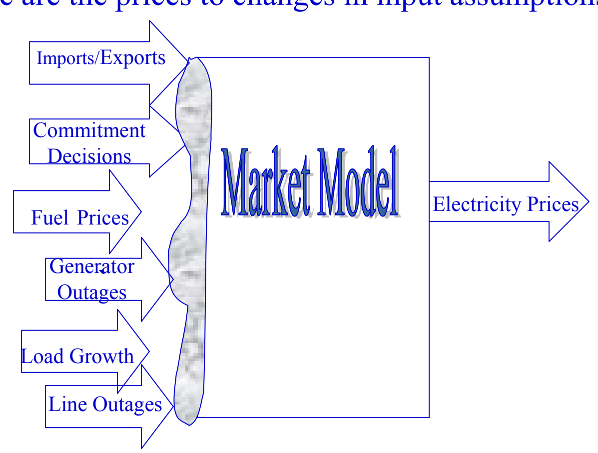
Load Requirements

- Forecasted peak load and hourly shape, and dispatchable demand
- Reserves requirements

Economic Entry and Retirements

Importance of Sensitivity Analysis

How sensitive are the prices to changes in input assumptions?



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Conclusions

- Forecasting models are not crystal balls and should not be used as such.
- They cannot account for market participants risk premiums or for gaming in the energy market.
- Models are good tools to forecast congestion patterns and levels on the system.
- They are useful to develop understanding of transmission system conditions and sensitivities to various random parameters.

Optionality Value of Transmission Assets

- Optionality value of a transmission line appears each time when there exists the ability to exploit instantaneous price differences at two ends of the line
- Optionality value will likely exist even if the average price spread is zero
- Optionality value increases with price volatility and decreases with price correlation

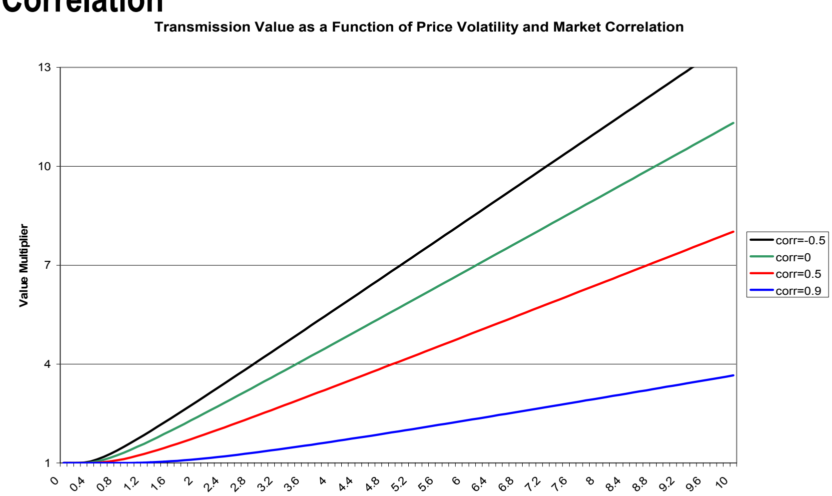
Why is Volatility Important

- Let P, Q be prices in regions A and B respectively which are normally distributed with correlation ρ with mean and standard deviation of $m_P, m_Q, \sigma_P, \sigma_Q$
- Then for the instantaneous value of the link, we have:

$$V = \sqrt{\frac{2(\sigma_P^2+\sigma_Q^2-2\rho\sigma_P\sigma_Q)}{\pi}}\exp\left[-\frac{(m_P-m_Q)^2}{2(\sigma_P^2+\sigma_Q^2-2\rho\sigma_P\sigma_Q)}\right]+$$

$$(m_P-m_Q)\left[\Phi\left[\frac{m_P-m_Q}{\sqrt{\sigma_P^2+\sigma_Q^2-2\rho\sigma_P\sigma_Q}}\right]-\Phi\left[-\frac{m_P-m_Q}{\sqrt{\sigma_P^2+\sigma_Q^2-2\rho\sigma_P\sigma_Q}}\right]\right]$$

Optionality Value as a Function of Volatility and Correlation



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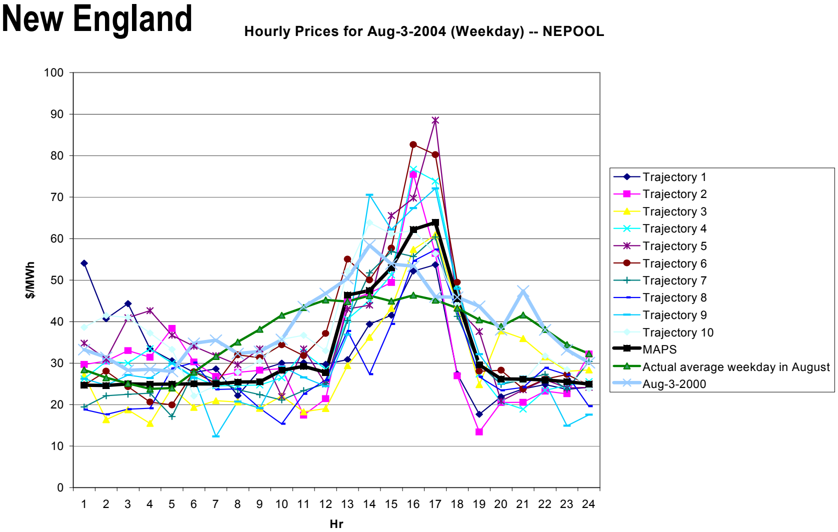
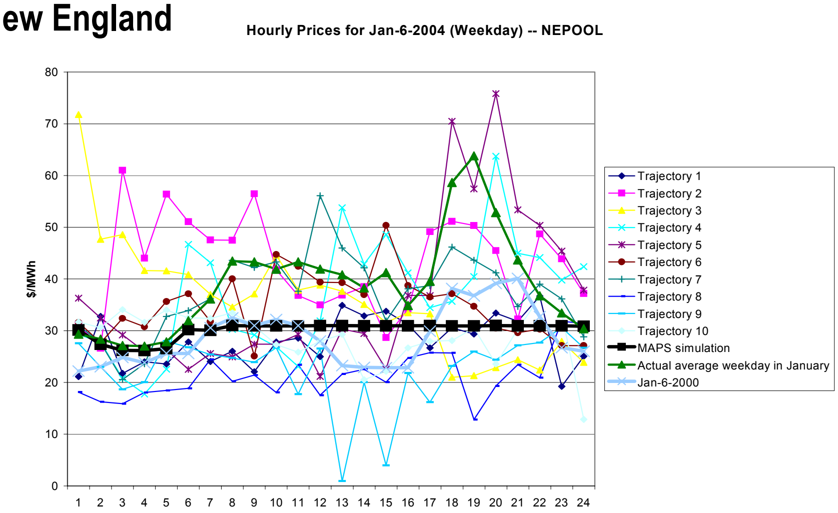
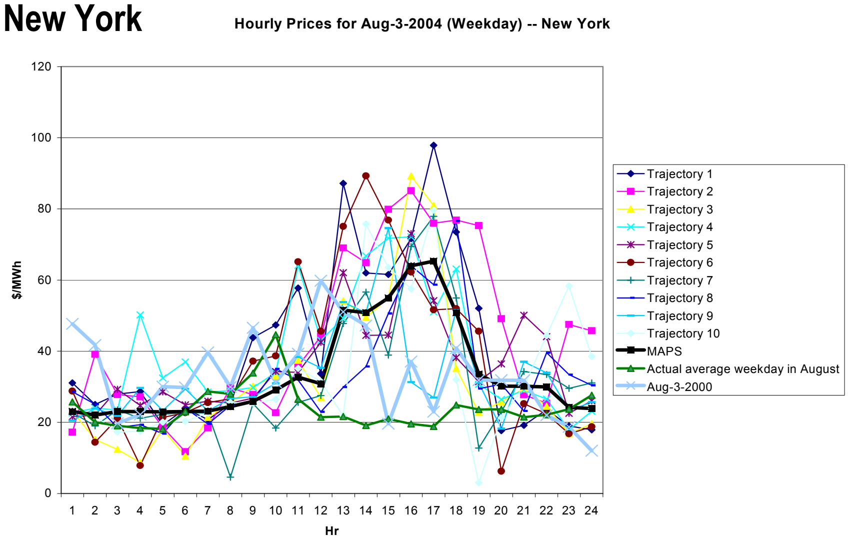
Simulated Price Trajectories vs. Statistics: Summer Day in New England



Simulated Price Trajectories vs. Statistics: Winter Day in New England



Simulated Price Trajectories vs. Statistics: Summer Day in New York



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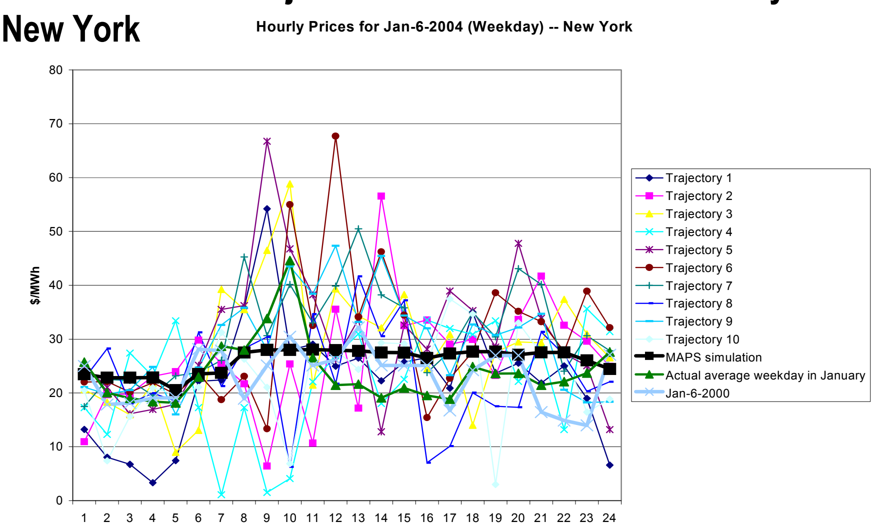
Simulated Price Trajectories vs. Statistics: Winter Day in New York



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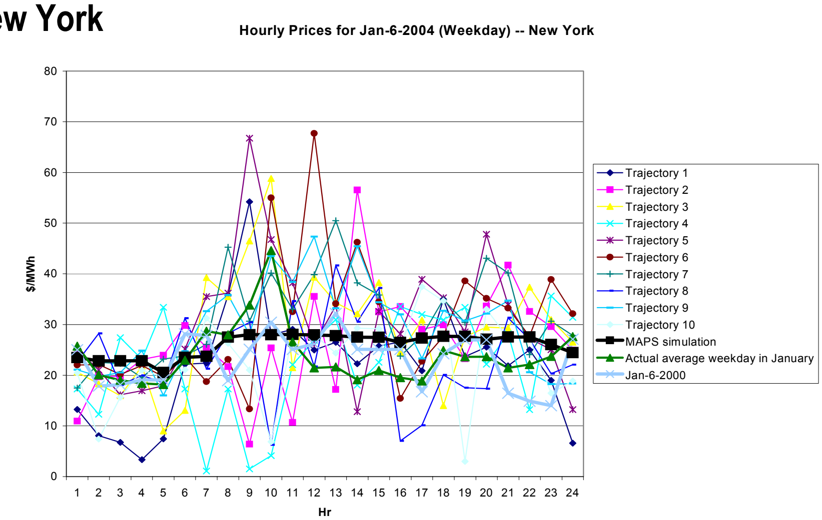
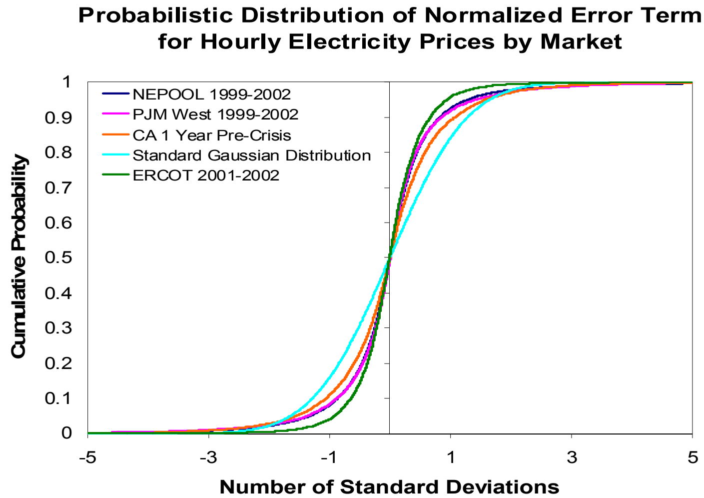


Problems

- How to come up with probabilistic distributions for prices?
- How to estimate volatility?
- How to estimate correlation?

Probabilistic Distributions



Volatilities

- Historical data – good start, but do not reflect future market conditions
- Implied volatilities – no good liquid data, lack of theoretical foundations (other than Black-Scholes) for estimation
- What's left? History and "expert judgment"

Correlation

- Historical data – good place to start, but do not reflect future conditions, especially, how would a new project affect correlation
- Implied correlation – no liquid market. No reliable theoretical foundations
- Multiple scenarios using simulation models