SARI / Energy

ELECTRICITY MARKETS DEVELOPMENT PROGRAM-GEMTP II

SARI / Energy

Role of System Operations and Market Operations

Frank A. Felder, PhD

Regulation of the System Operator

- *Reliability Regulation*: International Standards
- *Economic Regulation*: National/ State/ International
- *Planning Regulation*: Local/State/National/International
- *Market Regulation*

  Competition regulators, commodity regulators, energy regulators

Regulation of the System Operator: Reliability Regulation

Development of International Standards: Security Standards

- Loss of Load Probability
- Accountability for Impacts on Neighboring Systems
- Situational Awareness
- Emergency Response & Mutual Support
- Cyber Security
- Enforcement by the Regulator

Regulation of the System Operator: Reliability Regulation

Development of International Standards--- Adequacy Standards

- Planning Standards
- Build Out Standards
- Distribution Service Quality—CAIFI, SAIFI, SAIDI
- Local Supplemental Standards--- “Stormwatch”

Regulation of the System Operator: Economic Regulation

- Cost-based Power Transactions
- Purchased Power Adjustment Clauses
- Oversight of Security Constrained Economic Dispatch
- Monitoring for Market Abuses
- Antitrust Regulation of the Market
  - Policing Vertical Market Power
  - Policing Horizontal Market Power

Regulation of the System Operator: Planning Regulation

- Integrated Resource Planning
- Pre-approval
- Rules and Oversight of Planning Processes
- Siting Authority
- Rate Recovery Authority
- Market Based Planning

Regulation of the System Operator: Market Regulation

- Competition Regulation
- Commodity Regulation: Purchases and Sales
- Utility Regulation: Rate Recovery
- Regulation of Company Management Practices and Policies

Traditional Role of the System Operator

- Safe, reliable operation of the grid
- Non discriminatory operation of the grid
- Transmission Planning

Today's System Operator: Roles and Responsibilities

- Load forecasting
- Management of outages
- Congestion Management
- Frequency Control
- Provision of ancillary services
- Reliability Oversight and Control
- Invoking Emergency Procedures

Role of the System Operator

- System Monitoring
  - Wide area view
  - Transparency of Information
  - Load Forecasting
- Outage Oversight and Reporting
- Scheduling and Dispatch
  - Contract vs. Flow Based Paths
  - Deviation Penalties vs. Network Service

Role of the System Operator

Congestion Management

- TLRs
- Redispatch
  - Economic Signals vs.Directives
  - Just Compensation Mechanisms
  - Incentives for Availability

Long Term

Up to 4 years ahead — Month Ahead

Physical

- Transmission reservations
  - ARR allocations
  - Annual FTR auctions
  - FTR Secondary Market
  - Monthly FTR auctions

Financial

- Bilateral forward contracts / Over the counter

Week Ahead

Day Ahead

- Day-Ahead Market
- Reliability analysis
- Unit commitment

(Week Ahead / Day Ahead)

- Outage analysis
- Load forecast
- Forward reliability analysis

Real Time (operating day)

Hours Ahead — Minutes Ahead

- Near-term reliability analysis
- Real-Time Market
- Unit Dispatch System

Long Term

Up to 4 years ahead | Month Ahead

Physical

- Transmission reservations
  - ARR allocations
  - Annual FTR auctions
  - FTR Secondary Market
    - Monthly FTR auctions

Financial

- Bilateral forward contracts / Over the counter

Week Ahead

Day Ahead

- Day-Ahead Market
- Reliability analysis
- Unit commitment

- Outage analysis
- Load forecast
- Forward reliability analysis

Real Time (operating day)

Hours Ahead | Minutes Ahead

- Near-term reliability analysis
- Real-Time Market
- Unit Dispatch System

Role of the System Operator

Ensuring Adequate System Reserves

- Payment of Opportunity Costs
- Avoiding disincentives to providing needed ancillary services
- Bid based vs. Cost-based
- Uplift vs. Market Based

Role of the System Operator

Emergency Procedures

- Customer Notifications
- Uniform Alerts to Market Participants
- Ability to Order Curtailments
- Use of Demand Side Resources

System Restoration

- Centralized Command

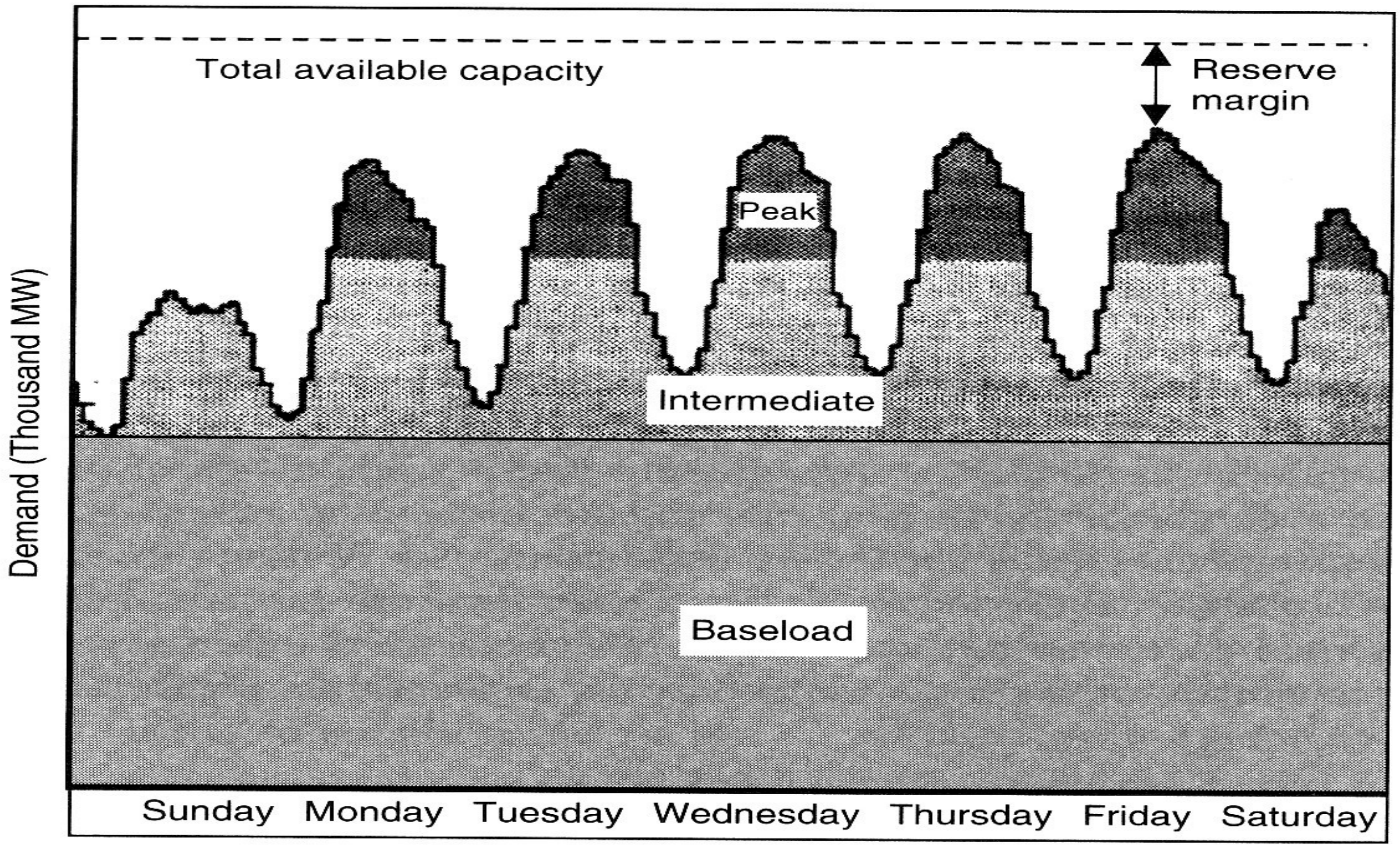
Structure of the System Operator

- For Profit/ Not for Profit
- Ownership of the transmission asset vs. no ownership
- Stakeholder Boards vs. Independent Boards
- Stakeholder Processes and Involvement

Potential New Roles for the System Operator

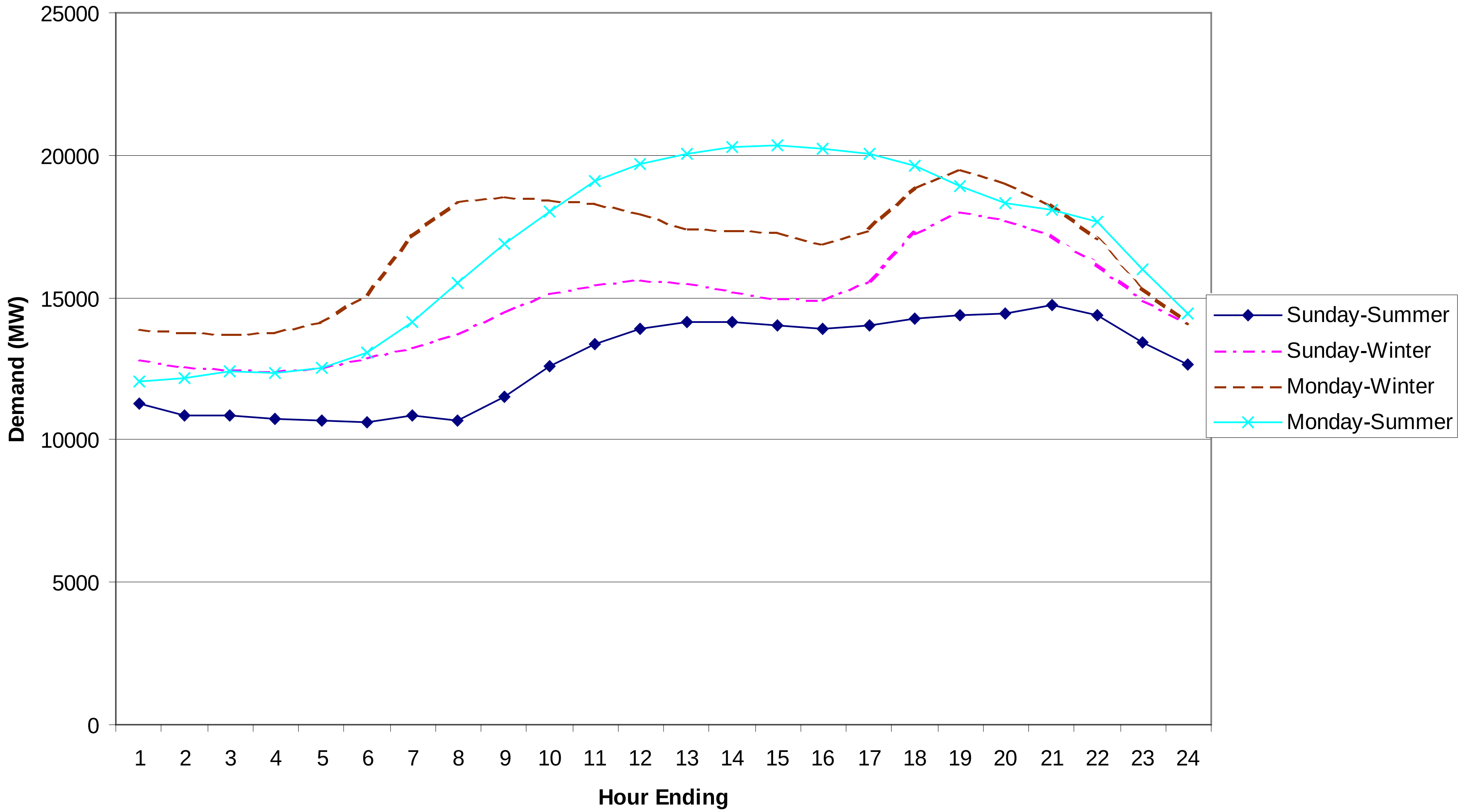
- Environmental Regulatory Role
- Generation Planning
- Infrastructure Development
- Environmental vs. Economic Dispatch
- Driver of social policy---universal service
- Managing hedging tools
- Managing/socializing credit risk

Weekly Load Fluctuations

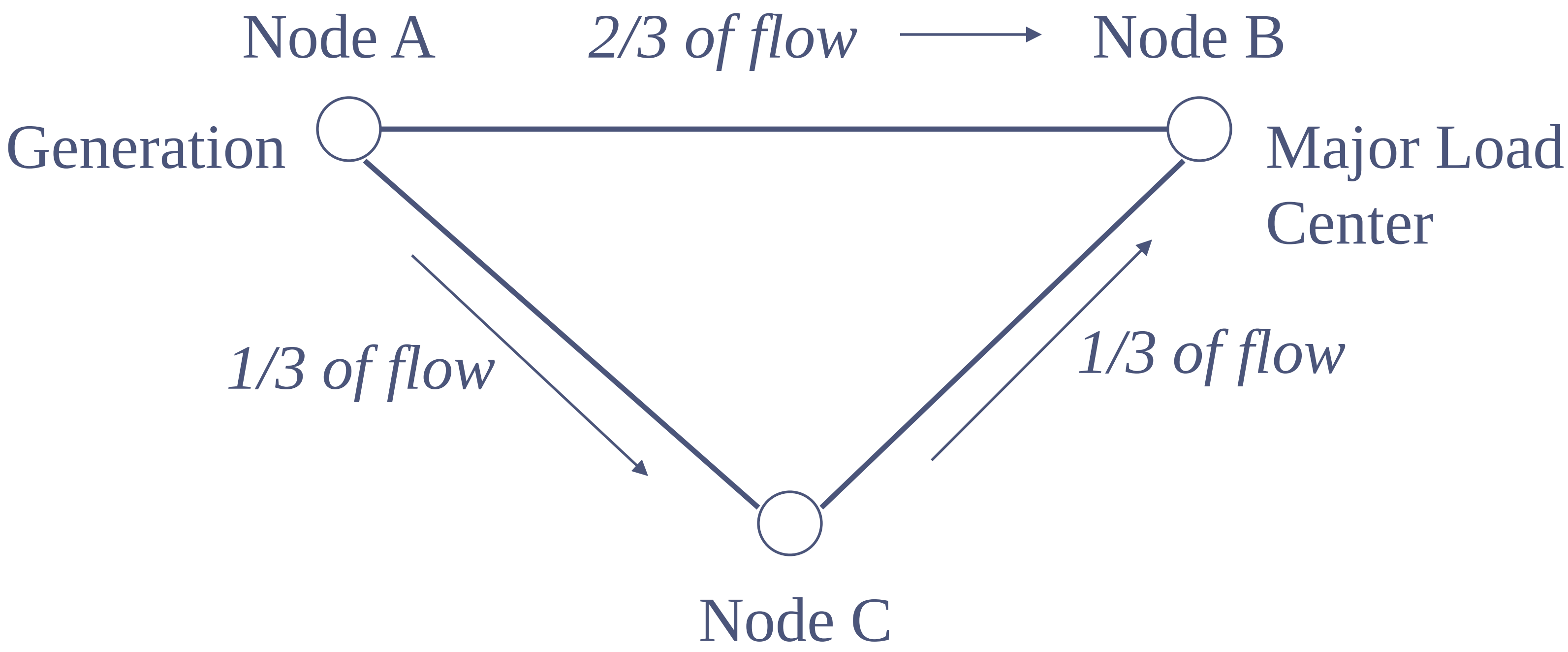


Source: Gilbert M. Masters, *Renewable and Efficient Electric Power Systems*, Wiley, 2004

Hourly Electricity Demand in New England During Typical Summer and Winter Mondays and Sundays



Loop Flows



Assume each transmission line has the same impedance (which is not true in practice)

Flows on each transmission line may be limited for a variety of reasons

Power System Least Cost Objective

- Objective: Operate the bulk power system so that it satisfies system loads and engineering criteria at the least cost
  - Load flow analysis determines the current and voltages on a power system
  - Optimal power flow (OPF) determines the least cost dispatch to satisfy system loads and engineering criteria

The Dispatch Problem

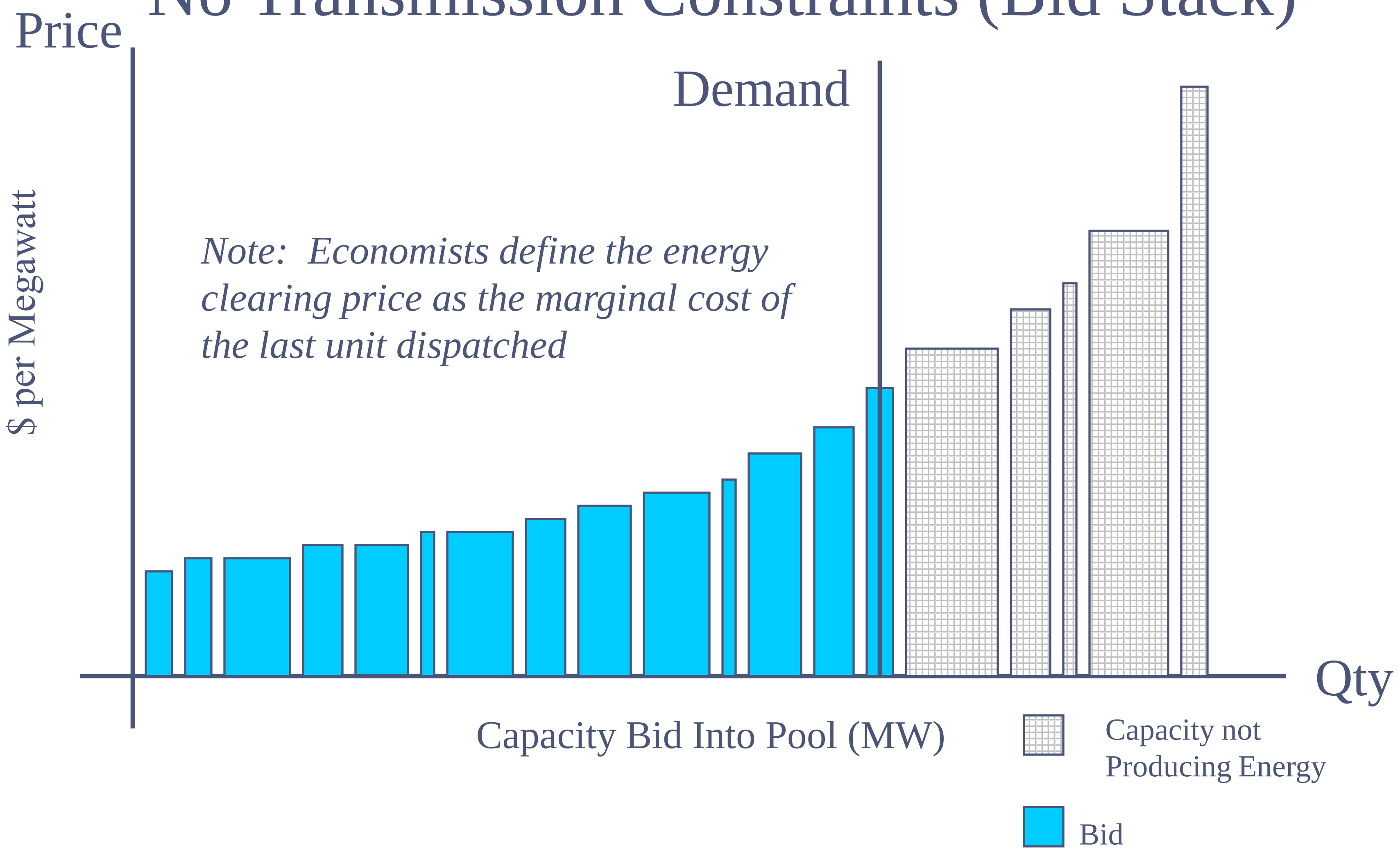
- minimize cost of serving electric energy demand
- subject to
  - Demand = Supply
  - Transmission constraints
    - thermal limits: prevent damage to transmission components
    - stability: keeping generation units in synchronism
    - voltage: maintain voltage within acceptable limits
    - frequency: maintain frequency within acceptable limits
    - contingency: ability to withstand the failure of components

Solution to the Dispatch Problem

- Dispatch Problem solution:
  - solution method is usually a linear program
  - for each time period (e.g., five minutes), a vector of generation output for each generator
  - for each time period, a vector of prices at each node that reflects the marginal cost of serving one more MWh at that node for that time period
- Nodal price (t) = marginal fuel cost + variable maintenance cost + transmission constraints + transmission losses

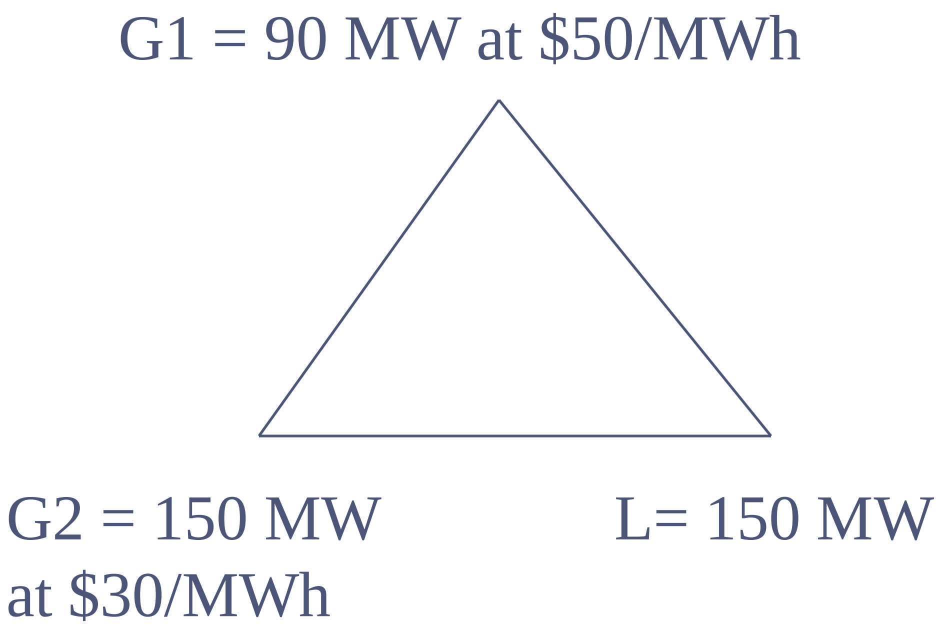
Note: LMPs = LBMPs = Nodal Prices = Locational Prices

Minimum Cost Dispatch Solution with No Transmission Constraints (Bid Stack)



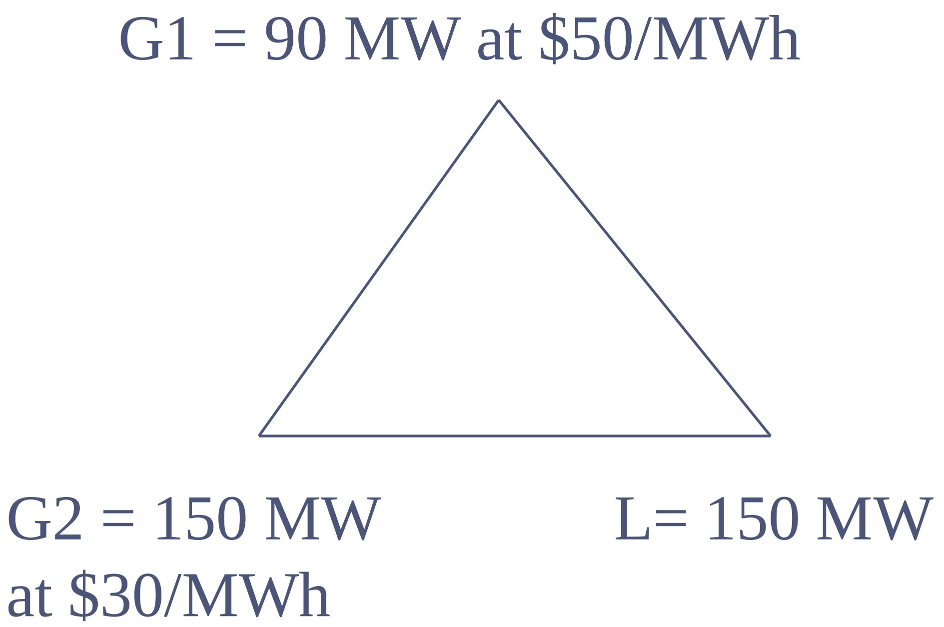
Locational Based Marginal Pricing - NO TRANSMISSION CONSTRAINT

- 3 Bus Example
  - Lines have identical impedance's
  - No transmission losses
- What is the least-cost dispatch?
  - Without any transmission constraint?



Locational Based Marginal Pricing - NO TRANSMISSION CONSTRAINT

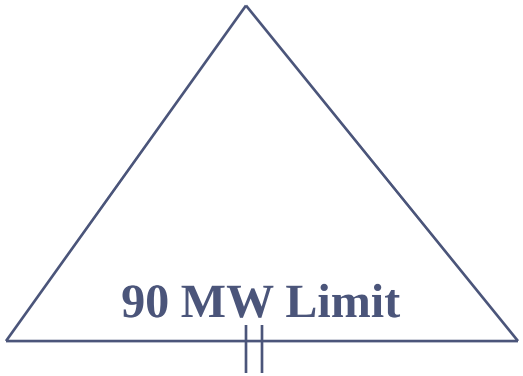
- 3 Bus Example
  - Lines have identical impedance's
  - No transmission losses
- What is the least-cost dispatch?
  - Without any transmission constraint?
- => Solution
  - G1: Dispatched 0 MW
  - G2: Dispatched 150 MW



Locational Based Marginal Pricing - TRANSMISSION CONSTRAINT

- 3 Bus Example
  - Lines have identical impedance's
  - No transmission losses
- What is the least-cost dispatch?
  - With a 90 MW transmission constraint

G1 = 90 MW capacity at $50/MWh

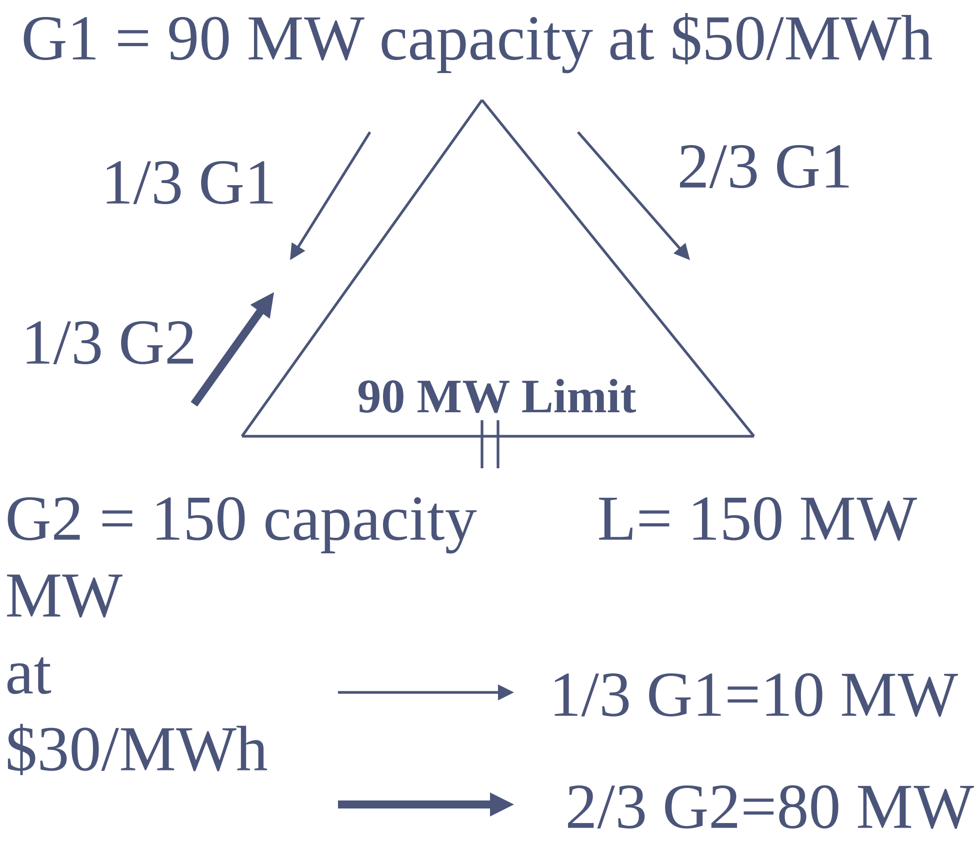


G2 = 150 MW capacity at $30/MWh

L= 150 MW

Locational Based Marginal Pricing - TRANSMISSION CONSTRAINT

- 3 Bus Example
  - Lines have identical impedance's
  - No transmission losses
- What is the least-cost dispatch?
  - With a 90 MW transmission constraint
- => Solution
  - G1: 30 MW
  - G2: 120 MW
  - G1+G2 = 150 MW = Load



Unit Commitment vs. Dispatch

- Minimize start-up, no-load, and running costs
  subject to meeting load reliably & the constraints of the generation units (size, start-up time, ramp rates, min. run times, min. down times, etc.)
- The solution to this optimization is not only the output level of individual generation units but which units to commit
- Requires the use of a more sophisticated and time consuming algorithm than the linear programming used for the dispatch problem

- Minimize no-load and running costs
  subject to meeting load reliably & the constraints of the generation units (size and ramp rates)
- The solution to this optimization problem is the output level of individual generation units
- Uses a linear programming (LP) technique
- Solved every 5 minutes

Aka: Security Constrained Unit Commitment vs. Security Constrained Economic Dispatch
See FERC July 31, 2006 report on this topic, available on its website

Example of Unit Commitment

- A system operator needs another 100 MW per hour of additional energy
  - Choice 1: 100 MW coal unit
    - Start-up cost bid = $5,000
    - Energy bid = $20/MWh
  - Choice 2: 100 MW natural gas combustion turbine
    - Start-up cost bid = $0
    - Energy bid = $30/MWh
- Which unit does the system operator commit if only needed for 1 hour? 10 hours?

Ancillary Services

- Operating Reserves
  - Ten minute spinning reserves
  - Ten minute non-spinning reserves
  - Thirty minute reserves
  - Replacement reserves
- Automatic Generation Control (AGC)
- Black Start Service, Voltage Control (VARs) aka Reactive Power, ...
- Definitions are not consistent
- Problems arise when ancillary services are such that they interact with the energy market