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# ELECTRICITY MARKETS DEVELOPMENT PROGRAM- GEMTP II





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## *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

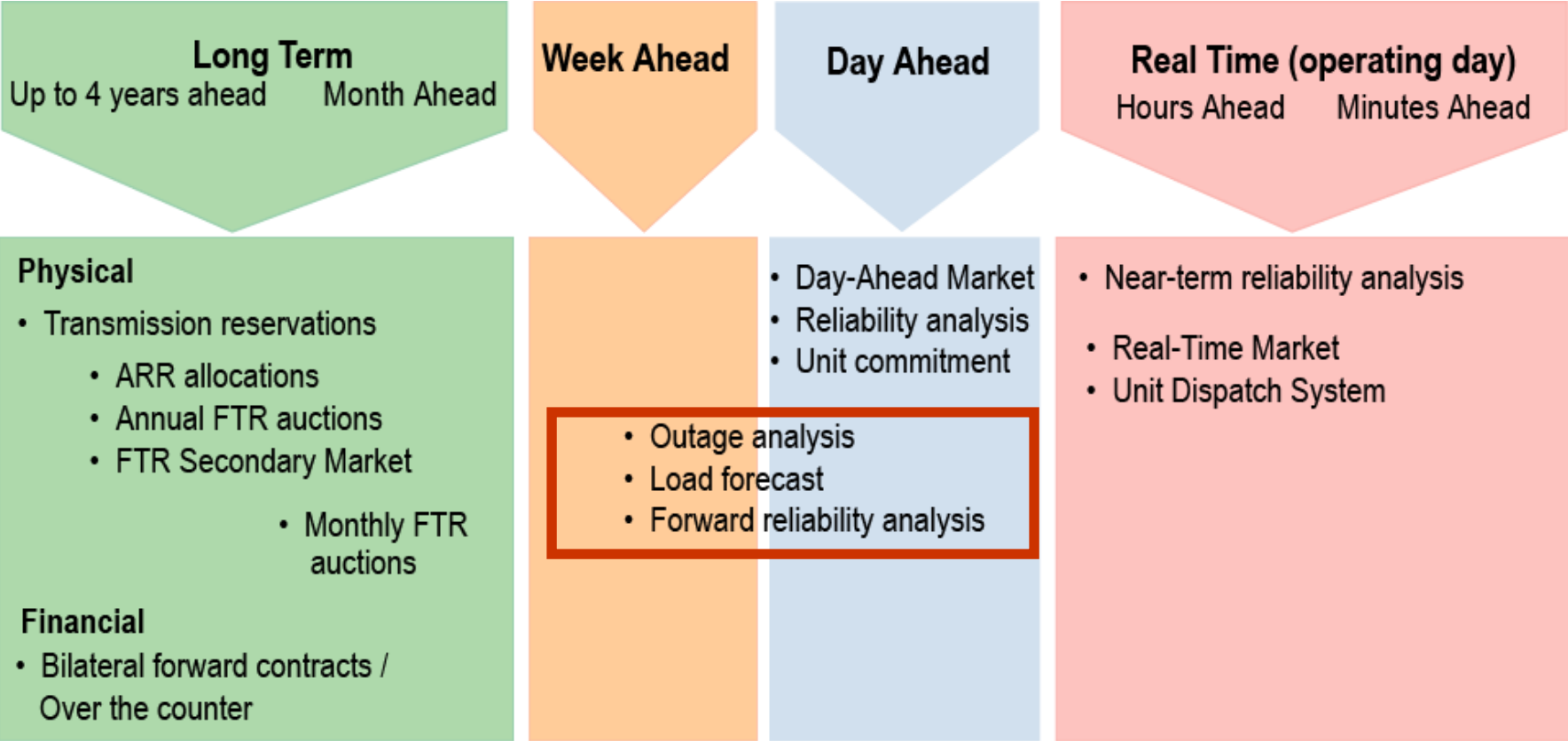
- System Monitoring
  - Wide area view
  - Transparency of Information
  - Load Forecasting
- Outage Oversight and Reporting
- Scheduling and Dispatch
  - Contract vs. Flow Based Paths
  - Deviation Penalties vs. Network Service



# 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

**Week Ahead**

**Day Ahead**

**Real Time (operating day)**  
Hours Ahead    Minutes Ahead

- Physical**
- Transmission reservations
    - ARR allocations
    - Annual FTR auctions
    - FTR Secondary Market
  - Monthly FTR auctions
- Financial**
- Bilateral forward contracts / Over the counter

- Outage analysis
- Load forecast
- Forward reliability analysis

- Day-Ahead Market
- Reliability analysis
- Unit commitment

- 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

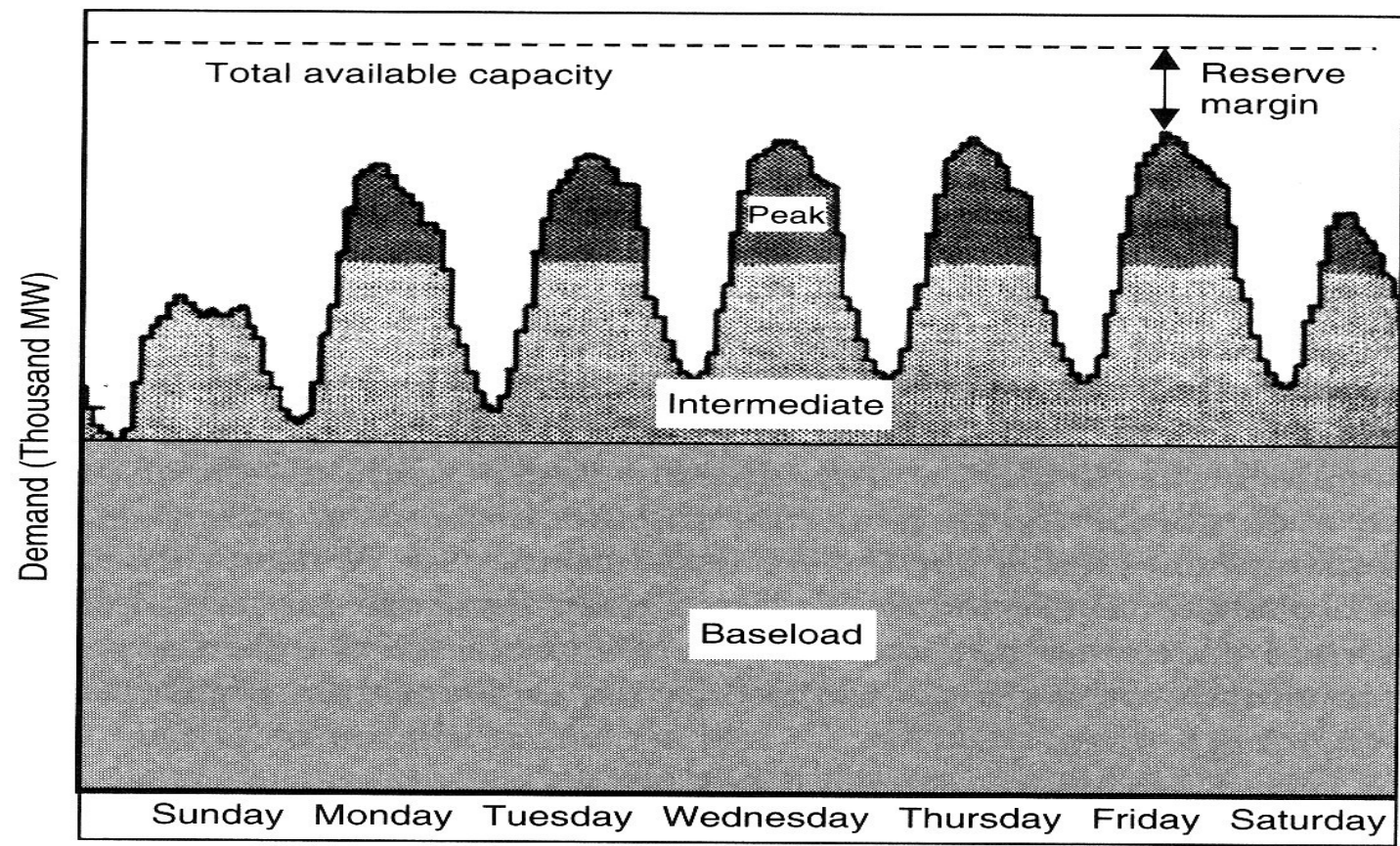
- For Profit/ Not for Profit
- Ownership of the transmission asset vs. no ownership
- Stakeholder Boards vs. Independent Boards
- Stakeholder Processes and Involvement

## 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



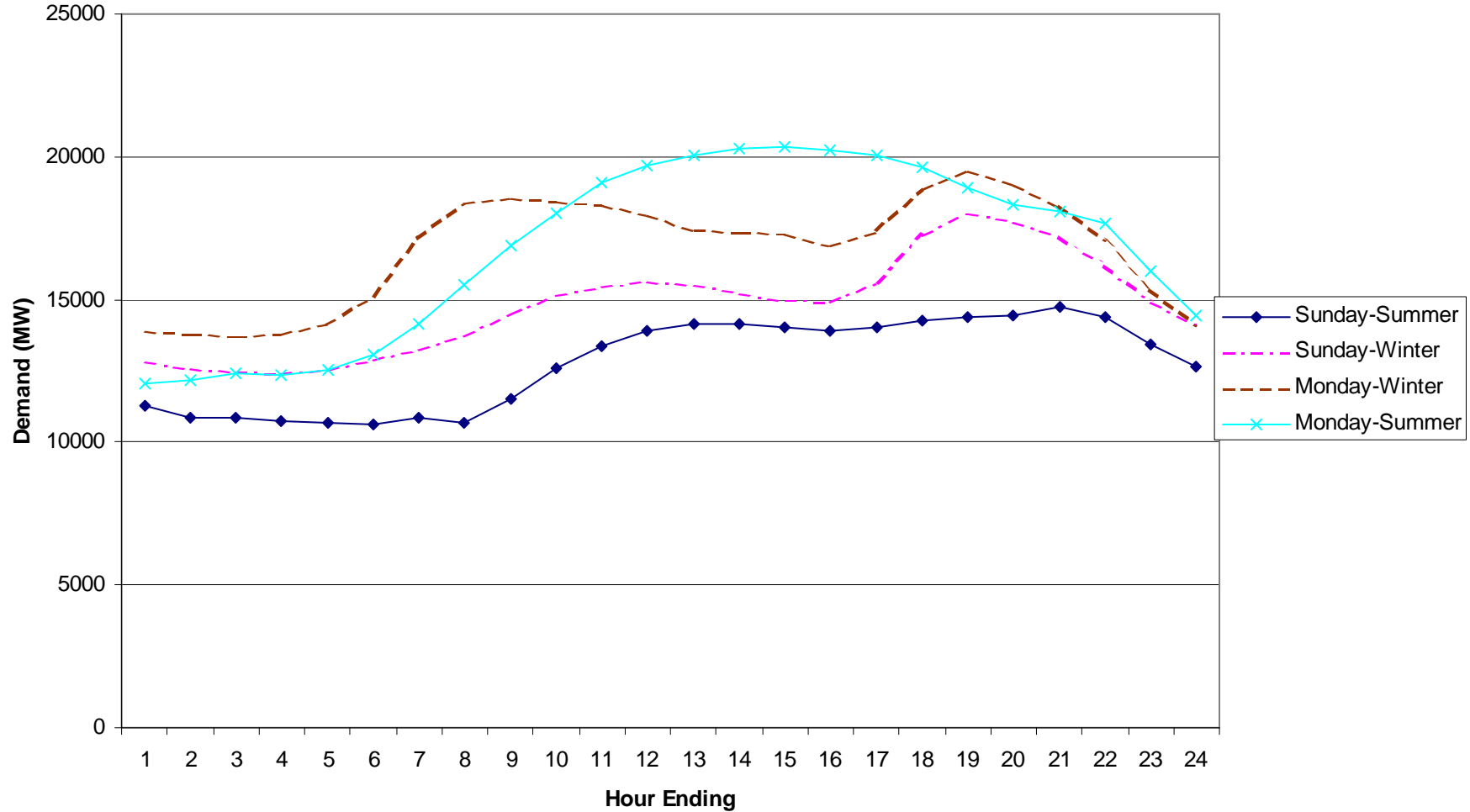
# Weekly Load Fluctuations



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

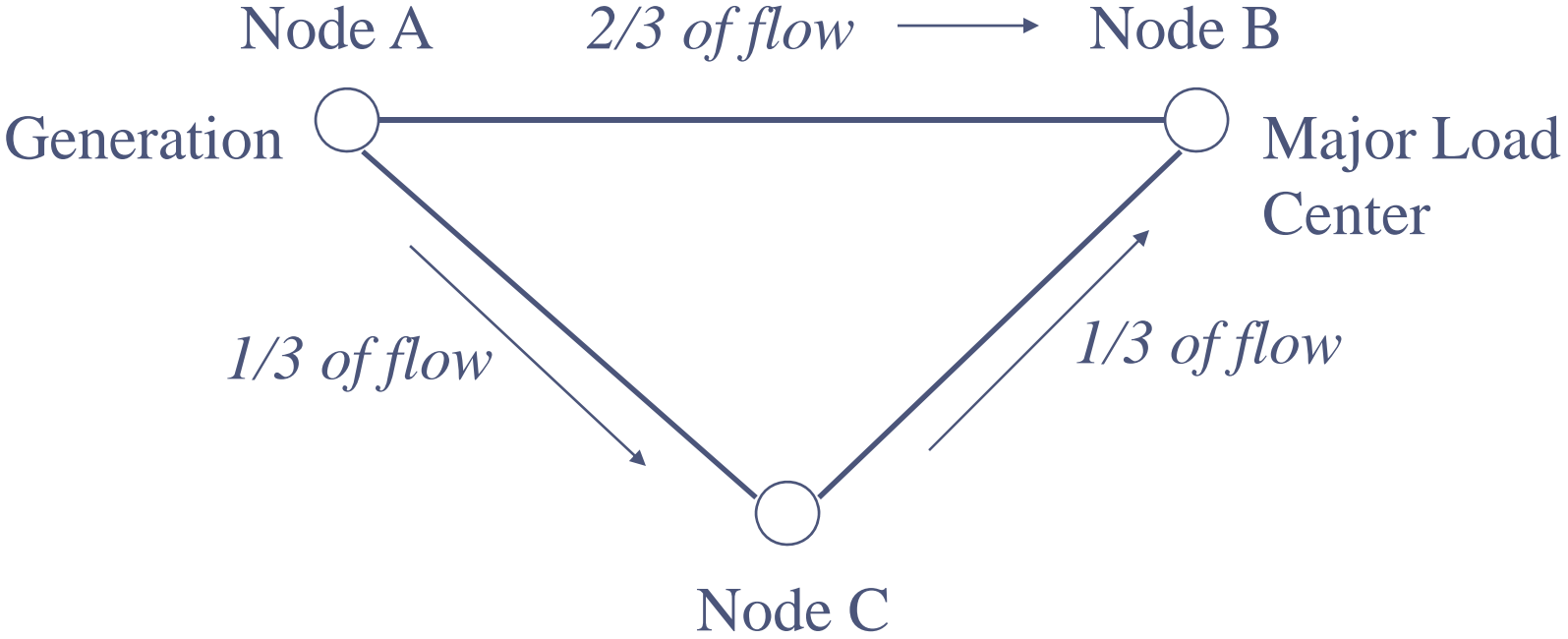


# Hourly Electricity Demand in New England During Typical Summer and Winter Mondays and Sundays





# 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

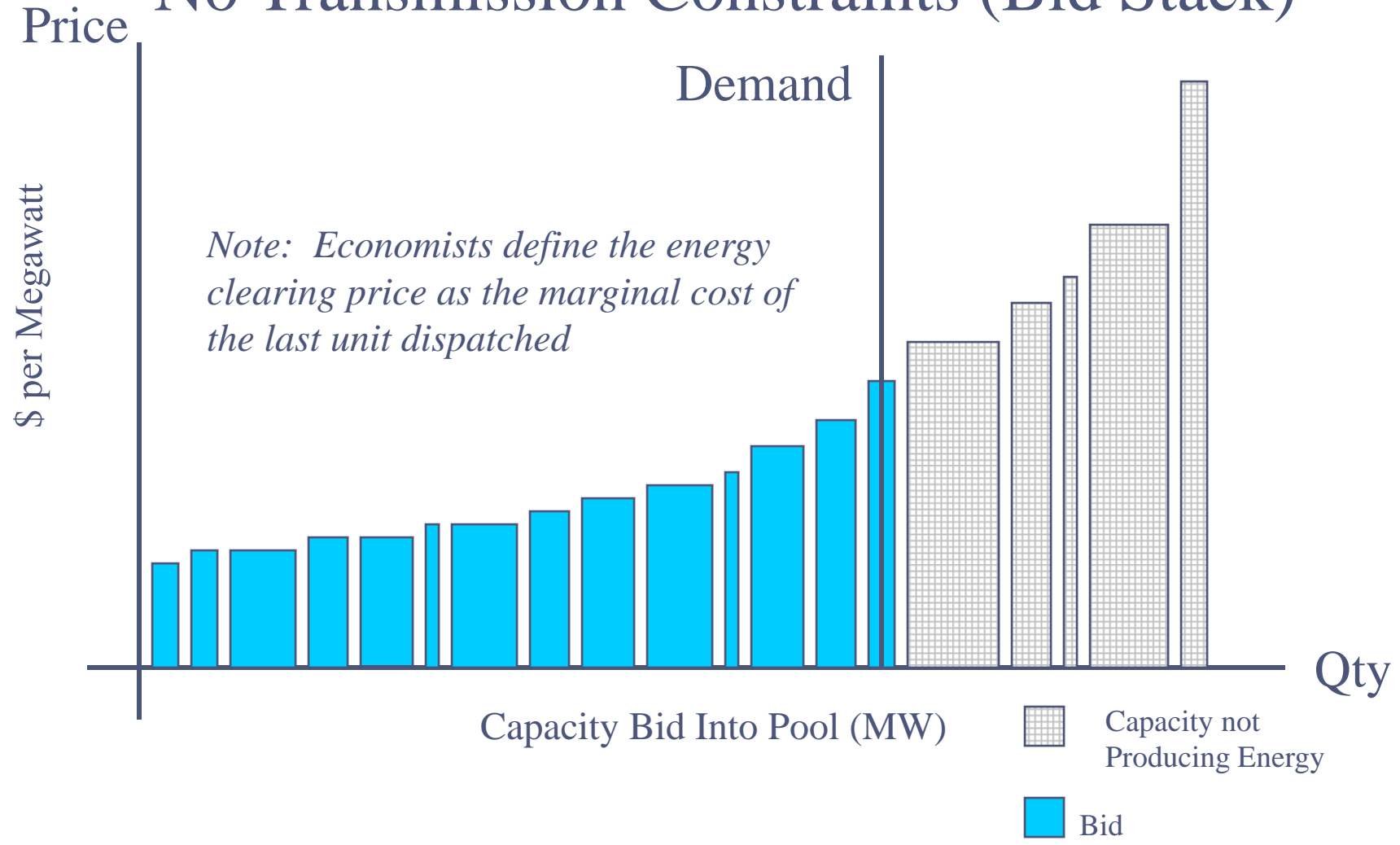


## Solution to the Dispatch Problem

- 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:  $LMP_s = LBMP_s = \text{Nodal Prices} = \text{Locational Prices}$

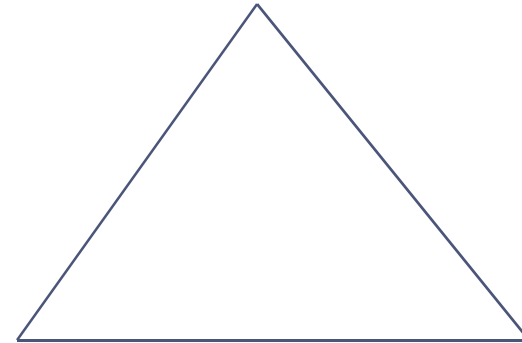
# Minimum Cost Dispatch Solution with No Transmission Constraints (Bid Stack)





## Locational Based Marginal Pricing - NO TRANSMISSION CONSTRAINT

$G1 = 90 \text{ MW at } \$50/\text{MWh}$



$G2 = 150 \text{ MW}$   
at  $\$30/\text{MWh}$

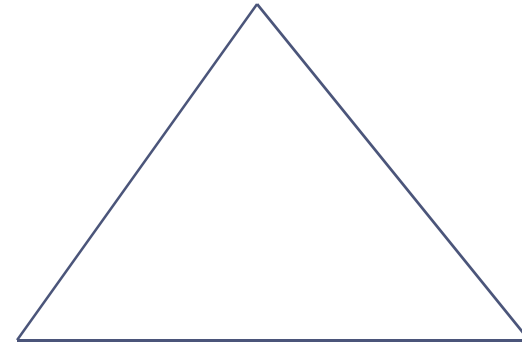
$L = 150 \text{ MW}$

- 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

G1 = 90 MW at \$50/MWh



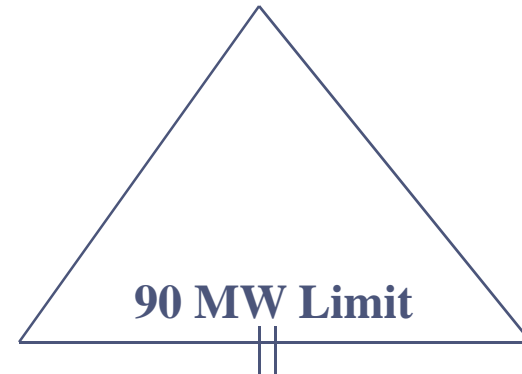
G2 = 150 MW  
at \$30/MWh

L = 150 MW

## Locational Based Marginal Pricing - TRANSMISSION CONSTRAINT

$G1 = 90 \text{ MW}$  capacity at  $\$50/\text{MWh}$

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



$G2 = 150 \text{ MW}$   
capacity  
at  $\$30/\text{MWh}$

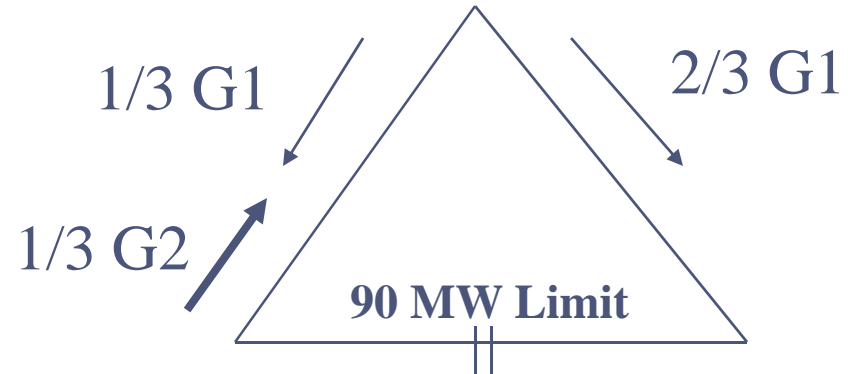
$L = 150 \text{ MW}$



# 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

G1 = 90 MW capacity at \$50/MWh



G2 = 150 capacity      L = 150 MW  
MW

at \$30/MWh

→ 1/3 G1 = 10 MW

→ 2/3 G2 = 80 MW



## 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