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Power System Operation and Control: Economic Dispatch

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- Long term system planning: Production cost
 - Decide what to build
- Hourly to monthly decisions: Unit commitment
 - Decide which plants to have warmed up and ready to go
 - Different technologies have different requirements
- Minutes to Hour: Economic dispatch
 - Decide which plants to use to meet the expected load now
 - 5 minutes to 1 hour
- Cycles to Minutes: Short term system operations and Load Flow Model
 - Maintain supply and demand balance moment to moment
 - ~17msec per cycle up to 5 minute control functions

What is “Economic Dispatch?”

- Economic dispatch (ED) determines the least cost dispatch of generation for a system.
 - To dispatch \equiv To order to generate (more) energy
- Economic Dispatch (from EPACT 1992)
 - The operation of generation facilities to produce energy at the lowest cost to reliably serve consumers, recognizing any operational limits of generation and transmission facilities.

Economic Dispatch Formulation

- Focusing on our objective
 - How do we represent our objective mathematically?
 - What mathematical tool do we use to obtain this objective?
- What does solving our (to be developed) set of equations help us to decide?

Economic Dispatch Formulation

- Therefore we need to understand
 - How to represent system generating costs mathematically
 - Costs of operating (dispatching) generators
 - Indirect costs associated with constraints on the system
 - How to find the minimum system cost given
 - Generator costs and
 - System constraints
 - Constrained optimization via linear programming

Generator Cost Characteristics

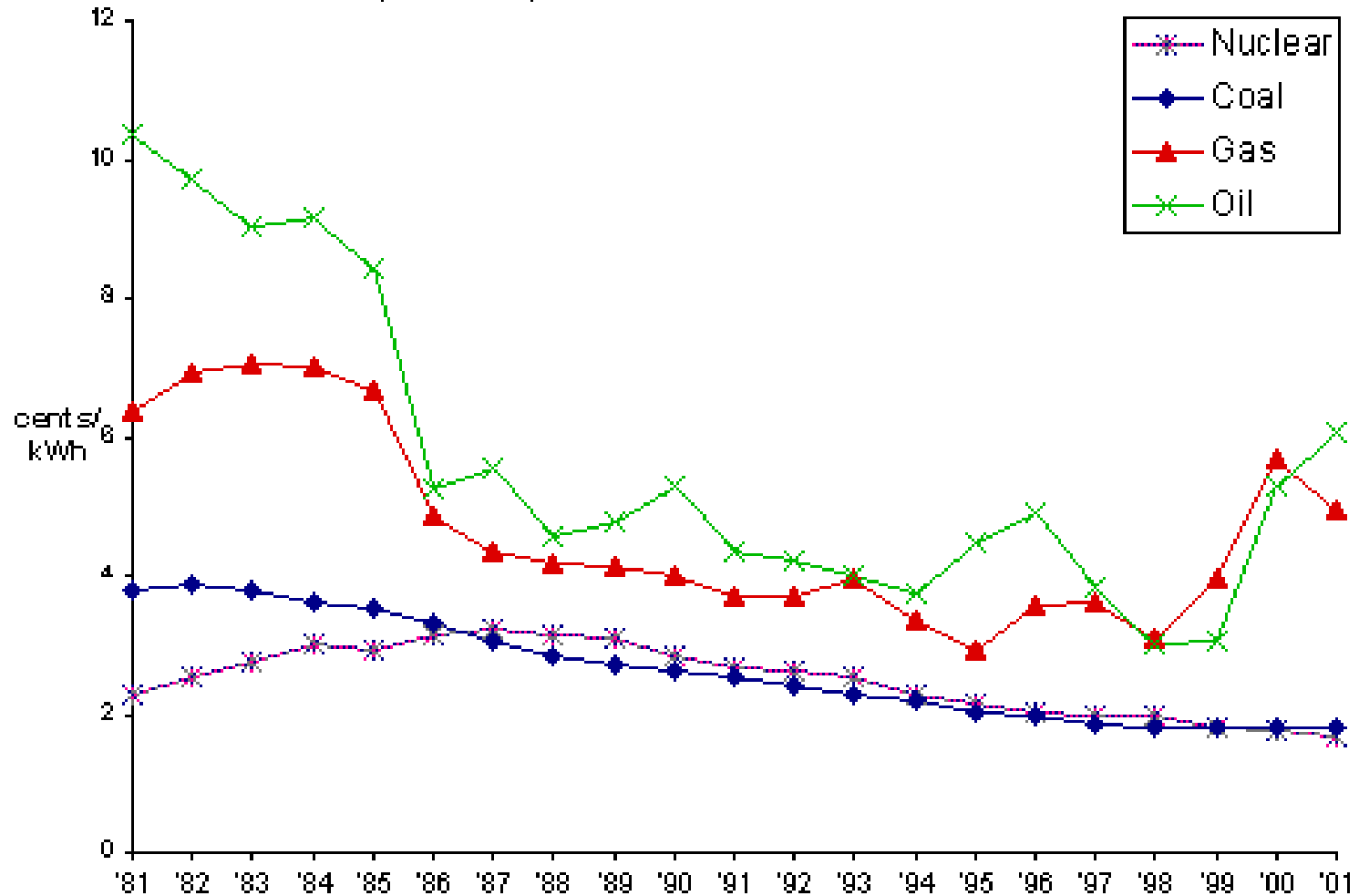
Generator Costs

- Many fixed and variable costs are associated with power system operation
 - The major variable cost is associated with generation
- The cost to generate a MWh can vary widely
 - For thermal units we have well-defined equations to calculate generating costs
 - For other generating units (e.g., hydro and nuclear) the cost is difficult to quantify

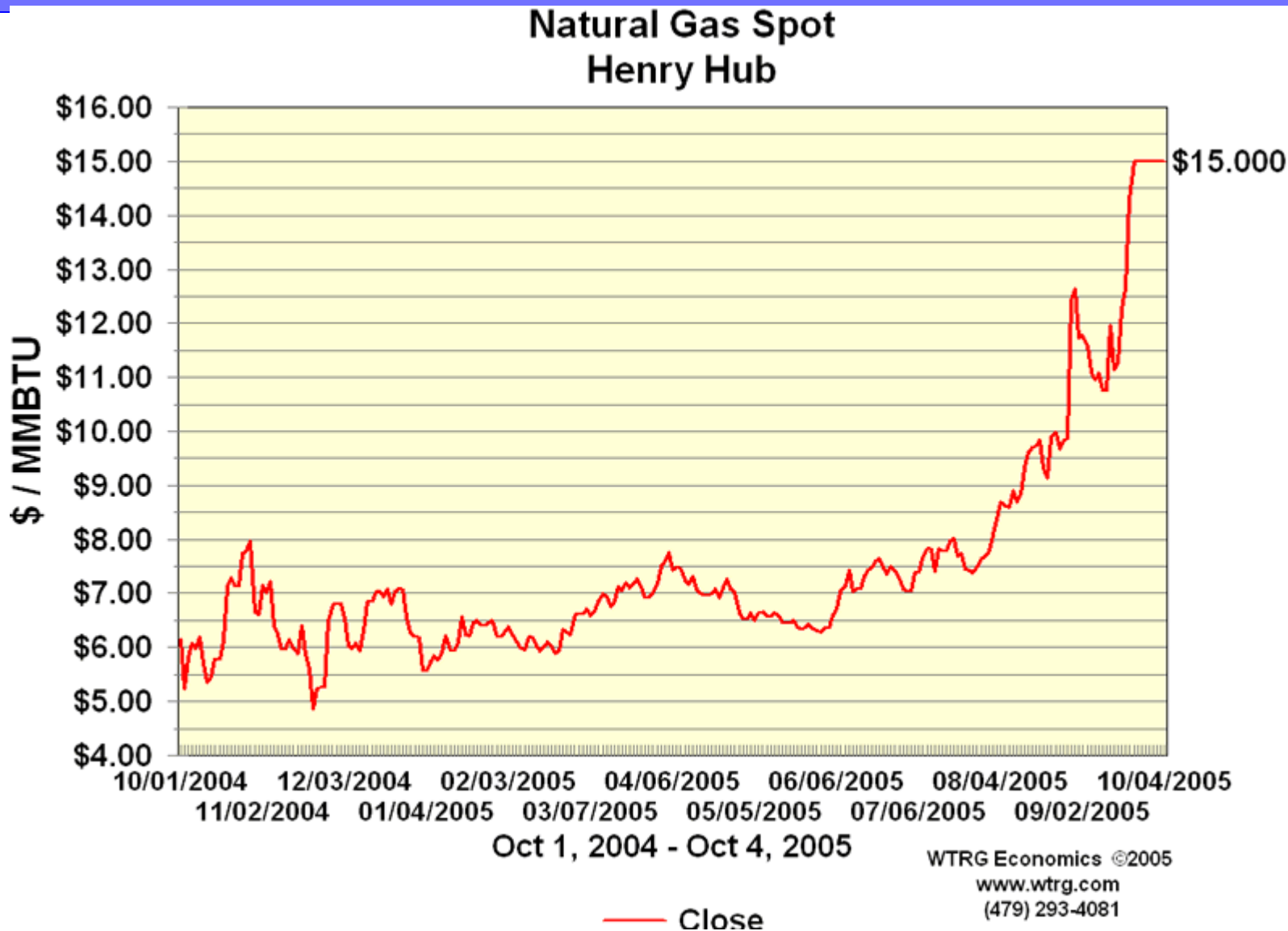
Time Variation in Costs

US Electricity Production Costs

(O&M+fuel) in constant 2001 cents/kWh

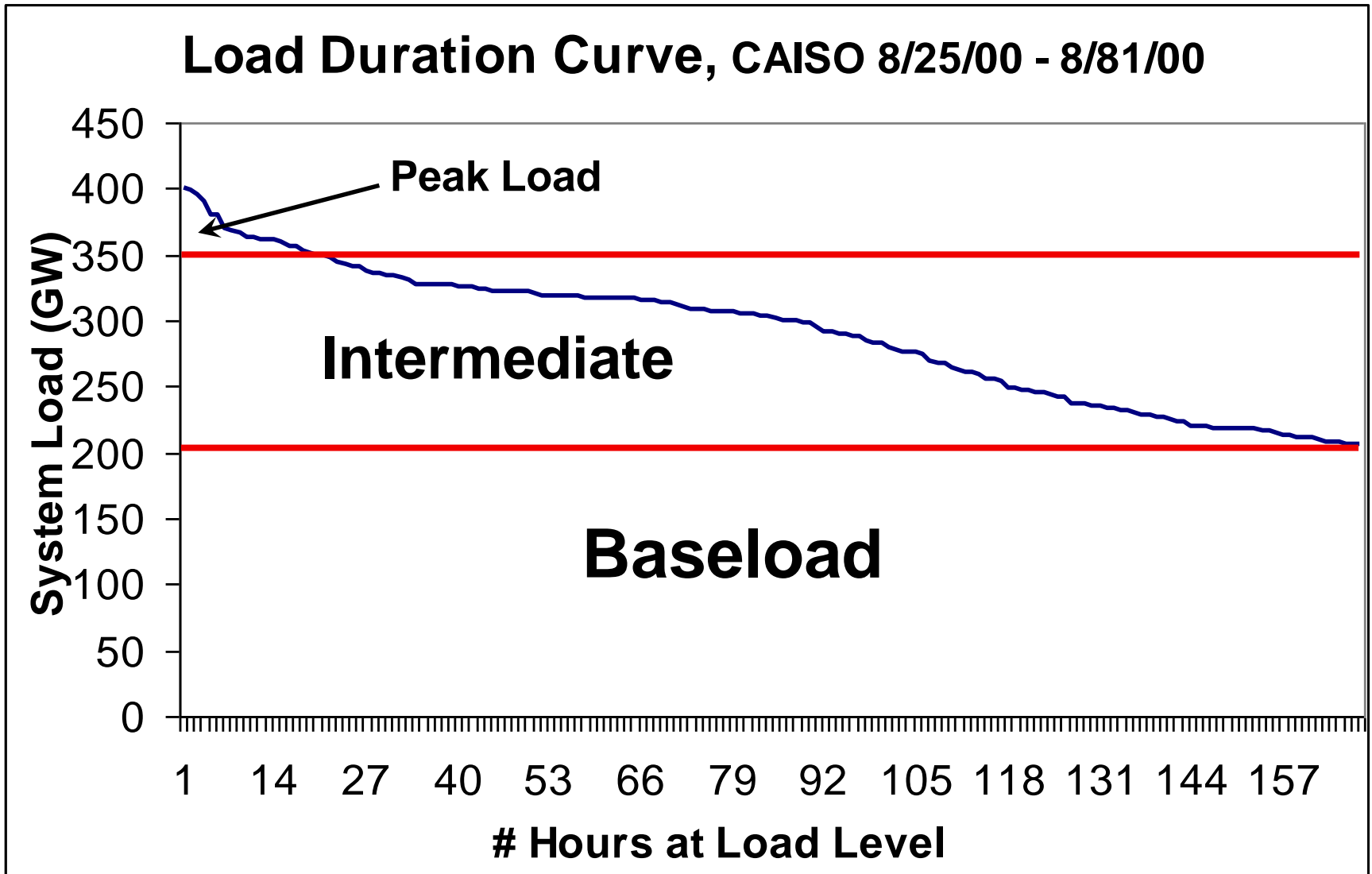


Natural Gas Prices Over the Years (adjusted for inflation)

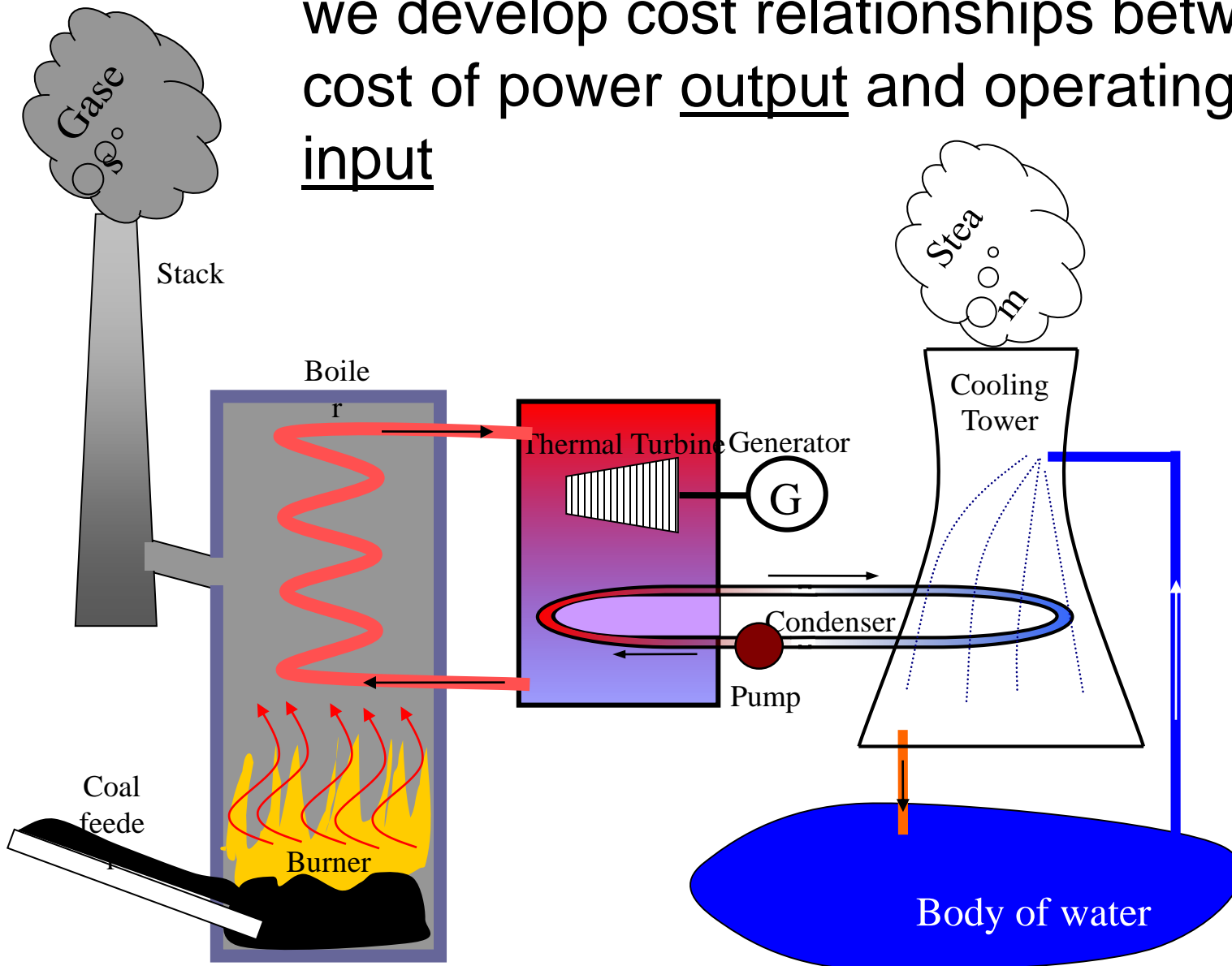


As we have already seen,
different generators are used in
different ways, as determined by
their different costs...

Generator Loading



To minimize total system generating costs we develop cost relationships between cost of power output and operating costs, input



Mathematical Formulation of Costs

- Typically curves can be approximated using
 - quadratic or cubic functions
 - piecewise linear functions
- Relying on the quadratic nature of HR, we will use a quadratic cost equation
- Standard quadratic representation is...?

$$C_i(P_{Gi}) = \alpha_i + \beta_i P_{Gi} + \gamma_i P_{Gi}^2 \quad \$/\text{hr}$$

Mathematical Formulation of Costs

- From total cost to marginal cost...
- The marginal cost is one of the most important quantities in operating a power system
 - Marginal cost = incremental cost: **the cost of producing the next increment of power (the next MWh)**
- How do we find the marginal cost?

Discussion Questions

- If we have 3 generators, our first-pass system cost equation is...?
- We find the minimum system cost by ...?
- How do we then find values for P_{G_i} from each generator (our original goal)?
- What is missing for the actual problem of finding the minimum system operating cost?

Summary

- Formulated the economic dispatch problem *conceptually*
- Examined the mathematical origin for generator costs
 - Defined heat rate
- Began mathematical formulation of the economic dispatch problem
- To be completed next Wednesday