Modelling Profit Maximisation in Deregulated Power Markets by Equilibrium Constraints

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Outline

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Introduction (I)

- Changes in global electric industry:
  - Deregulation
  - Competition
- Spanish electricity market
  - Beginning in January, 1998
  - Based on a simple merit order of the bids
  - Market clearing price is the highest accepted bid

Introduction (II)

- New Framework: Deregulated Power Market
  - Increased **opportunities** and increased **risks**
  - New **responsibilities**:
    - Unit commitment
    - Hydrothermal coordination
    - Biding prices and quantities
- Electric companies need original models that consider:
  - The technical operation constraints
  - The new **competitive framework**:
    - Profit maximisation behaviour

Modelling Approaches

- Other modelling approaches:
  - Based on the **market equilibrium**
  - Theoretical and practical advances
  - However, with **some limitations**
- Our approach:
  - **Detailed modelling operation** of thermal, hydro and pumped units
  - Single shot optimisation procedure
  - Competitive behaviour of the market

Model Overview (I): Traditional Production Cost Models

- Traditional Production Cost Models:
  - Medium term operation planning studies
  - Minimum generation cost subject to operating constraints
- Two relevant characteristics of these models:
  - A **detailed representation** of the electric system operation
  - Their **main** decision **variables** are the generation **output levels** offered to the market

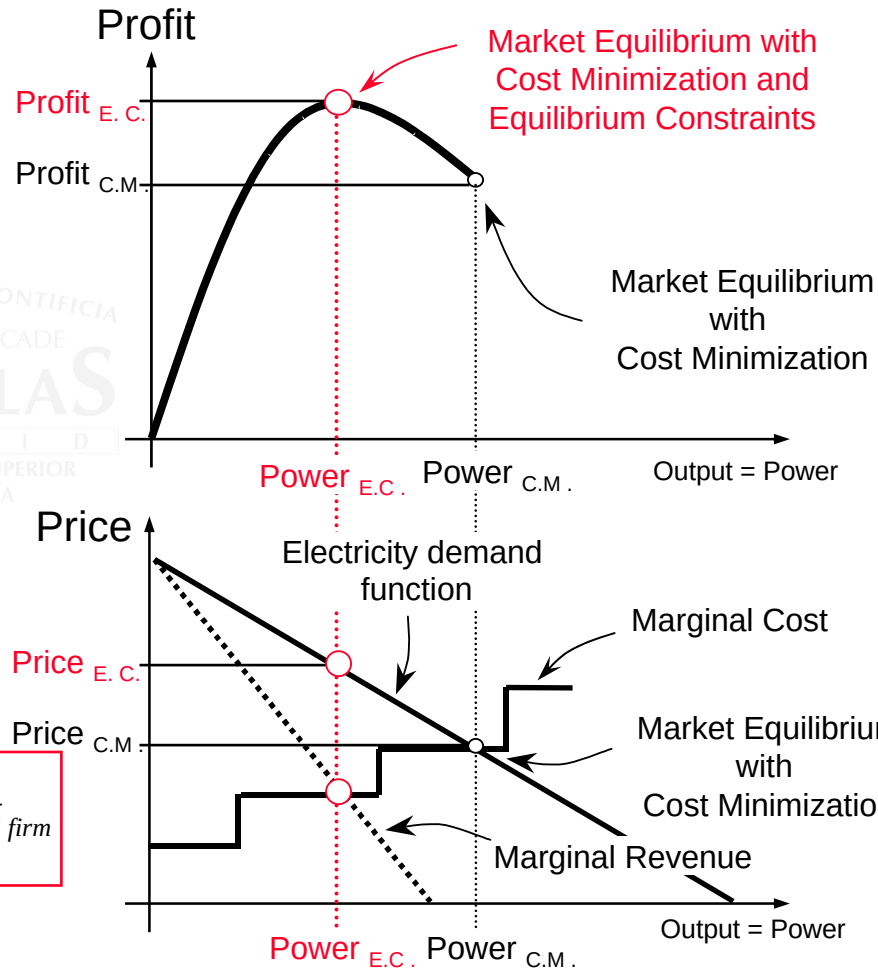
Model Overview (II): Equilibrium Constraints

- Equilibrium Constraints reproduce the first order optimality conditions of the firms' profit maximisation objective

$$Profit_{firm} = Price \cdot Power_{firm} - Cost_{firm}$$

$$\frac{\partial Profit_{firm}}{\partial Power_{firm}} = 0$$

$$\underbrace{Price + Power_{firm} \cdot \frac{\partial Price}{\partial Power_{firm}}}_{Marginal\ Revenue} = MarginalCost_{firm}$$



Scheme of the production cost model with Equilibrium Constraints

Minimisation of:

Objective Function →

Total Generation Variable Costs +
+ Costs of non accepted demand bids

Subject to:

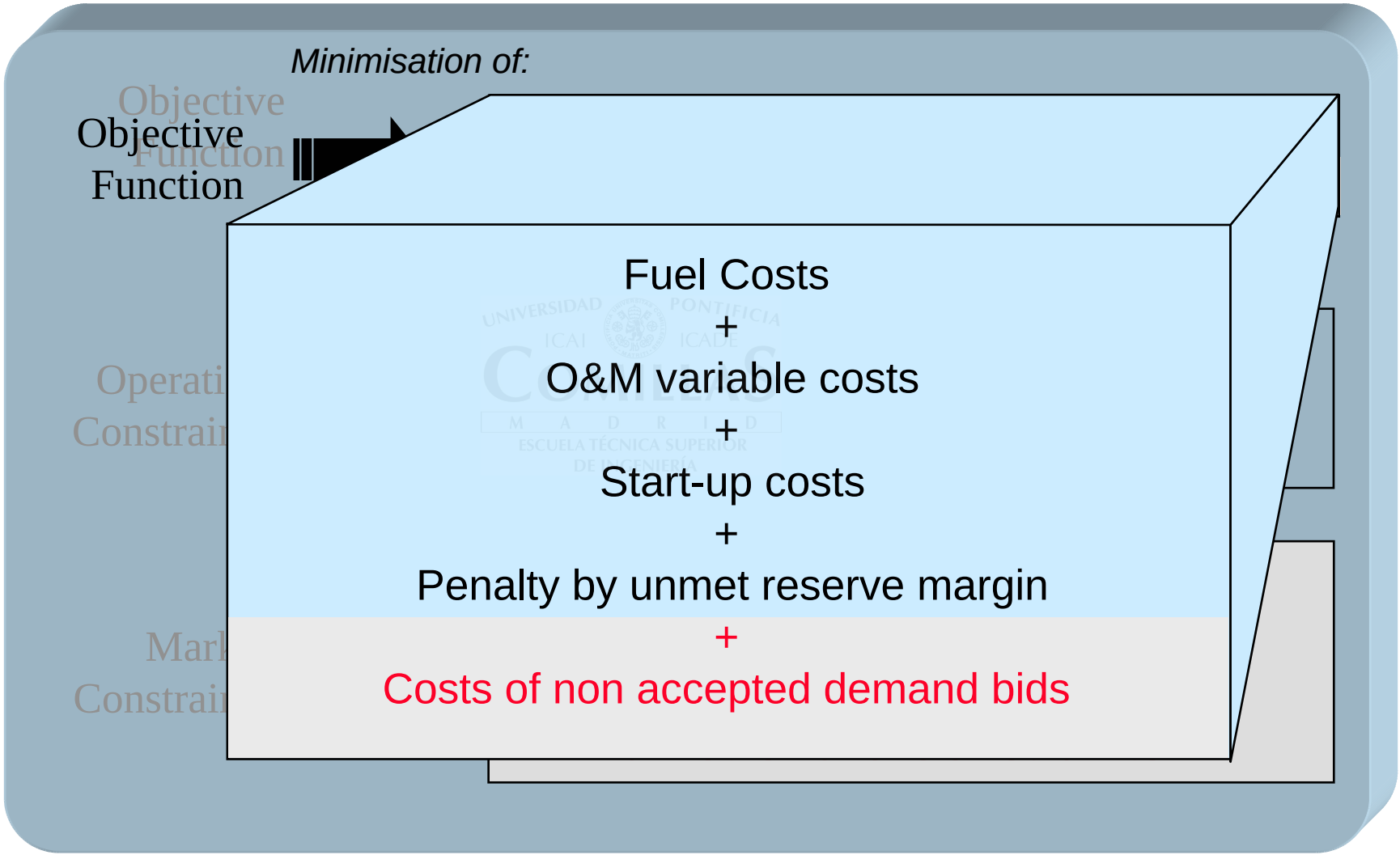
Operating Constraints →

- Interperiod Constraints
- Intraperiod Constraints

Market Constraints →

- Equilibrium Constraints
- Price equation
- Market Share Constraints

Objective Function



Operating Constraints

Minimisation of:

Objective Function

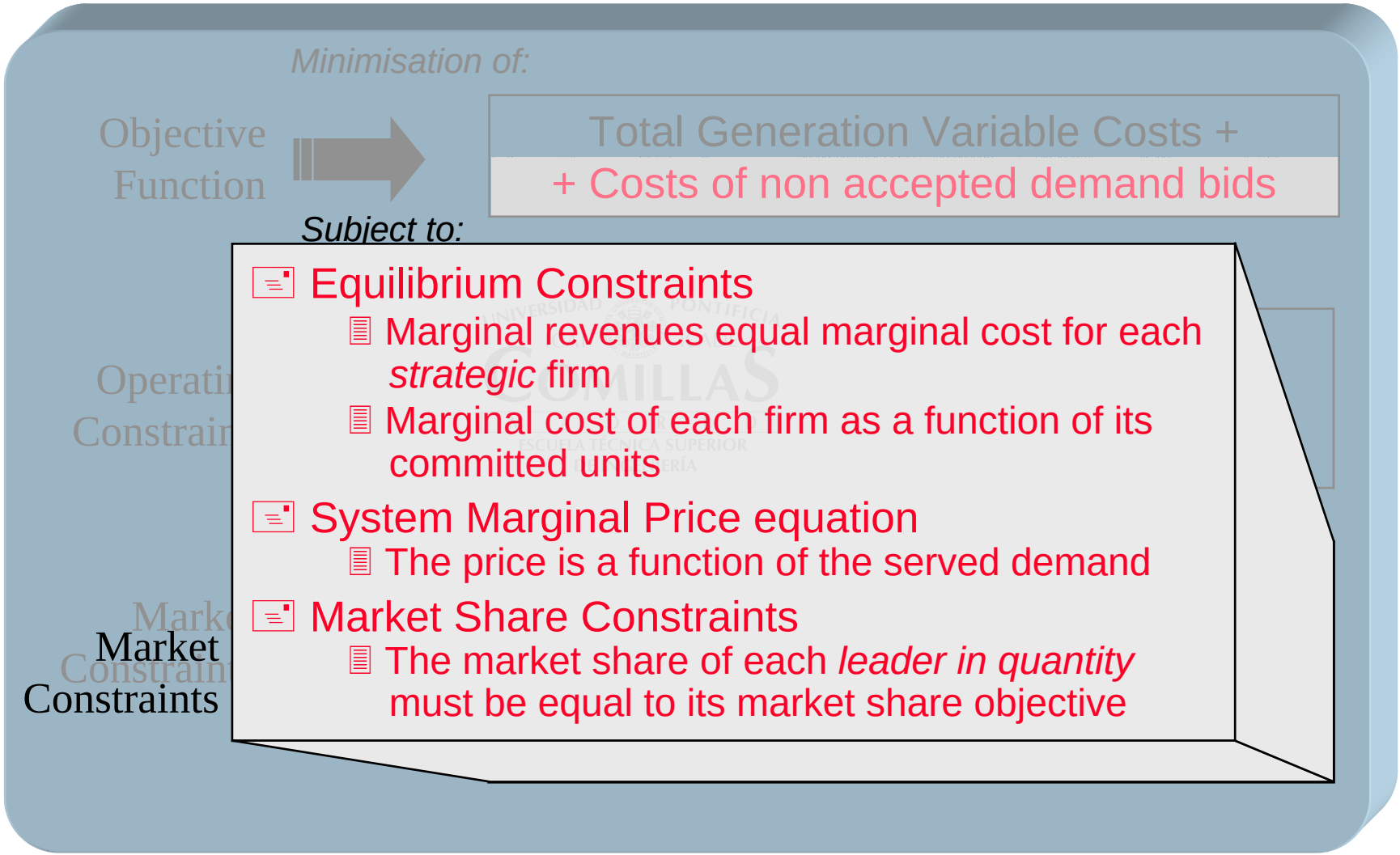
Total Generation Variable Costs +
+ Costs of non accepted demand bids

Subject to:

Operating Constraints

- Interperiod Constraints
  - Hydro management
  - Seasonal operation of pumped-hydro units
  - Fuel management
  - Maintenance scheduling
- Intraperiod Constraints
  - Balance between generation and demand
  - Generation Limits
  - Daily/Weekly pumped-storage units
  - Reserve Margin

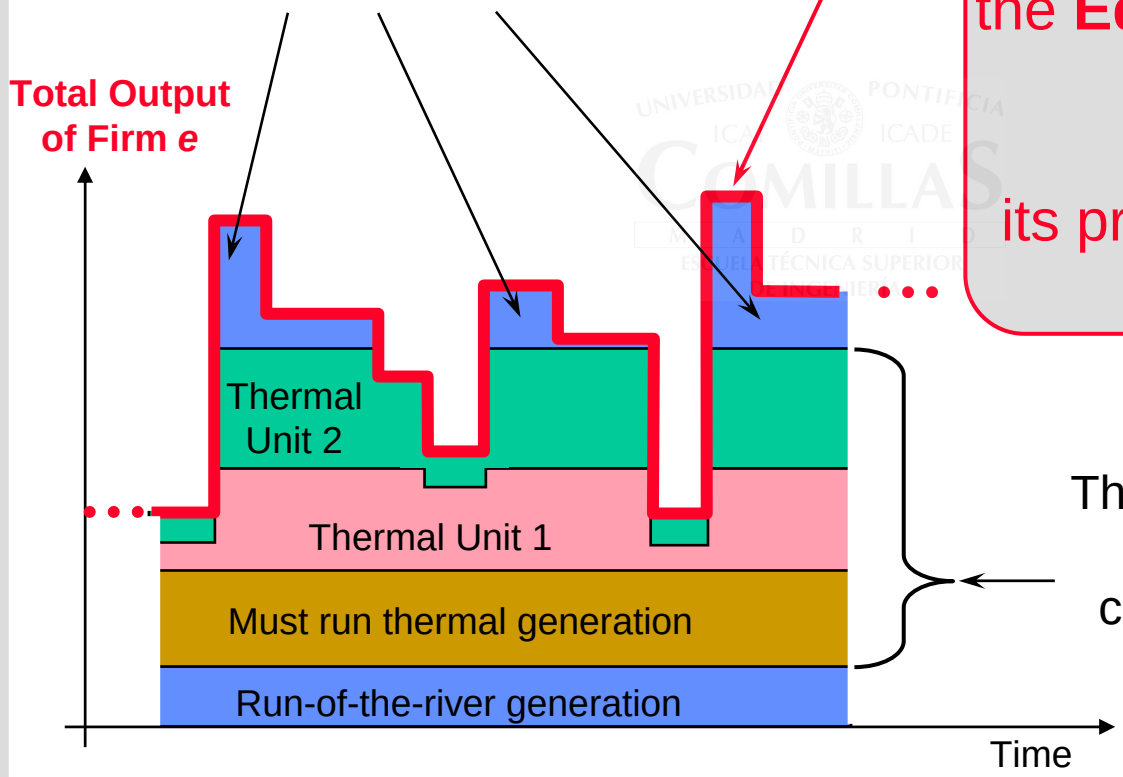
Market Constraints



How the Equilibrium Constraints Work

The **Cost Minimisation** achieves the cheapest feasible scheduling of hydro generation of each firm for the entire scope

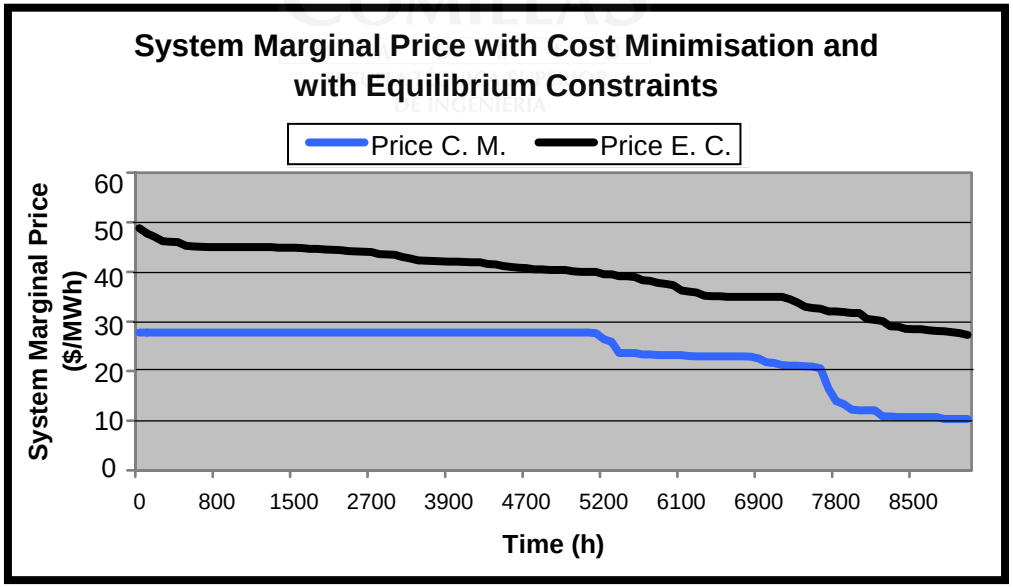
For each firm, the **Equilibrium Constraints** choose the output that maximises its profits for each load level



The **Cost Minimisation** achieves the cheapest feasible commitment of thermal units of each firm for each load level

Case Study

- Our model has been applied to the Spanish power market: 73 thermal units and 30 equivalent hydro units.
- The size of the MIP is 25,000 continuous variables, 2,000 binary variables and 33,000 constraints.



Model Applications

- Use of results for analysing strategies:
  - In the **long term**, it is essential to find **specific quantities** in order to maximise the profit
  - In the **short term**, **forecasted prices** help in defining bidding tactics in the wholesale market

Conclusion

- Power market approach based on MPEC
- **Maximise** the **producer profit** while taking into account **operating constraints**
- The equilibrium constraints implies only **minor modifications** to traditional models