ECE 573 – Power System Operations and Control

14. Introduction to Unit Commitment

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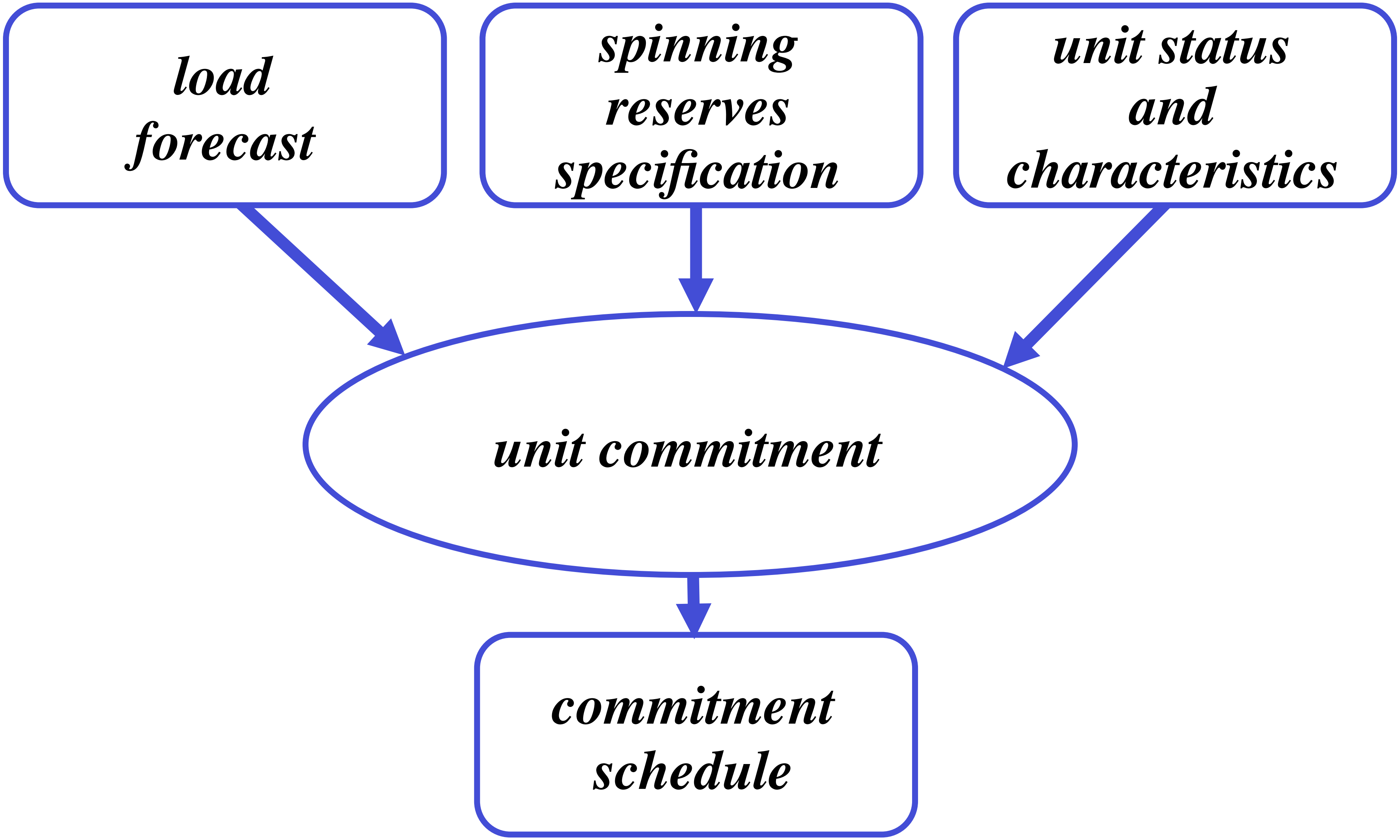
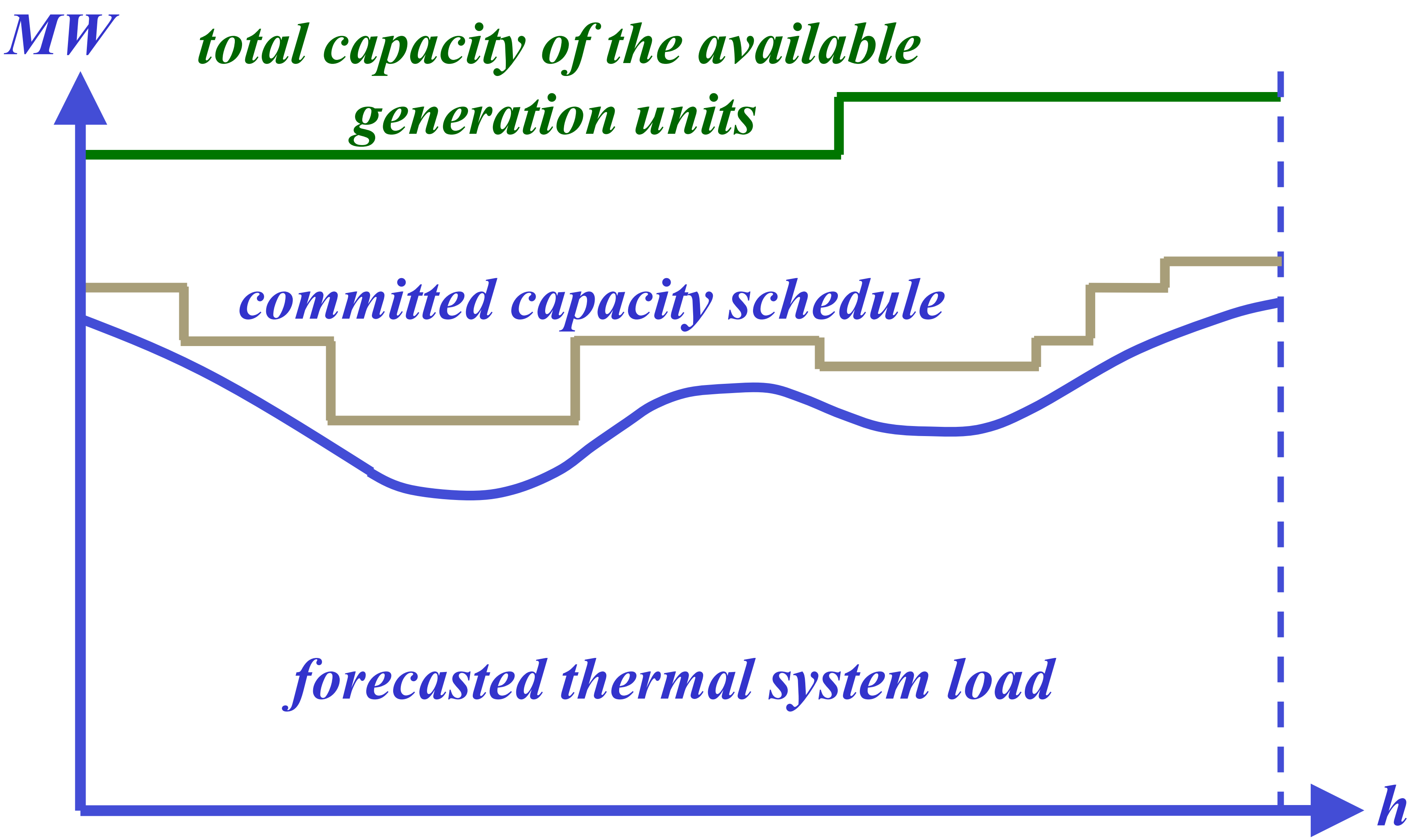
TOPICS

- The unit commitment (UC) problem statement
- Thermal system description
- UC problem formulation and statement
- Solution approaches
- Issues in UC

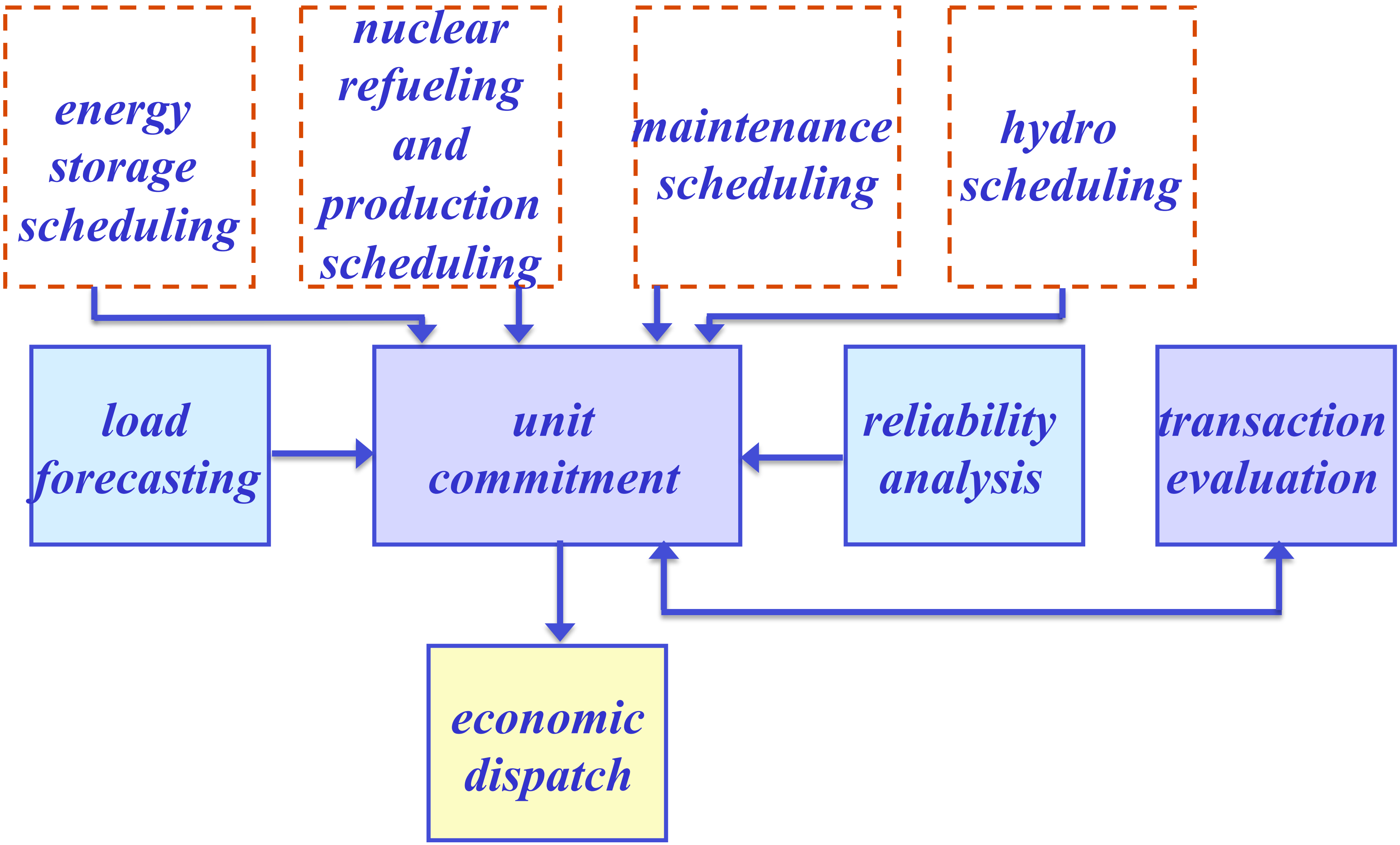
UC DECISION PROCESS



MATCHING SUPPLY AND DEMAND



UC ROLE IN SCHEDULING



THERMAL SYSTEM UNIT TYPES

- **Base–loaded units**
  - **are continuously on line**
  - **include, typically, nuclear, geothermal, very large steam units and also all *must–run units***
- **Cycling units**
  - **have on/off characteristics with minimum**

THERMAL SYSTEM UNIT TYPES

up/down times specified

- are, typically, steam units

- **Peaking units**
  - have on/off behavior as they are, typically, loaded at full capacity
  - good examples are combustion turbines

THERMAL SYSTEM DESCRIPTION

- **Constraint types considered**
  - **unit**
  - **plant related**
  - **system wide**
- **Cost components of scheduling unit operations**
  - **fuel**
  - **maintenance**
  - **start – up/shutdown**

THE UNIT COMMITMENT TASK

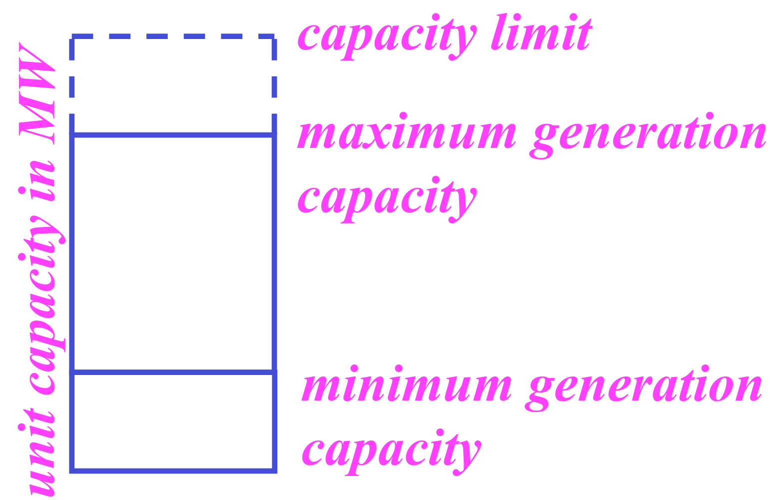
- **Scope**: to determine the minimum cost strategies for the start–up and shutdown of thermal units to supply the forecasted thermal load for a given period in a manner consistent with the generation equipment limitations and operational policies

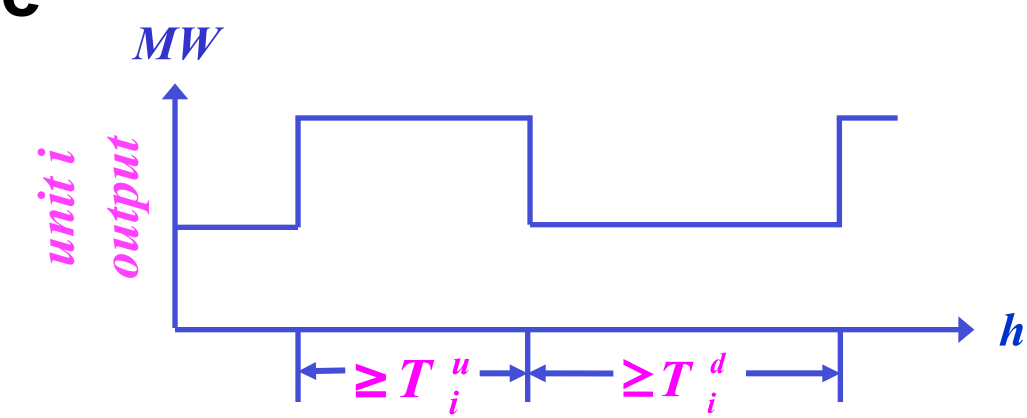
THE UNIT COMMITMENT TASK

- **Period**: typically, from one day to one week
- **Basic unit of time**: typically, one hour
- **Decisions**: the schedule of the hourly start–up and shutdown of thermal units
- **By–products**: hourly generation level for each thermal unit

REPRESENTATIVE UNIT CONSTRAINTS

- ❑ Minimum output
- ❑ Maximum output
- ❑ Minimum up time
- ❑ Minimum down time
- ❑ Start-up delay
- ❑ Derating
- ❑ Ramp rate (load pick up/reduction per minute)





REPRESENTATIVE PLANT RELATED CONSTRAINTS

- Maximum number of units which can be started up in a period k taking into account
  - crew limitations
  - auxiliary system constraints
- Maximum output from a plant
- Fuel constraints

REPRESENTATIVE SYSTEM-WIDE CONSTRAINTS

- *Load supply* : **commit sufficient generation to supply the forecasted load**
- *Spinning reserves* : **commit adequate number of generation units to meet the spinning reserves requirements**
- *Operating reserves* : **commit adequate number of generation units to meet the operating reserves requirements**

REPRESENTATIVE SYSTEM-WIDE CONSTRAINTS

- *Area Protection* : **satisfy area load protection requirements**
- *Environmental* : **satisfy emissions and effluent discharge limitations**
- *Transmission* : **comply with tie–line–flow limitations**
- *Fuel* : **comply with storage and inventory restrictions**

CONTRIBUTORS TO RESERVES

- **Synchronized units that operate *below full capacity***
- **Gas turbine units that can be synchronized in *t minutes* or less**
- **Interruptible loads (e.g., pumping loads)**
- **Purchase capacity interchange contracts (limited by tie–line constraints)**

RESERVES REQUIREMENTS

- Security and reliability considerations impose reserves requirements for every system
- Reserves requirements must be aligned with the level of security and reliability that the system wishes to maintain: the higher the reliability, the higher the reserves requirements for a given system

RESERVES REQUIREMENTS

- Reserves requirements are typically expressed as a fraction of the peak load for a given period: in essence, they constitute a deterministic criterion and act as a *proxy* for the probabilistic reliability measures
- The reserves requirements are a function of:
  - system net load

RESERVES REQUIREMENTS

- capacity obligations to other entities
- capacity of largest unit committed
- generation of the most heavily loaded unit
- level of interruptible imports and loads

- Reserves provide critically important *insurance* for the system operator

RESERVES DEFINITIONS

- *t – minute reserves of unit i* **: the additional load that unit i is capable to pick up in t minutes, with respect to its current operating point**

$$r_i^t[k] = min\left\{p_i^{max} - p_i[k], t \cdot (\, ramp\ rate\ of\ unit\ i\,)\right\}$$

- *t – minute system reserves*: **the additional load which the system is capable of picking up in t minutes from its current state**

$$period\ k\ system\ reserves = \sum_{\substack{commited \\ units\ i}} r_i^t[k]$$

RESERVES DEFINITIONS

- Reserves are functions of the:
  - response time, and
  - on–line/off–line status of contributors
- Reserves depend on the current system loading and on the loading of the committed generating resources
- *Spinning reserves*: typically defined as the 5–*minute* system reserves provided solely by on–line units

RESERVES DEFINITIONS

- *Operating reserves*: usually defined as the 10–*minute* or the 30–*minute* system reserves provided solely by the on–line units
- *Supplemental or backup reserves*: capacity that may become available on a longer basis, typically one hour, provided by units which need not be already synchronized

GENERATING UNIT ECONOMICS

- **The generator economics are, usually, represented in terms of the input–output curves**
- **The input–output curve determines the generator costs of production in** ***$/h*** **and are used to evaluate the marginal costs of production in** ***$/MWh***
- **These curves are** ***idealizations*** **of the input–output characteristics of a unit**

