NTNU – Trondheim
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Introduction to the Unit Commitment Problem in Electric Power Production

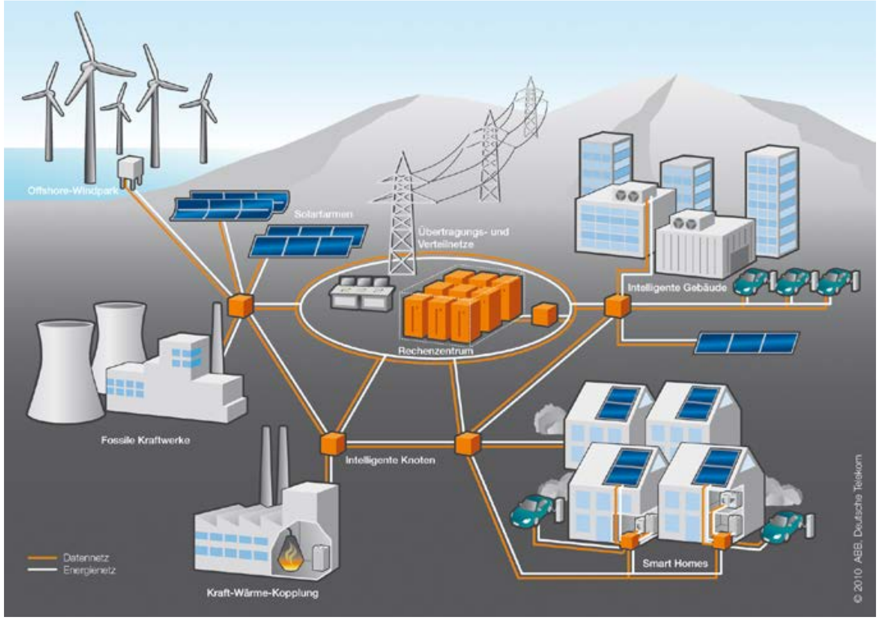
Outline

1. Problem defintion.
2. The structure of electric power generation
   1. Norway.
   2. The US.
3. The unit commitment and economic dispatch problem.
   - Various extension.
4. Solution approaches.

Unit commitment (UC)

Basic definition:

To find the least cost dispatch of available generation resources to meet an estimated electric power demand over a given time horizon.



Source: abb.de

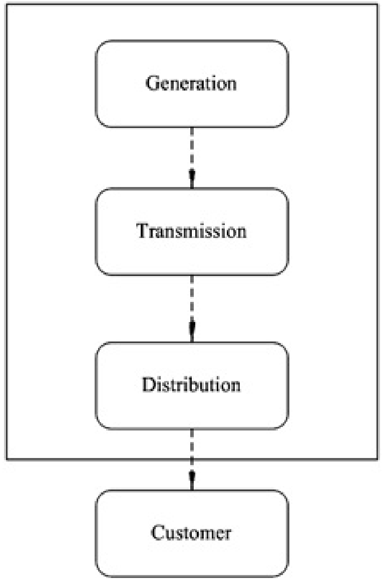
A variety of versions:

- Level of integration.
- Constraints included such as emission or security-of-supply constraints.
- Time horizon.
- Cost minimization or profit maximization.

Electricity market:

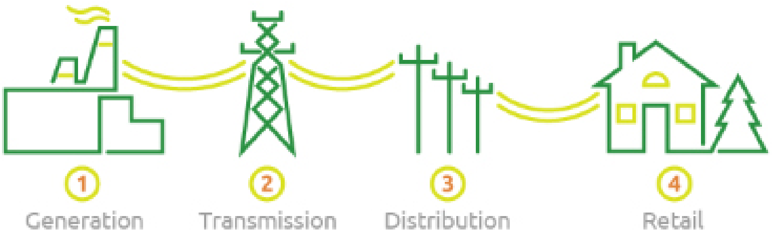
Regulated markets

- **One** utility controlling the power production for a whole region.
- Minimizing cost = maximizing profit.
- Vertical integration (monopoly)



Deregulated markets

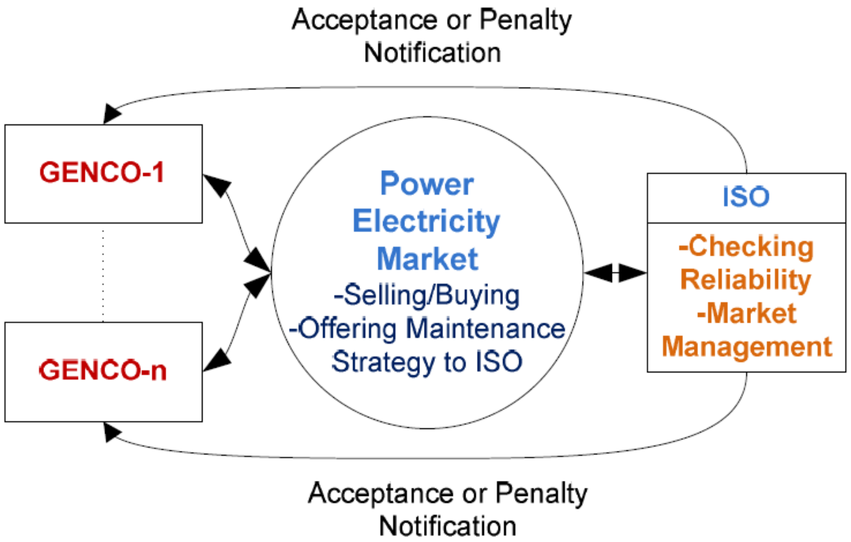
- **Several utilities** competing of being the most attractive provider of electricity.
- Different providers for different services.
- Generating companies (GENCOs) try to maximize their profit: revenue from sales minus generation cost.
- Independent system operators (ISO) coordinate, control and monitor the operations of the electrical power systems.



Source: xenogyre.com/

UC - a bid and auction system

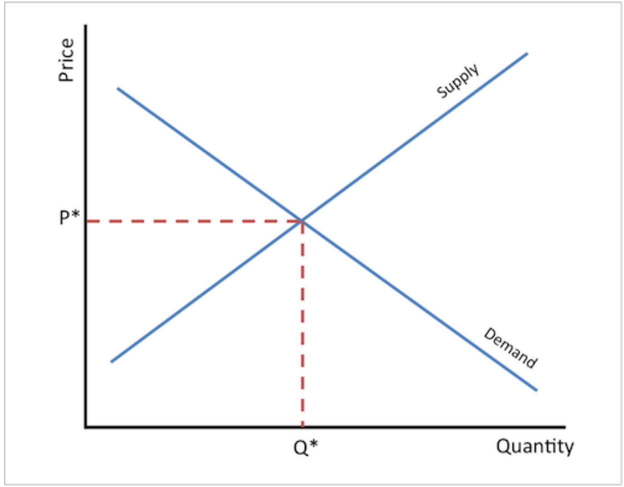
Source: Manbachi et.al



Basic sequence of trading for day-ahead UC

1. Transmission companies delivers capacity estimates in an area.
2. Power suppliers (sellers) delivers their offers → supply curve.
3. Buyers give bid on how much power there are willing to buy at which price → demand curve.
4. ISO adjust curves to ensure sufficient supply and a partly control prices to prevent squeezing of small suppliers and to maintain on acceptable prices for customers.
5. Prices is cleared – prices are set.

Note: Many variants in integration of ISOs and GENCOs



Market clearing price

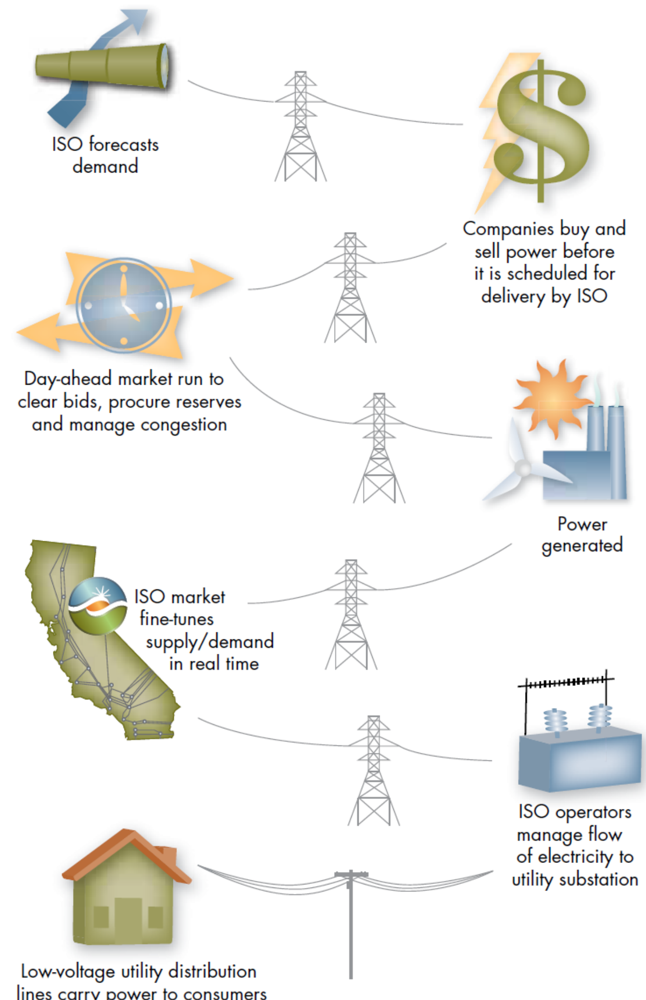
Adjusting the UC schedule

Power levels and units committed must be adjustment:

- Consumption differs from forecasted demand.
- Intermittent, stochastic resources (wind mills, solar cells etc.)

Different markets with different horizons:

1. Day ahead market: 24 hours – hourly dispatch plans.
2. Look-ahead unit commitment
   - Constantly adjust status of fast-starting units to ensure reliability of supply and meet *system changes* within the next 3-6 hours.
3. Real-time market:
   - Recommit very fast units (water, natural-gas) based on actual system operating conditions.
   - Time frame: 15 minutes to 2 hours.



Source: caiso.com

Unit commitment and economic dispatch

Given a forecasted demand d_k from an independent system operator (ISO)

UNIT COMMITMENT

Decide **which units** to operate when with respect to

- Min. generation costs:
  Fuel, maintenance and start-up costs
- **Power balance**
- Constraints:
  Spinning reserve, switching of units, generation capacity

MIP

ECONOMIC DISPATCH

Optimize **power level** for commited units

- Min. generation costs:
  Fuel - (maximize efficiency)
- **Power balance**
- Constraints:
  Maximum line power-flow, voltage constraints, generation limits for each unit

QP/NLP

THE UNIT COMMITMENT AND ECONOMIC DISPATCH PROBLEM

$\Downarrow$

Large-scale, complex MINLP

The conventional unit commitment problem

- Objective function: minimize total costs.
- Constraints shared by all units (global constraints):
  - Power demand.
  - Spinning reserve.
- Constraints for each unit:
  - Power capacity (min/max).
  - Minimum up down-time constraints.
  - Ramping constraints.

Extension of the unit commitment problem 1:

Emission-constrained unit commitment

1. Hard upper bound (constraints) on allowed emissions.
2. Penalty/cost on emissions in the objective function.
3. Emission allowance system (cap and trade).

Source: pennenergy.com

Extension of the unit commitment problem 2:

Stochastic unit commitment:

1. Uncertainty in demand.
2. Intermittent renewable generation resources.
3. Capacity of generators
   - Generators dropping out.
4. Varying fuel prices.

Extension of the unit commitment problem 3:

Security-constrained unit commitment

- Sufficient spinning reserves:
  - Abrupt changes in load.
  - Units dropping out.
- Transmission capacity.
- Natural-gas availability.

Source: http://buildipedia.com/

Source: forbes.com

Solution approaches for UC

- Solve as large-scale MILP or MINLP – need a tight formulation.
- Units are coupled by power balance and spinning reserve: Utilize block structure and apply a decomposition approach:
  - Lagrangian relaxation/decomposition