Monopolist: short term UC

At the heart of short term optimization problems there is the (short-term) Unit Commitment (UC). This problem requires to optimally operate a set of hydro and thermal generating units, over a given time horizon in order to satisfy a forecast energy demand at minimum total cost. The generating units are subject to various technical restrictions, depending on their type and characteristics. The UC is typically a large-scale, non-convex complex optimization problem.

Here we list several optimization problems from different entities perspective:

- **Monopolist systems**: here the actors are centralized in a single entity that manages the production, the transmission and distribution systems. Its main goal is a least cost schedule in order to supply load while respecting the several physical constraints. Depending on the power plants mix and level of details, several fuel unit constraints, hydro units (see below) and network constraints (e.g. voltage profile across the nodes, maximum active power flow across branches) are take into account. In increasing order of complexity we have the following problems:
    1. *Single centralized entity:*
        1. Load Flow
        2. Single Bus Economic Dispatch: only active power from units are optimized, status is assumed to be fixed, network is not considered
        3. AC/DC Optimal Power Flow: only active power from units are optimized, status is assumed to be fixed, network is considered only with DC approximation or full AC equations
        4. Short Term UC: both status and power of units can change, but network is not considered
        5. Security Constrained UC: both status and power of units can change, network is considered (with DC/AC equations)
- **Market based models**:
    1. *GenCo*: For GenCo the main goal is to maximize profit from selling energy and balancing capabilities. Depending on the size and risk profile GenCos can approach the maximum profit with different models, such as:
        1. Pure Price Taker
        2. Supply function equilibrium
        3. Residual Supply
        4. Cournot competition
        5. Bertrand competition
        6. Other more complicated models could include multi market maximum profit optimization models. In these models one tries to optimally allocate energy of power units among the different markets on cascade possibly with different clearing logic while respecting the operating - often multi periodal - restrictions of the power units. Also, if zonal prices are considered by the electricity market, some form of arbitrage could be tried by GenCos with production plants geographically spread across the system.
    2. *MO*: For Market Operators the goal is to clear the (hourly) energy market solving a maximum welfare optimization problems. Depending on the market rules MO problems can have different additional peculiarities, such as portfolio bid (i.e. the GenCos are allowed to bid energy from a portfolio of generation units), zonal prices (i.e. MO problem includes zonal transmission constraints that potentially creates different prices for GenCos) and other.These peculiarities do change the form of the maximum welfare optimization problem ranging from middle scale Linear Programming to much more complex Mixed Integer Non linear Problems. From the beginning of 2015 European Community started the so called Price Coupling of Regions (PCR), a unified electricity market at European level that clears energy prices at EC level including the several differences among previous national market rules.
    3. *TSO*: For Transmission System Operator the goal is to maintain overall system stability including network. This broad goal is achieved at different time scale, in the short term this basically amount of solving:
        1. Residual Demand Offer Based SCUC (i.e. a residual demand SCUC, after energy market are cleared. This SCUC is based on the offer made by GenCos to the TSO). This essentially is the goal of the Balancing Markets.
        2. Detailed OPF including full Alternative Current (AC) representation of the network laws. (see also the section Operationa l-Network Management)
        3. Renewable coordination, since these types of production plants are subject to uncertainty, TSO in modern systems must take care of these issues in solving BM. This calls for specialized methodologies for the reserve requirements satisfaction.
        4. Optimal Transmission Switching (OTS). Very recently TSO are investigating the possibility of opening (tripping out) some line of the High Voltage network in order to alleviate some constraints in the network itself. This problem must be solved in conjunction with SCUC or OPF and give raise to very complex optimization problems. (see also the section Op erational-Network Management)

In both monopolist and market based models of course production power plants dynamics have to be modeled in a correct way. In the short term, GenCos must consider these constraints in the most detailed way, here we sketch some of the most important:

- **Thermal units:** Thermal (including nuclear) power plant are modeled in a somehow detailed manner. Main constraints and objective function include:

1.
    1. quadratic cost curves possibly including some important (interdicted) valve point.
    2. min and maximum stable production.
    3. ramp rates and start up rates, possibly depending on the working points for bigger coal plants.
    4. complex operating dynamics for Combined Cycle Gas Turbine (CCGT) that have several Gas Turbine (GT) coupled with Steam Turbine (ST).

- **Hydro Units:** Also hydro units are modeled in a somehow detailed manner. Main constraints include:

1.

1. Water-to-Power non linear relationships, for thin basin the bilinear dependency of the basin level, together with the discharge, can be included. This severely complicates the models.
2. Complex cascade dynamics, including delays in the water flows from one basin to another. These delays can be also of different hours for big cascade and as a results their consideration strongly couples the decision variables along the time dimension.
3. Additionally a forecast of possible natural inflows must be considered, due to rain or snow melt in some situations.

- **Renewable non programmable (i.e. wind and solar):** These power plants do not actually have operational constraints but due to their intermittency the TSO (or the monopolist) must carefully forecast their production profile perhaps by geographical aggregation. In turns the inherent uncertainty in their (forecasted) schedule calls for stochastic-like approaches.

CPLEX applications

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