Joint solution to the long-term power generation planning and maintenance scheduling

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1. LTGMP problem

Long-term electric power planning is a stochastic optimization problem. It has to be solved for new plant planning, fuel acquisition, and long- and short-term operation. Another decision that can be optimized is where to set the maintenance periods of the thermal units.

The Bloom and Gallant formulation (1) with the maximization of the profit (for a liberalized market) is a quadratic programming model that optimizes the expected generation of each unit of the pool in the intervals in which the long term period is split. The maintenance scheduling model is a linear binary problem (4). The union of both models results in a quadratic mixed binary problem (QMBP):

$$
\begin{aligned}
\text{minimize } & h'x + \frac{1}{2}x'Hx && \text{(1a)}\\
\text{subject to: } & Ax \geq b && \text{(1b)}\\
& Cy = d && \text{(1c)}\\
& 0 \leq x_j^i \leq \overline{x}_j^i y_j^i \quad \forall\, i,\, j && \text{(1d)}\\
& y_j^i \in \{0,1\} \quad \forall\, i,\, j && \text{(1e)}
\end{aligned}
$$

where constraints (1b) are part of the generation planning model (with continuous variables) and constraints (1c) models the maintenance schedule (with binary variables). The constraints on the upper bound (1d) links the two models. The subindex j indicates the unit and the supraindex i indicates the interval.

2. LTGMP solution approach

We solve problem (1) using some global optimization methods together with a specialized interior point technique.

Therefore, problem (1) is transformed into the continuous equivalent programming problem

$$
\begin{aligned}
\text{minimize } & h'x + \frac{1}{2}x'Hx - \lambda y(y-1) && \text{(2a)}\\
\text{subject to: } & Ax \geq b && \text{(2b)}\\
& Cy = d && \text{(2c)}\\
& 0 \leq x_j^i \leq \overline{x}_j^i y_j^i \quad \forall\, i,\, j && \text{(2d)}\\
& 0 \leq y_j^i \leq 1 \quad \forall\, i,\, j && \text{(2e)}
\end{aligned}
$$

by using the non-convex constraint

$$y_j^i(1 - y_j^i) = 0 \quad \forall\, i,\, j,$$

with $\lambda \geq 0$.

For a suitable given values of $\lambda := \lambda^*$ the global optimal solution of both problems, (1) and (2), are the same.

The objective function (2a) is a difference of two convex functions. By using global optimization techniques (2; 3) we can transform problem (2) into an equivalent convex minimization problem with a reverse convex constraint:

$$
\begin{aligned}
\text{minimize } & h'x + \frac{1}{2}x'Hx - t && \text{(3a)}\\
\text{subject to: } & Ax \geq b && \text{(3b)}\\
& Cy = d && \text{(3c)}\\
& t - \lambda y(y-1) \geq 0 && \text{(3d)}\\
& 0 \leq x_j^i \leq \overline{x}_j^i y_j^i \quad \forall\, i,\, j && \text{(3e)}\\
& 0 \leq y_j^i \leq 1 \quad \forall\, i,\, j && \text{(3f)}
\end{aligned}
$$

The new problem introduces a new variable, t, and one quadratic reverse convex constraint (3d). Notice that problem (2) and (3) are equivalents for any nonnegative value of λ, but the problems

(1), (2) and (3) are equivalent only for a suitable $\lambda := \lambda^*$.

By using problem (3) a sequence of programming problems are generated in order to obtain a good approximation to λ^*, and therefore, to the optimal solution of the original problem (1). Each new problem updates the λ value and adds linear constraints that limit the feasible domain.

Each generated problem is initialized with warm-start techniques and solved with interior point methods.

In the presentation the main parts of the model and the relevant details of the implementation will be further developed. Application to the solution of realistic cases of the Spanish electricity system will be presented.

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