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Bilevel programming algorithms for optimal strategic bidding of energy producers in day-ahead electricity markets

This PhD dissertation considers the problem of devising optimal price-offers (bids) for an energy producer participating in a day-ahead electricity market which exhibits non-convexities due to the discrete nature of the generation units' commitments. The problem definition assumes perfect knowledge of the technical characteristics and bidding offers of all remaining producers. The problem is formulated as a bilevel optimization model with linear constraint sets at both levels. The model utilizes discrete variables to represent the commitment of the production units, which prohibits the application of typical methodologies for finding its optimal solution, such as the substitution of the lower-level problem by its first-order KKT optimality conditions.

Utilizing several important theoretical properties which hold true for this optimization problem, the dissertation develops specialized solution methodologies for treating several of its variants. The first one is an exact solution algorithm, which, utilizing important findings from the theory of integer parametric programming, handles the single period variant of the problem. The underlying theory is exploited next for the development of a heuristic, as well as an exact solution methodology for the multi-period variant of the problem. The heuristic solution approach works iteratively, optimizing a single price-offer at each iteration, given that the remaining ones are kept fixed at their current values. The exact solution approach succeeds in identifying the global optimum of the problem, through the generation of special valid inequalities which are added to a suitable relaxation of the original formulation.

Next, the dissertation develops an improved version of the exact solution algorithm for the treatment of the multi-period variant of the problem. The significant advancement of this algorithm lies in the inclusion of special optimality conditions ensuring that the energy quantity distribution in each time period of the planning horizon is optimal for the corresponding set of producers that has been identified as active in that time period. Consequently, solving the original problem to global optimality becomes equivalent to identifying the optimal set of active producers in each time period of the planning horizon.

The application of the proposed methodologies is illustrated on small case studies, while their behavior and performance is demonstrated on randomly generated problems. This has been made possible through the actual implementation of these methodologies using source programming code interacting with the commercial optimization software packages CPLEX and LINGO. As the presented results reveal, the proposed methodologies are capable of handling problems of considerable size using reasonable computational resources. The dissertation concludes with an insightful discussion on how the proposed algorithms can be modified to fit alternative market designs.

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Διαδικτυακή πλατφόρμα τηλεδιασκέψεων “zoom”.