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Stochastic Dual Dynamic Integer Programming: finding better Lagrangian Cuts and application on energy planning problem

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Energy planning plays a fundamental role in managing the generation resources in a power system. This planning must meet both present and future energy demands, considering various operational, electrical, environmental, political, and other constraints. The main objective is to allocate resources in a way that minimizes costs while mitigating risks associated with future uncertainties, ensuring the system's energy security.

Hydroelectric plants, which represent the main energy source of the Brazilian system, have operational constraints that lead to integer optimization modeling. These constraints can significantly impact the overall system operation. Therefore, it is crucial to accurately represent them in the optimization models used in energy planning to ensure time consistency, where the characteristics of the problem in future stages should be as close as possible to what will be implemented in the future.

However, the application of mixed-integer stochastic optimization for large-scale problems is still a developing field, especially when seeking detailed modeling of non-convex constraints. Thus, this work aims to identify and analyze various challenges related to energy planning, with an emphasis on mathematical modeling, solution algorithms, and computational robustness.

The main objective of this work is to explore the modeling of constraints involving integer variables in medium and long-term energy planning with an emphasis on the Stochastic Dual Dynamic Programming (SDDiP) algorithm. A conceptual evaluation of the cuts used in the SDDiP algorithm was carried out, focusing on the characteristics of the dual problem and the impact on the method's convergence rate. Based on this analysis, a methodology capable of obtaining more robust cuts is proposed. Results of the SDDiP method is applied in the context of stochastic energy planning, evaluating both the existing methods for constructing cuts and the proposed methodology.

Keywords: Energy Planning, Stochastic Optimization, Mixed-Integer Linear Programming, Stochastic Dual Dynamic Programming, Lagrangian Cuts

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