LONG-TERM POWER EXPANSION MODEL WITH INTERMITTENT RENEWABLE ENERGY — A MULTISTAGE STOCHASTIC OPTIMIZATION BASED ON NESTED BENDERS DECOMPOSITION

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Overview

Renewable energy has gradually become the key to the energy transition around the world. Aggressive development of renewable energy will require significant expansions in both generation and transmission infrastructure. However, the intermittent and uncertain nature of renewable energy makes us have to consider this part of the factor and the corresponding costs when planning for capacity expansion. This paper is mainly devoted to the long-term power expansion model considering the nature of intermittent renewable energy, detailed operational constraints,power flow between regions. We present a multistage multi-region power planning model which based on mixed-integer linear programming, aiming to choose the optimal annual investment strategy and hourly operating schedule for the power system over the time-horizon for each location and use it to evaluate inter regional power reinforcements. Based on China's real data, we conduct a case study of China's power industry to optimize the capacity expansion until 2040 considering the uncertainty of wind power and solar PV.

Methods

We tackle this complex decision problem in three steps. First, we present a deterministic planning model to meet the desired renewable energy penetration level. It integrates unit commitment into a long-term generation expansion planning framework. Hourly power dispatch, taking into account characteristics such as start-up and shut-down decisions, is combined with investment decisions for power generation and transmission technologies. Next, the deterministic model is extended to a multistage stochastic model taking into the uncertainties of renewables,which is characterized by a scenario tree. A clustering method is used to determine the capacity factors of wind power and solar PV for each node in the scenario tree. Finally, we develop an efficient modified nested Benders decomposition algorithm to search for the optimal solutions. Our decomposition adapts previous nested Benders methods by handing integer and continuous state variables, although at the expense of losing its finite convergence property due to potential duality gap. Meanwhile, we take advantage of *Two-Phase Method* to solve it more efficiently.

Results

Our results show that ignoring the nature of renewables has quantifiable economic consequences, and that considering uncertainty can yield decisions that have higher expected costs than traditional deterministic planning model. There is 1.1% difference (about 342.5 billion yuan) between the two model based on the case study in China. Compared to deterministic models, natural gas plants account for a larger proportion. East China, South China, and Central China are more vulnerable to neglecting the uncertainty of renewable energy. Further, massive computational savings from our decomposion was demonstrated when solves this model, especially when the MILP has a small integrality gap, just half the time of traditional algorithms.

Conclusions

Compared with traditional deterministic power planning model, the stochastic method can more accurately describe the intermittent renewables. The cost of considering uncertainty is far lower than the loss of ignoring uncertainty. The formulation and solution framework are tested for a case study in China. The result show the algorithm can provide substantial speed-up and allow the solution of large instances.

References

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