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Adapting Long-Term Generation Scheduling to Climate Variability in a Hydro-Dominant Power System

Climate variability is increasingly affecting energy generation, particularly renewable sources that depend directly on weather patterns. Variations in temperature, precipitation, and wind patterns are altering the availability and reliability of hydropower, wind, and solar energy, posing challenges for power system stability and long-term planning. As climate patterns shift, our perception of risk must also evolve. Instead of preparing solely for the worst historical scenarios, it is now essential to account for potential deviations between climate projections and past extremes. This growing uncertainty demands adaptive strategies to ensure the resilience of energy systems in the face of unprecedented climatic conditions. This study focuses on hydropower generation and how power system operation can be adapted to address these changes, with a case study on the Brazilian power system. Inflow projections up to 2099, derived from four global climate models (MIROC5, HadGEM2, CANESM2, and BESM) and two carbon concentration scenarios (RCP 4.5 and 8.5), are analyzed to assess their deviations from historical observations. The results indicate significant regional disparities, with a potential increase in inflows in southern Brazil and a decline in other regions over the coming decades. These projections are incorporated into a long-term generation scheduling model as stochastic scenarios. The problem is solved using the state-of-the-art Stochastic Dual Dynamic Programming algorithm. The results show that disregarding climate variability in optimization scenarios can increase the cost of the most expensive cases by up to 50%. To mitigate the risks associated with climate-driven inflow variability, this study evaluates different risk metrics: Expected Value (EV), Conditional Value at Risk (CVaR), and Distributionally Robust Optimization (DRO). Both CVaR and DRO provide effective protection against climate risks, reducing the cost of the most expensive scenarios by 50% and in 80% the percentage of scenarios with load cuts. A comparison between the metrics shows that DRO yields smoother marginal costs and has an easier calibration, making it particularly effective in managing projected uncertainties. The proposed strategies enhance the resilience of the power system under climate projection scenarios, contributing to more robust and sustainable long-term energy planning.

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