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STOCHASTIC OPTIMISATION OF A VIRTUAL POWER PLANT USING BLOCK BOOTSTRAP-BASED SCENARIO GENERATION

Kiran Nivrutti Borse, Ramy Salah, Simon Uhlenbrock, Ulf Häger, Christian Rehtanz
Institue of Energy Systems, Energy Efficiency and Energy Economics, TU Dortmund University, Dortmund, Germany

Extended Abstract

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Abstract Summary

Many Distributed Energy Resources (DERs) have uncertain operating behaviour, requiring increased ancillary services to maintain power system stability. Due to smaller capacities, they need to be aggregated in a Virtual Power Plants (VPP) for market participation and ancillary provision. This work focuses on the development of a scenario-based stochastic optimisation framework designed to optimise a VPP pool participating in Day-Ahead (DA) energy, Frequency Containment Reserve (FCR) and automatic Frequency Restoration Reserve (aFRR) markets. Using Mixed Integer Linear Programming (MILP) approach, the model includes specific market regulations, along with technical limitations of individual DERs. To account for uncertainty, the markets prices and DER generation scenarios are generated using seasonality-aware Moving Block Bootstrap (MBB) and conditional Bootstrap methods, respectively. These methods are specifically chosen to preserve the temporal dependence and serial correlation found in historical time series. Furthermore, risk-awareness is considered using CVaR to protect the VPP operator from extreme negative economical outcomes. Mean Percentage Error (MPE) and Mean Absolute Percentage Error (MAPE) are considered as evaluation metrics to quantitatively analyse the market prices and DER generation scenarios, and compare stochastic optimisation model results against deterministic optimisation approach with perfect generation foresight and German market prices data. Results show that stochastic optimisation combined with Block Bootstrap-based scenario generation provides a robust basis for uncertainty-aware VPP operation in DA, FCR, and aFRR markets. The generated scenarios preserve the relevant temporal structure of market prices and renewable generation and yield plausible inputs for the optimisation. Relative to a deterministic perfect foresight benchmark, the stochastic model achieves comparable annual profitability while avoiding unrealistically high profit peaks and producing decisions better suited to uncertain real-world operation. The Conditional Value-at-Risk (CVaR) analysis further indicates a generally favourable risk–return relationship, while winter periods exhibit larger deviations due to higher uncertainty.