Design of a decentralized market with locational marginal pricing for efficient congestion management in distribution grids

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Overview

Grid operators worldwide are challenged by growing electricity generation from renewable energy sources (RES-E). Distribution grids in particular face an increase in volatile feed-in from numerous, highly-volatile and widely-distributed RES-E generators. In congested areas, grid operators curtail RES-E generation in order to protect the infrastructure from taking damage through overload and to maintain a stable quality of the supplied electricity. To ensure efficient congestion management the energy industry requires enhanced decision support tools, based on comprehensible algorithms.

Current research largely focuses on congestion management on the highest voltage levels of the transmission grid. In this paper, we analyse grid congestion caused by RES-E and its necessary curtailment on the distribution grid level in Germany. The majority of renewable generators are connected to the distribution grid and most RES-E induced congestion in Germany occurs on this level. To explore the possibilities of enhanced congestion management, we develop a simulation model that represents a distribution grid in Germany which is highly affected by RES-E induced congestion. Our modelling approach includes the detailed representation of power demand and supply on a high spatial and temporal resolution, a power flow analysis of the distribution grid and the formulation of a formal optimization problem for congestion management.

Our analysis quantifies interdependencies between a decentralized market and the wholesale market, e.g. price effects from increased power demand as a result from RES-E curtailment. Based on distribution locational marginal pricing (DLMP) theory we implement a decentralized market design for congestion management and evaluate the impact of different strategies for congestion management on effectiveness with respect to RES-E utilization and system cost.

Methods

Locational marginal pricing (LMP), DC load flow calculation, linear optimization, agent based simulation

Results

The developed and presented modelling approach can reproduce historic congestion events and resulting curtailment satisfactorily.

Significant shares of the German renewable power generation potential are being curtailed, sometimes reaching up to several giga watt.

Missing renewables in the power supply stack due to curtailment are large enough to affect wholesale markets.

Conclusions

An optimal power flow algorithm based on a load flow analysis with DC simplifications is an adequate tool for decision support for congestion management in distribution grids. The extent of curtailment in Germany has a significant relevance for the wholesale market, thus the algorithms for congestion management applied by grid operators need to be transparent and reproducible. The presented approach to model congestion management allows a flexible application of different market designs in order to simulate and quantify welfare effects.

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