IMPROVING THE COORDINATION BETWEEN ELECTRICITY AND GAS SYSTEMS: A DISTRIBUTED MARKET-CLEARING APPROACH

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Overview

The ambitious European goals of becoming climate-neutral by 2050 are affecting the energy systems' and markets' structures in its entirety: The *decarbonization* of the energy sector requires a comprehensive expansion of fluctuating renewable energy sources and calls for cross-sectoral solutions, cf. [1]. The *decentralization* of supply and demand, especially due to a high number of small-scale units of renewable energies, encumbers the existing infrastructure and involves high future investments for its expansion and flexibilization, cf. [2]. Meanwhile, the ongoing *digitalization* in the energy sector provides new opportunities to improve communication and coordination, cf. [3]. Regarding these changes, the role of electricity and natural gas systems protrude, not only due to their economic importance: An improved coordination of both sectors' markets and infrastructures is promised to provide an additional source of flexibility, cf. [4], which is foreseen to be crucial for the short-term operation of electricity systems with high shares of renewables, cf. [5].

Methods

We propose a novel framework that has the potential to improve the coordination between electricity and natural gas markets with respect to their short-term operation, while addressing the beforehand challenges of decarbonization, decentralization, and digitalization of the energy sector. The framework enables the participation of individual units, especially coupling units between electricity and natural gas systems, in a distributed market-clearing process that goes beyond current single-bid auction schemes. More precisely, the framework is based upon decomposition techniques for large-scale optimization: We decompose the fictional problem of an omniscient cross-sectoral single operator of natural gas and electricity systems into the individual yet dependent problems of each entity, i.e., (coupling) units and (electricity and natural gas) system operators. Thereupon an iterative market-clearing can be accomplished via a parallel optimization of each entity and by iteratively exchanging offers and bids, i.e., electricity and gas quantities and prices. Once convergence is reached, the result of this distributed market-clearing is identical to that of a fictional omniscient cross-sectoral single operator with perfect information. Therefore, this approach allows for a dynamic exchange of information and adaptations to updates, while preserving the confidentiality of commercially sensitive data of each entity.

Results

The reliability and scalability of the proposed framework are assessed using a tractable polyhedral convex relaxation of the natural gas model. In contrast to other approaches, we are capable to take the flexibility of natural gas pipelines' line-packs into account and link it directly to the generation of renewables and possible congestions in the electricity system. The framework is applied to two test cases: a small test system and the case study of the independent German electricity and gas system. In both cases, the computational effort and the performance of the different models are assessed in detail.

Conclusion

This paper addresses the deficiencies of existing market and system architectures while focusing on the short-term operation of interdependent electricity and natural gas systems. It presents a novel distributed market-clearing framework that encourages the active participation of cross-sectoral units in the market-clearing process while preserving the confidentiality of commercially sensitive information of all entities, i.e., units and system operators. The proposed framework has the potential to enhance the coordination between the electricity and natural gas sectors, paving the way for a more efficient, flexible, and climate-neutral energy system.

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