SIMPLIFICATIONS IN INTEGRATED OPERATION OF ELECTRICITY AND GAS SYSTEMS TO FACILITATE THE INTEGRATION OF RENEWABLE ENERGIES

Christian Perau, Karlruhe Institute for Technology, Chair of Energy Economics, +49 721 608 44577, Christian.perau@kit.edu
Manuel Ruppert, Karlsruhe Institute for Technology, Chair of Energy Economics
Wolf Fichtner, Karlsruhe Institute for Technology, Chair of Energy Economics

Overview

Increased generation of electricity from Renewable Energy Sources (RES), due to ambitious green house gas reduction targets, poses challenges regarding their integration into the energy system. These challenges mainly arise due to the volatile generation of RES, and power-to-gas (PtG) technologies are considered an important element of a successful energy system integration. electrolysis uses electricity to split water into hydrogen and oxygen. The former can be synthesized into a variety of different energy carriers such as synthetic methane or liquid fuels in the next process stage (power-to-liquid). In cases where surplus electricity is used by these PtG facilities, curtailments of RES, CO_2 emissions, and potentially system costs can be reduced [1,2]. The production of hydrogen is not only affected by the electrical system, i.e. the surplus electricity that is available, but can also be limited by the gas system infrastructure and possible contingencies [3]. Therefore, an integrated modelling of both the electricity and gas system, needs to be considered to improve the validity of modelling when investigating the role of PtG in the future energy system. In literature, different approaches have been applied in order to model PtG in an integrated energy system. Since both systems can be characterized as nonlinear and include discrete decisions, different simplifications have been used in order to tackle computational complexity and solve time. Different approaches including piecewise linearization are compared regarding their adaptability in the integrated modelling of electricity and gas systems.

Methods

A general mathematical formulation of an integrated electricity and gas modelling is introduced. This formulation includes generation, consumption, storage, and transportation within the two systems. Different approaches of simplification of either system are explained and formulated. These simplification include primarily the approach of piecewise linearization of different nonlinear interdependencies of the distinct physical variables. Another infrequently considered characteristic of the gas network is linepack, i.e. the gas stored inside of a pipeline, within the gas system. While its consideration results in a significant increase of complexity of the model, it also allows for a more accurate modelling of available storage capacity and gas flow.

Results

The different versions of the integrated model developed by the authors are applied to a benchmark test case. It can be seen that the choice of linearization approach significantly impacts the computation time as well as model size and complexity. Of special importance is the choice of consideration of linepack in the gas system since it significantly increases the complexity of the model and the computation time.

Conclusions

Model complexity is of highly relevant regarding real-world applications in energy system modelling due to spatial and temporal resolution constraints. It has been shown that simplifications of nonlinear interdependencies in both the electricity and gas system can decrease the computation time significantly. The choice of method of piecewise linearization of these nonlinear terms highly influences the required computational time of the optimization model. It can be shown that the approach of SOS2 constraints and the incremental method perform best overall. Furthermore, the consideration of linepack results in a drastic increase in model complexity and computation time.

References

[1] Co-planning and Feasibility Assessment of an Integrated Energy System Embedded with Power-to-Gas Plants, Zhou, H., Zheng, J., Wu, Q.H., Zhou, X., 2019, IEEE PES GTD Grand 19.03.2019 – 23.03.2019, p. 372-777, doi:10.1109/GTDAsia.2019.8715874

[2] Optimal coordinated operation of integrated natural gas and electric power systems: A review of modeling and solution methods, Raheli, E.; Wu, Q.; Zhang, M.; Wen, C., 2021, Renewable and Sustainable Energy Reviews, doi:10.1016/j.rser.2021.111134

[3] Robust Co-Optimization Scheduling of Electricity and Natural Gas Systems via ADMM, He, C.; Wu, L.; Liu, T.; Shahidehpour, M., 2017, IEEE Trans. Sustain. Energy (IEEE Transactions on Sustainable Energy), p. 658-670, doi:10.1109/TSTE.2016.2615104