CONSIDERING REACTIVE POWER IN ENERGY SYSTEM DESIGN

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Motivation

The increasing penetration of renewable converter-interfaced generators (CIGs) in today's energy systems is reducing the share of conventional synchronous generators, thereby changing not only the dynamic but also the steady-state behavior of the system. For maintaining steady voltages, traditionally the reactive power supply of synchronous generators and additional devices for reactive power compensation is used [1]. Studies on energy system design predominantly neglect reactive power [2] and can thus potentially require a large amount of compensation devices to realize a feasible system operation. However, state of the art capacity expansion planning approaches do not consider the corresponding costs [3][4]. Accordingly, we analyze the question if modeling reactive power and considering the ability of renewable CIGs to supply reactive power can lead to more suitable energy system designs.

Methodology

We formulate a generation expansion problem which incorporates reactive power and voltage magnitudes. Both are included via a linearization of the AC-OPF problem [5]. We validate this linearization separately using test networks from a benchmark library [6], for which the results are compared to those of a solution of the full AC-OPF formulation by the PowerModels framework [7]. Furthermore, we compare our approach with the conventional capacity expansion approach, which ignores reactive power and voltage magnitudes. Both approaches are evaluated with respect to the number of snapshots which are AC-feasible. Moreover, the model results are compared regarding the costs of necessary reactive power compensation devices.

Results

We apply our method to a case study, where expansion of two types of CIGs is examined. We focus on different types of wind energy converters, of which the more expensive type has greater capabilities to supply reactive power. As we assume perfect knowledge of the potentials for renewable generation, the model is deterministic. For the numerical experiment we use a 20-bus network representing the German power grid, which is based on a spatial reduction of PyPSA-Eur [8]. As a first result, we observe that our approach leads to a larger number of feasible operational states of the planned system. Moreover, a smaller amount of reactive power compensation devices is needed.

References

[1] R. W. Kenyon et al., "Stability and control of power systems with high penetrations of inverter-based resources: An accessible review of current knowledge and open questions," Solar Energy, vol. 210, pp. 149–168, 2020, doi: https://doi.org/10.1016/j.solener.2020.05.053.

[2] F. Neumann, V. Hagenmeyer, and T. Brown, "Assessments of linear power flow and transmission loss approximations in coordinated capacity expansion problems," Applied Energy, vol. 314, p. 118859, 2022, doi: https://doi.org/10.1016/j.apenergy.2022.118859.

[3] S. Wogrin, D. Tejada-Arango, S. Delikaraoglou, and A. Botterud, "Assessing the impact of inertia and reactive power constraints in generation expansion planning," Applied Energy, vol. 280, p. 115925, 2020, doi: https://doi.org/10.1016/j.apenergy.2020.115925.

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[4] T. Brown, P.-P. Schierhorn, E. Tröster, and T. Ackermann, “Optimising the European transmission system for 77% renewable electricity by 2030,” IET Renewable Power Generation, vol. 10, no. 1, pp. 3–9, 2016, doi: https://doi.org/10.1049/iet-rpg.2015.0135.

[5] Z. Yang, H. Zhong, A. Bose, T. Zheng, Q. Xia, and C. Kang, “A Linearized OPF Model With Reactive Power and Voltage Magnitude: A Pathway to Improve the MW-Only DC OPF,” IEEE Transactions on Power Systems, vol. 33, no. 2, pp. 1734–1745, 2018, doi: 10.1109/TPWRS.2017.2718551.

[6] S. Babaeinejadsarookolaee et al., “The Power Grid Library for Benchmarking AC Optimal Power Flow Algorithms.” 2021. [Online]. Available: https://doi.org/10.48550/arXiv.1908.02788

[7] C. Coffrin, R. Bent, K. Sundar, Y. Ng, and M. Lubin, “PowerModels.jl: An Open-Source Framework for Exploring Power Flow Formulations,” in 2018 Power Systems Computation Conference (PSCC), Jun. 2018, pp. 1–8. doi: 10.23919/PSCC.2018.8442948.

[8] J. Hörsch, F. Hofmann, D. Schlachtberger, and T. Brown, “PyPSA-Eur: An open optimisation model of the European transmission system,” Energy Strategy Reviews, vol. 22, pp. 207–215, 2018, doi: https://doi.org/10.1016/j.esr.2018.08.012.