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PARTICIPATORY DECISION SUPPORT FOR POWER SYSTEMS PLANNING: EMPIRICAL FINDINGS FROM A CASE STUDY IN THE CONTEXT OF THE GERMAN ENERGY TRANSITION

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Overview

The energy sector continues to undergo substantial structural changes. Currently, the expansion of renewable energy sources (RES) leads to an increasing decentralisation of energy systems and brings about new challenges. For instance, the number of transmission grid expansion projects increased recently and is expected to further increase. Technically, their need depends on various factors such as the operation and expansion decision of conventional and RES electricity producers. However, grid expansion projects are often accompanied by the so-called NIMBY ("Not In My Back Yard") syndrome, resulting in acceptance problems. An adequate decision support therefore needs to consider the interdependencies of the different drivers. Moreover, the decentralisation of energy supply leads to new players entering the market. Since the different players typically pursue different objectives and have different preference perceptions, multiple and usually conflicting targets need to be considered. As a result, decision processes need to be designed in a participatory way. With a steadily increasing importance of ecological and technical criteria as well as the public acceptance as a key dimension of power systems planning, a purely economic optimisation is no longer sufficient to support decision making in energy systems. We therefore propose an approach combining multi-criteria decision analysis (MCDA) and energy systems modelling.

Method

The application of MCDA to energy problems increased significantly in the past (see e.g. reviews by Wang et al. 2009; Ribeiro et al. 2011). While many of the existing models are capable of taking social aspects into account, only few allow for considering power grid constraints. In order to support strategic power systems planning with respect to multiple criteria, however, models are needed, which allow for the provision of quantitative data under consideration of grid constraints. For this purpose, the nodal pricing based energy systems model PERSEUS-NET is chosen. Being part of the PERSEUS model family ('Program Package for Emission Reduction Strategies in Energy Use and Supply'), PERSEUS-NET extends the earlier versions by including a multi-period mixed integer linear programming (MILP) direct current (DC) load flow model (Eßer-Frey 2012; Nolden et al. 2013). With the aim of supporting simultaneous regional operation and expansion planning for electricity generation and transmission, PERSEUS-NET was recently extended by the option of an endogenous grid expansion (Slednev et al. 2014). Concerning the choice of an appropriate MCDA method, it is important to note that the method needs to allow integrating quantitative (e.g. costs, emissions, system stability) and qualitative (e.g. public acceptance) information and bringing together knowledge from different stakeholder and expert groups in order to design a participatory power systems planning process. We therefore use the tool SIMADA ('Simulation-Based Multi-Attribute Decision Analysis') for the MCDA, including a graphical user interface and providing various sensitivity analysis and visualisation techniques (Bertsch et al. 2007; Bertsch 2008). SIMADA is a MATLAB implementation based on multi-attribute value theory (MAVT, see Keeney and Raiffa 1976 for an overview), which is chosen because of its transparent nature. The elicitation of both, the public acceptance of alternative power systems planning strategies and the subjective preference parameters, needed to conduct the MCDA, is based on a large-scale online survey. This participatory preference elicitation is complemented by various sensitivity analyses provided by SIMADA, enabling exploration of the results' sensitivity with respect to variations of the different subjective parameters.

Results

We demonstrate our approach within a case study in the context of the energy transition in Germany. The extension of PERSEUS-NET by an endogenous grid expansion has a strong impact on the allocation of power generation and transmission capacities. For instance, it is shown that the need for grid expansion can be reduced by optimising operation and expansion of conventional and RES electricity producers under consideration of load flow restrictions. Moreover, the results reveal that RES curtailment can reduce the grid expansion requirements.

Based on the preference parameters empirically assessed within the large-scale online survey, the results of our approach show that the ranking of power systems planning strategies, when considering multiple criteria, by nature differs significantly to the ranking solely based on an economic optimisation. Since large infrastructure projects, especially grid expansion projects, are facing an increasing acceptance problem, it is highly relevant for the success of the energy transition to include such criteria into the process of evaluating alternative power systems strategies.

Conclusions

The power system's complexity and its elements' mutual interdependencies necessitate an integrated optimisation under consideration of grid restrictions. The introduced approach constitutes an added value for managing grid congestions, arising in the future, through a selected grid and generation capacity expansion. Through the combination with MCDA, the approach provides the basis for an evaluation of alternative future technology mixes with respect to multiple criteria, where especially the consideration of non-economic criteria becomes increasingly important. However, while evaluating different strategies, involving different technology mixes, for a given set of preference parameters can be very helpful, the main benefit of the approach is that it explicitly reveals the trade-offs between the different criteria contributing to a deeper understanding of the considered strategies' performance.

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