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OPPORTUNITY COST OF REACTIVE POWER PROVISION

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Overview

Transmission grids require reactive power in order to ensure voltage stability. Capacitive and inductive reactive power can be provided either by generation units or by reactive power compensators, such as Flexible AC transmission systems. With a shift of electricity generation from large central power stations to decentralized renewable power plants, the need of reactive power from renewable power plants increases. Wind and PV plants are technically capable of providing reactive power to the distribution grid, diminishing the need for compensation facilities or voltage-induced redispatch. To analyze the role of reactive power from renewable sources in the high voltage transmission and the distribution system, an AC-load flow model of the German electricity grid is developed, which can cope with real and reactive power flows. Based on this techno-economic model of the German electricity grid the economic benefits of reactive-power feed-in from renewable energies are determined based on a comparison of opportunity cost of reactive power provision as well as system cost.

Method

Electricity grid models based on PTDF or DC-approximation approach, that are common in energy economics, neither consider voltage stability nor reactive power exchange. This makes them inadequate for the assessment of reactive power provision. A techno-economic AC load flow model of the European transmission grid is developed to cope with these shortfalls. Generation facilities are represented with their generator capability curves characterizing their ability to provide reactive power. To test the model validity, model results are compared to a DC-approximation model and – based on a test network – as well to a commercial load flow calculation software. As model results indicate a good model accuracy, the model is used to analyze the value of renewable energies for providing reactive power. Opportunity cost of reactive power provision determined by the model is compared across different load situations as well as the economic benefits of reactive power provision from RES are estimated. The work includes an analysis of the status quo as well as a future outlook considering a higher degree of renewable energy feed-in as well as network extensions.

Results

The AC load flow model increases the accuracy compared to a DC approximation approach, although the deviations between AC and DC model are rather small (< 5%) in most cases. The backtesting of the AC model with a commercial load flow software shows a very good fit with most deviations being less than 1%. Preliminary results for the status quo of the German transmission network show, that in situations with a low residual load there is an opportunity cost for the provision of reactive power by conventional power plants in the order of 3 EUR/Mvarh (capacitive). In general opportunity cost should be near to zero as conventional power plants provide reactive power without changing their real power output. In the case of a low residual load, this increased value can be explained by a small number of conventional power plants dispatched and able to provide reactive power. In these situations that will occur more often in the future, the feed-in of reactive power from the distribution grid could reduce this opportunity cost to zero.

Conclusions

The work shows that a techno-economic AC load flow model does not only allow the analysis of the value of reactive power supply by means of opportunity cost, but also improves the accuracy of load flow calculation compared to common DC approximation models. As feed-in of renewable energy is on the one hand a major factor concerning the opportunity cost of reactive power supply and on the other hand RES are technically capable of providing reactive power, mechanisms to incentivize this provision should be fostered. In this context, the work allows a fair valuation of reactive power and helps to answer the question in which situations, provision from RES or from compensation devices is to be preferred from an economic point of view.

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