TECHNO-ECONOMIC ANALYSIS OF REACTIVE POWER PROVISION IN DECENTRALIZING ENERGY SYSTEMS

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Overview

During the last decade, the energy landscape has been undergoing severe changes. In the period from 2005 to 2015, the globally installed capacity of wind turbines has increased by nearly 400 GW with a compound annual growth rate of 22%. At the same time, PV installations have been increased from 5 GW to 227 GW, which corresponds to a growth rate of over 46%. The major part of this capacity has been installed to distribution or sub-transmission grids. An increasing share of decentralized renewable energy in the electricity mix leads to lower dispatch times for conventional power plants and may consequently lead to a replacement of these technologies. As large power stations have historically been the main source of ancillary services, new approaches have to be developed in order to foster a higher degree of system responsibility for renewable energy sources.

Besides reserve power, voltage stability and reactive power management is a major concern in decentralizing energy systems. The decrease in the availability of large power stations leads to diminishing reactive power potentials in the transmission grid, while necessary grid extensions generate the necessity for more reactive power flexibility. Besides the installation of compensation devices, such as inductors, capacitors or SVC, also a controlled reactive power exchange between the transmission grid and the underlying grids could support voltage stability and reactive power management.

On the one hand, state-of-the-art decentralized energy sources, such as wind turbines and PV parks, are technically capable of reactive power provision and the necessary information and communication technology is increasingly available. On the other hand, economic research regarding the reactive power provision is scarce. Therefore, the aim of this work is to analyze the economic effects of the contribution of different technologies and approaches to the voltage stability of decentralizing electricity systems.

Method

Electricity grid models based on PTDF or DC-approximation approaches, that are common in energy economics, neither consider voltage stability nor reactive power flows. This makes them inadequate for the assessment of reactive power provision. For this purpose, an AC load flow model is developed to cope with these shortfalls. Power plants are represented with their generator capability curves characterizing their ability to provide reactive power. Reactive power from compensation devices and HVDC converter stations is considered as well. Furthermore, the reactive power potentials from underlying grids are considered and their utilization is optimized by the model.

In order to estimate the reactive power potentials from the 110 kV grid, a linearized AC grid model is developed, which replaces the non-linear power flow equations by linear approximations in an iterative approach. This approach allows to calculate minimum and maximum reactive power exchanges per substation based on the grid, load and generation structure for different situations.

The approaches are applied to a transmission and a 110 kV distribution grid model of Germany and a simplified representation of the neighboring countries. Based on the status quo, different electricity system scenario for 2025 and 2035 are defined and analyzed.

Results

Model results indicate that annual savings of up to 40 mio. EUR can be generated if reactive power sources in the 110 kV distribution grids are utilized to provide reactive power for the transmission grid in a controlled manner. In comparison, the total volume of ancillary services in 2014 was about 1 bn.

EUR. Both the reactive power potentials and the possible savings augment with increasing shares of decentralized energy sources. The savings potential can be attributed to the reduction of thermal losses both in the transmission and in the distribution grid, to decreases in the curtailment of renewable energy sources and to less frequent redispatch measures. It can be observed that the inclusion of renewable energy sources in the reactive power management generates potential savings. However, an amplification of the reactive power range through the implementation of STATCOM behavior does not sufficiently reduce operational expenses in order to compensate the related investment cost. Yet, through the installation of additional reactive power compensators, operational expenses can be further diminished.

On the one hand, considering increasing installations of decentralized energy sources, possible delays in grid extension measures would cause a severe increase in redispatch and curtailment cost. On the other hand, the inclusion of reactive power sources in the 110 kV grid would mitigate the related increase in operational expenses.

Conclusions

The analysis shows that common techno-economic grid modelling methods can be adjusted in order to be applicable to an economic analysis of voltage stability and reactive power management. In decentralizing electricity systems the controlled provision of reactive power can be one component in order to assign more system responsibility to renewable energy sources. Although no exorbitant reductions in operation expenses are to be expected, the available potentials should be tapped. Not only cost savings could be realized, but also positive effects on system security can be expected. Further research is required in order to investigate the potential to replace compensation devices or must-run capacities by a controlled reactive power provision from the underlying grids.

References

Baughman, M., Siddiqi, S., 1991. *Real-time pricing of reactive power: theory and case study results.* IEEE Transactions on Power Systems 6

FERC, 2005. *Principles for Efficicient and Reliable Reactive Power Supply and Consumption.* Technical Report. Federal Energy Regulatory Commission. Washington, D.C.

Frank S., Rebenack, S., 2012. *A Primer on Optimal Power Flow: Theory, Formulation and practical Examples*

Frías, P., Gómez, T., Soler, D., 2008. *A Reactive Power Capacity Market Using Annual Auctions.* IEEE Transactions on Power Systems 23

Leuthold, F.U., Weigt, H., Hirschhausen, C., 2010. *A Large-Scale Spatial Optimization Model of the European Electricity Market*. Networks and Spatial Economics 12

Rueda-Medina, A.C., Padilha-Feltrin, A., 2013. *Distributed Generators as Providers of Reactive Power Support - A Market Approach.* IEEE Transactions on Power Systems 28,

Schweppe, F.C., Tabors, R.D., Caraminis, M., Bohn, R.E., 1988. *Spot pricing of electricity.* Kuwer, Boston

SolarPower Europe, 2016. *Installierte Leistung der Photovoltaikanlagen weltweit in den Jahren 2005 bis 2015* Online: https://de.statista.com/statistik/daten/studie/232835/umfrage/weltweit-installierte-photovoltaik-leistung/

WWEA, 2016. *Installierte Windenergieleistung weltweit in den Jahren 2001 bis 2015.* Online: https://de.statista.com/statistik/daten/studie/158323/umfrage/installierte-windenergie-leistung-weltweit-seit-2001/

Zhong, J., Bhattacharya, K., 2002a. Reactive power management in deregulated electricity markets - A review. 2002 Ieee Power Engineering Society Winter Meeting, Vols 1 and 2, Conference Proceedings