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EVALUATING THE EFFECT OF STORAGES ON ELECTRICITY MARKETS WITH HIGH PENETRATIONS OF RENEWABLE ENERGY SOURCES

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Overview

As the penetration of generation from renewable sources increases, the value of effective storage also increases due to its capability to mitigate the inherent variability of these sources. However, it is not trivial to identify the effect of storages on electricity markets, which will provide support for the adoption of renewable energy sources (RES) into the electricity system. The underlying question is how to better manage the uncertainty of these RES, specifically wind, using energy storage system (ESS), so social planners can optimally operate and contract for energy and ancillary services, and make use of the available network resources. The main objective of this paper is to evaluate the contribution of ESS located at individual nodes on the network in adopting RES, and in particular, the effects of ESS collocated at individual wind farms versus distributed ESS located at demand centers (deferrable demand (DD)). While using storage collocated with wind farms is a supply side mechanism that allows reducing the variability in outputs from RES, the use of deferrable demands actively engages the demand side of the market, with benefits in terms of the transmission congestion observed and system metrics, like the amount of capacity needed to reliably cover the demand. In addition, the second objective of this paper is to determine how well the net earnings of storage at a node (value of discharging – cost of charging in the wholesale market) measure its contribution to system benefits. This will provide a basis for comparing the efficient size of storage that maximizes the profits for a merchant investor versus the size that minimizes the net system costs, taking the investment cost of storage into account in both cases.

An analysis is conducted to illustrate these effects, in a reduced network on the North Eastern Power Coordinating Council (NPCC). A wind penetration close to the renewable portfolio standard (RPS) for this area is placed in an area close to the geographical location according to information from the Renewable Energy Laboratory in the Eastern Wind Integration Study (EWITS 2010). The analysis of ancillary services is conducted for load following reserve and contingency reserve. Storage resources and deferrable demand can provide both energy and reserves into this formulation, with hourly steps used for a representative day. The analysis includes the appraisal of environmental damages from electricity generation, with a dataset representative of the generator fleet characteristics.

Methods

The study uses simulation using a stochastic form of multi-period Security Constrained, Optimal Power Flow (SCOPF), implemented using Matpower (Zimmerman, Murillo-Sanchez, and Thomas 2011). In order to determine the wind inputs, a statistical clustering analysis for the placement of the wind farms is performed, and a k-means methodology is used to represent the stochastic characteristics of wind resources and the spatial correlations among the locations. The optimization is performed with CPLEX for the quadratic programming parts and an Interior Point Method for the non-linear parts of the optimization.

Results

The results obtained show a big potential of demand resources to reduce the amount of generation capacity needed for adequacy, help reduce the capital costs and have environmental benefits in terms of the emissions of local pollutants in the system. The use of ancillary services for inter-temporal reserves provide an extra source of income for the deferrable demand, which helps to offset part of the capital cost of installation of the infrastructure necessary for performing this function. This is especially important because the elimination of the differences in demand will tend to be decreased, and therefore the income from price arbitrage is reduced. Hence the importance of income coming not only from the sales of energy, but also reserves. Additionally, the expected environmental damages are reduced, due to the usage of cleaner combined cycle natural gas turbines at off-peak hours, sustaining the flows of renewable energy in the system.

The use of supply side mechanisms is effective in reducing the overall operational cost of the conventional fleet, and increase the amount of wind that can be accommodated in the network. These increases are achieved thanks to the reduction in intermittency of the wind resource, which allows treating these resources as dispatchable generation. However, the congestion in the system at peak hours is not eliminated, and consequently the need for higher capacity needed to reliably cover the contingencies considered. This also has environmental consequences, with more damages coming from legacy oil generators in the system that need to ramp in congested areas.

Conclusions

The engagement of customer resources provides a symbiotic role for better using the renewable resources available in the network and provides economical and environmental benefits for all market participants. However, to reap these benefits, regulators need to restructure the way customers pay for electricity and how ancillary services are compensated, and making payments to customers that provide services to the network. The payment of a demand charge for capacity proportional to the peak demand periods will provide incentives for customers to modify their load profile, therefore improving the management of the system. Given the complexity of the individual household management, it is likely to be more effective to use aggregators at the distribution level, which can then interact with system operators in the bulk electricity system.

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