MARKET FAILURE CAUSED BY WIND-POWER INTEGRATIONS IN A COMPETITIVE ELECTRICITY MARKET WITH TRANSMISSION CONGESTIONS

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Overview

I investigate the market equilibrium of a competitive electricity market with significant wind-power penetration when transmission congestion is expected to occur. Specifically, I build a two-stage stochastic model to simulate the forward and spot electricity markets. The stochastic model captures the impacts of wind-energy uncertainty when a transmission line is expected to be congested in a forward electricity market. The proposed model considers conventional generators' ramp rates as well as grid topology. I conclude that integrating wind power into a grid system either brings overconsumption of electricity or leads FTR holders to pursue high FTR entitlement by generating electricity when the market price is less than their marginal generation costs. Both of the two effects lead the market equilibrium to deviate from the social optimum. The implementation of real-time retail price or carbon tax will aggravate the inefficiency. In contrast, if FTR holders have market power in the electricity market, the inefficiency caused by integrating wind power is less than when the market is completely competitive.

The remainder of the paper is organized as follows: the two-stage power market model is described in Section 2; in Section 3, I analyze the social optimum when a transmission congestion occurs in a electricity market with wind power; then, Section 3 examines the market failure when WPPs are not CR; Section 4 analyze the failure of the FTR policy when WPPs are CR; Section 5 presents the impact of implementing two counter factual policies, which are the real-time retail price and the carbon tax; lastly, in Section 6, I draw final conclusions.

Methods

I adopt a multi-stage, stochastic framework to assess the impacts of wind-energy uncertainty on the market equilibrium in both the forward and spot markets. Under the stochastic framework, the social optimization problem is to maximize the expected total social surplus while considering wind-energy uncertainty. Compared with static models, the stochastic model is able to measure the risks caused by the interaction between wind-energy uncertainty and transmission congestions.

The analyses in this research also examine the impact of grid topologies. I first analyze the interaction between wind-power uncertainty with transmission congestion in a two-node network. In the appendix, I repeat the analyses in a three-node loop network. The results demonstrate that market failure caused by using wind power occurred in both two networks. The conclusions based on these two networks can be generalized to more complicated grid networks

Results

The analyses demonstrate that the market equilibrium deviate from the social optimum when the wind power producers (WPPs) are defined as capacity resource (CR). When the WPPs are CR, they must participate in the day-ahead forward market and make generation commitment. If a WPP's generation is less than its commitment level, the WPP must purchase electricity from the real-time spot market to fill the gap between its generation and commitment level. In this scenario, the demand side will overconsume electricity because the price in the spot market does not affect consumers' utility function.

When the WPPs are not defined as CR, the ``financial transmission right'' (FTR) policy will fail by the interaction of wind-energy uncertainties and transmission congestions.

Conclusions

I have demonstrated that integrating wind power into an electricity market with transmission congestions creates a situation in which market operators face either overconsumption of electricity or the failure of the FTR policy. In a completely competitive market, both the two effects will lead the market equilibrium to deviate from the social optimum.

In many electricity markets, WPPs are defined as RC and need to make generation commitment in the DA market. In this scenario, consumers do not respond to the unexpected shortfall in the RT market. Consequently, they consume too much electricity.

However, if WPPs are not defined as RC, the risk of loosing all FTR entitlement will stimulate FTR holders to strategically bid in the electricity market. Consequently, the distribution of the FTRs is connected with electricity-market equilibrium. In order to gain a high expected FTR entitlement, a GenCo holding FTRs will bid, even if the market price is lower than its marginal costs. More FTRs held by a conventional GenCo can encourage the GenCo to commit more with the same price in the DA market. Consequently, the total consumption level is higher than the socially optimal level too.

If the real-time residential price, the dead weight losses are even higher than when the residential price is flat. The effects of the carbon tax is complicate and need to be examine case by case.

References

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