Death Spiral, Transmission Costs, and Prosumers in the Power Market

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Overview

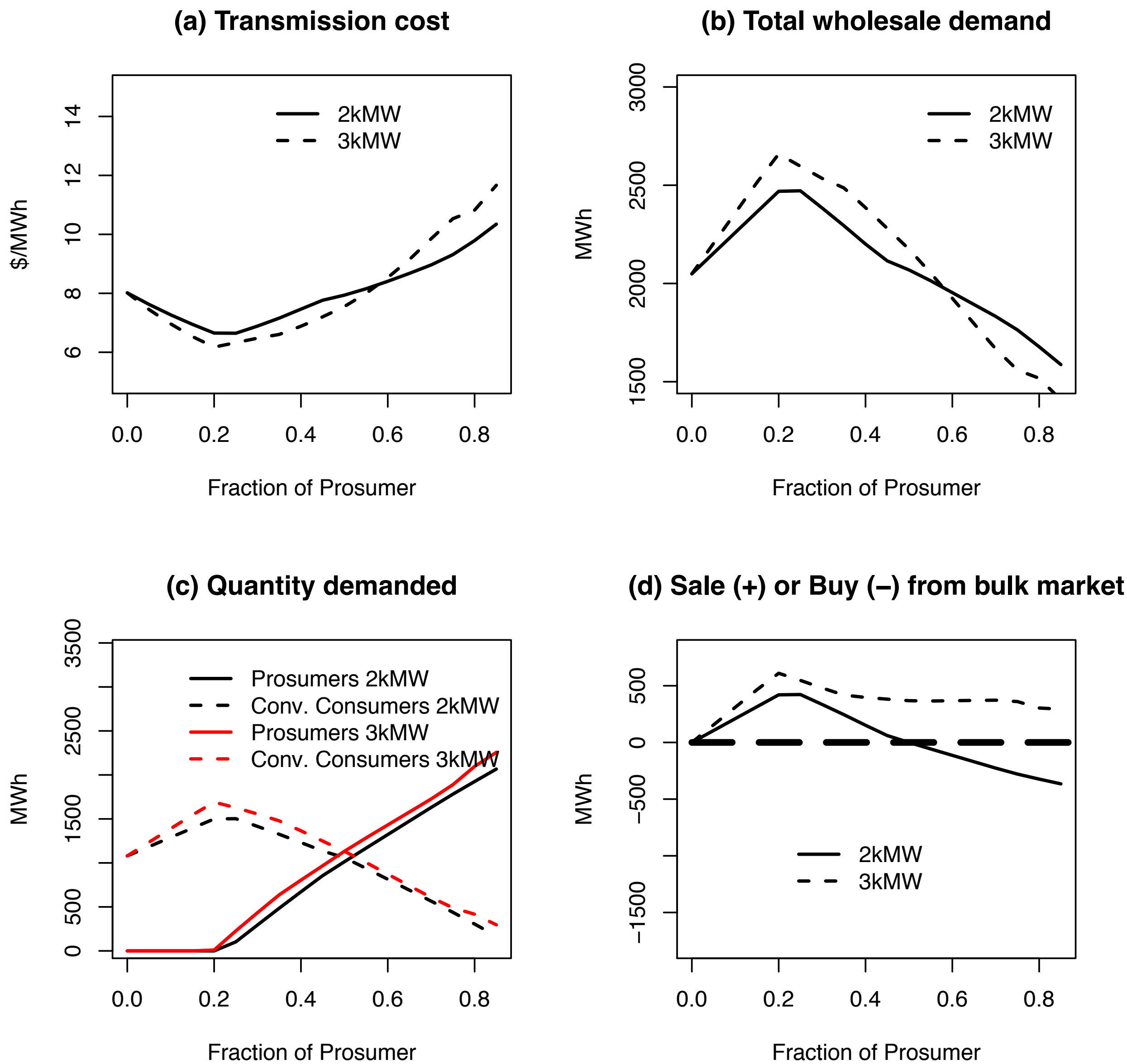
A prosumer who owns a set of renewable units coupled with backup options, such as fossil-fueled units and storage, in order maintain a stable energy supply, has been viewed as an effective distributed energy source to enhance the power system resilience. While their presence strengthens the grid resilience by shifting energy supply to local energy sources, thereby bypassing energy transmission in bulk market, it also creates financial burden to those consumers who rely on their utility's procurement of energy from the bulk market. The current rate design is such that the transmission charge is mainly for the purpose of recovering costs associated with lumpy transmission investment, variable cost related to routine maintenance, and expected revenue to cover other costs of transmission system. A decline in reliance of bulk power market by prosumers will therefore increase transmission costs to other traditional consumers. As residential prosumers are likely to be "wealthier" than average consumers, the impacts might be regressive. This paper studies the impacts of transmission costs in presence of prosumers. For our analysis, we assume that a fixed amount of transmission cost needs to be distributed on volumetric basis to all the consumers in the bulk market. We highlight the fact that while traditional consumers might be borne an increased proportion of transmission costs, they could also benefit from lower energy costs as a result of self-generation and power sales by prosumers.

Methods

We extend the model by Hobbs [1] with an explicit consideration of prosumers' problem in the market. The resulting problem is a complementarity problem, which is a collection of first-order conditions from producers, prosumers, consumers, and the grid operator as well as market clearning conditions defining congestion charge [2]. For our analysis, we make the following assumptions. 1) While each prosumer might be relatively small it his/her size with a limited ability to impact the bulk energy market, we assume that a large number of prosumers enter a contract with single aggregator, who participates in the bulk energy market on their behalf. We therefore model the joint optimization of a aggregator and prosumers together. In particular, the prosumers decide amount of renewable to forgo, amount of dispatchable energy to produce, and amount of energy to sell into or buy from the bulk energy market while subjecting to exogenous and uncertain output from renewables. 2) Amount of renewable and dispatchable capacity owned by prosumers changes in commensurate with the proportion of the prosumers in the market. For example, when the percentage of the prosumers is double, the renewable output and dispatchable capacity will be double as well. 3) A fixed amount of transmission cost needs to be collected in order to recover transmission owners' investment, routine O&M cost, and other administrative costs. We then vary the percentage of prosumers and the level of renewable output, e.g., 2000 and 3000 MW and dispatchable capacity 100MW when 100% demand is represented by prosumers, in order to understand its impact on transmission cost and market outcomes.

Results

Figures (a)-(d) summarize the preliminary results of the analysis. We plot transmission cost in \$/MWh, total demand in MWh in the bulk market, quantity demanded in MW by conventional consumers and prosumers, and power sales or purchases in MWh by prosumers against the faction of prosumers in x-axis. A number of observations emerge. First, the transmission cost does not necessarily increase with the fraction of the prosumers in the market. Prosumers, in low fraction cases (< 0.2 or 20%), could forgo all (or part) of their consumption, and act a producer to sell their zero-cost renewable energy into the bulk market, thereby lowering the power prices and inflating energy demand. This leads to a decline in transmission cost. The continuingly increased fraction of prosumers in the power sector causes a decline in the bulk power demand due to a shift of the demand curve to the left, even when prosumers sell their surplus energy in 2000 MW case (< 0.4 or 40%) or 3000MW case through out. This could also be seen in (c), at which prosumers continue their thirst for energy with a decrease in energy demand by conventional consumers. Finally, with an increase in prosumers' fraction in the market (2000MW case), prosumers rely more on purchasing energy from the bulk market. In 3000MW case (high renewable), the prosumers always sell surplus energy into the market while in 2000MW case, the prosumers become a net buyer when they gorw in size.



Conclusions

Death spiral, which describes a situation at which as power price increases (due to elevated transmission cost) transferred to remaining traditional consumers cause some of those customers to "exit" the grid themselves through self-generation, is a direct consequence from cross-subsidy from conventional consumers to prosumers [3]. This paper analyzes the market outcomes of increasing prosumers by formulating the problem as a complementarity problem. We show that while "replace" consumers with prosumers in the market might change the supply-demand in the bulk energy market, leading to a disproportional burden to conventional consumers, prosumers could also benefit the power market by providing surplus energy.

References

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[3] Jacobs, S. B. (2017),"The Energy Prosumer," *Ecology Law Quarterly*, 43(4): 519-579.