[*PROSUMERS' INVESTMENT DECISIONS AND SOCIAL WELFARE UNDER DIFFERENT PRICING SCHEMES*]

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Overview

Further investment in distributed energy resources (DERs) and their efficient operation is necessary for decarbonization and sustainable energy systems. In particular, the emergence of prosumers who own renewable DERs has brought about a paradigm shift in the electricity market. The prosumer is an entity that consumes electricity, similar to a conventional consumer, while simultaneously generating electricity as a producer to supply it in the electricity market using its own power generation resources.

On the other hand, the increase in the volume of DERs may cause the fixed cost recovery problem vis-à-vis electric power transmission systems, which is referred to as the death spiral. Owing to the increase in the prosumer self-consumption of electricity from DERs, fewer consumers are to bear the fixed costs of transmission systems. Thus, it is necessary to recover the fixed cost for the expansion and maintenance of networks by increasing DER penetration via appropriate tariffs and pricing schemes that can address the death spiral problem.

The decision-making of prosumers with renewable DERs has recently received attention (e.g. Ramyar et al., 2020; Chen et al., 2021) but the issues have not been fully investigated in the literature. The purpose of this study is to analyze the decision-making of prosumers under different pricing schemes along with other market participants (consumers, producers, and ISO) in the electricity market, focusing on prosumer investments in PVs, battery operations, the level of transmission tariffs, and the total social surplus. Specifically, this study compares the equilibrium outcomes under two different pricing schemes, namely, net metering and net billing. In net metering, prosumers' electricity consumption and sales are priced at the same rate, while net billing generally sets the sale price of electricity lower than that for consumption. First, we discuss that the capacity of PVs invested in by prosumers and the total social surplus increase as the capital costs of PVs decrease under both pricing schemes without considering battery operation. Next, we show that battery operation increases the capacity of prosumer investment in PV under both pricing schemes. Furthermore, the total social surplus under net billing is larger than that under net metering, with and without battery operation. We find that net billing provides a larger social surplus than net metering in our setting.

Methods

We formulate the complementarity problem to analyze the behavior of market participants, considering prosumer investment in PVs, battery storage operation, network with loop flow, pricing schemes for prosumers, and fixed cost recovery of the grid. In this study, we model the annual decision-making of market participants in a situation where multiple nodes are connected via transmission lines, and each node's electricity demand varies in each period. First, we consider the optimization problems for each market participant and derive the Karush–Kuhn–Tucker (KKT) conditions. Thereafter, we define the market equilibrium problem in the electricity market by overall KKT conditions for all market participants and the condition for the fixed cost recovery of networks.

Results

Prosumers in net metering decide to sell their electricity by investing in a larger PV capacity. This prosumer decision-making leads to an increase in the transmission tariff, which affects the surplus of other market participants. On the other hand, prosumers in net billing tend to invest in less PV capacity than that in net metering and cover their electricity consumption with their generation. This results in less sales by prosumers and a smaller impact on transmission tariffs. Comparing the two pricing schemes, the total social surplus in net metering and net billing is approximately the same for a high PV capital cost. However, if the capital cost of PVs is sufficiently reduced, the total social surplus in net billing becomes much larger than that in net metering because the consumer surplus in net metering decreases significantly with a sharp rise in the transmission tariff (See Figure).

In addition, we show that battery operation increases the capacity of prosumer investment in PV under both pricing schemes. Furthermore, the total social surplus under net billing is larger than that under net metering, with and without battery operation.

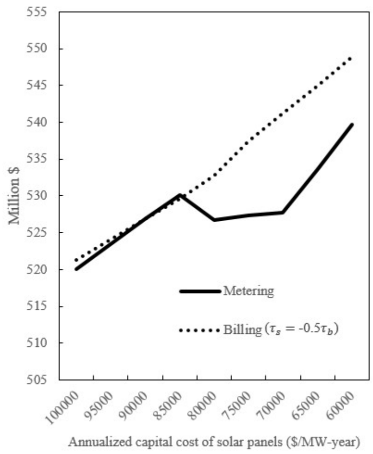

Figure: Total social surplus

Conclusions

This study examines the decision-making of prosumers in the electricity market under net metering and net billing schemes. The result that net billing is superior to net metering in terms of social surplus is also established both with and without considering prosumer battery operation. This suggests that net billing could be a better regulatory scheme in the future, especially when the capital cost of PVs falls sufficiently.

Future research could include a variety of additional analyses, such as investments in other renewable energy sources and implementation of other pricing schemes. Furthermore, the battery capacity could be treated as an endogenous decision variable, anticipating that the capital cost of battery storage will significantly decrease in the future.

References

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