Win-win possibilities through capacity tariffs and battery storage in microgrids

Kevin Milis, University of Antwerp, Faculty of applied economics, +3232654074, kevin.milis@uantwerpen.be
Herbert Peremans, University of Antwerp, Faculty of applied economics, +3232654670, herbert.peremans@uantwerpen.be
Johan Springael, University of Antwerp, Faculty of applied economics, +3232654084, johan.springael@uantwerpen.be
Steven Van Passel, University of Antwerp, Faculty of applied economics & Hasselt University, Centre for Environmental Sciences, +3232654895, steven.vanpassel@uantwerpen.be

Overview

This paper investigates the impact of capacity tariff design on microgrids. While the possible benefits for utilities of capacity tariffs are well researched, comparatively little work has been done investigating the effects of capacity pricing on prosumers. Through simulating a grid connected microgrid and solving the day-ahead dispatch problem for a calendar year, we show that a well-designed capacity tariff will not only smooth out demand profiles, but could also lead to less erratic charge/discharge cycles in a real-time pricing scenario, lessening battery degradation. These results show that a properly designed capacity tariff has the potential to be beneficial for both the utilities as well as the battery-owning prosumer. Furthermore, we propose a new, heuristic approach to solve the day-ahead economic dispatch problem, which we prove to be effective and efficient. Additionally, we demonstrate that our novel approach does not impose mathematical restrictions such as continuous differentiability of the objective function.

Methods

We simulate three grid-connected microgrid set-ups: load and intermittent generation, load and electrical storage as well as load combined with both intermittent generation and electrical storage. Furthermore, a base case, consisting of only consumer load is also simulated for comparison purposes.

We solve the day-ahead economic dispatch problem using a rolling 24-hour window. The novelty in our approach consists in the use of a heuristic method, operating in the frequency domain to solve this problem. We opt for a heuristic approach, as this allows us to easily model and explore the impact of discontinuous objective functions. The choice to operate in the frequency domain stems from the observation that this allows the heuristic to explore the solution space in a faster and more efficient manner.

Based on exogenous load, intermittent generation and real-time electricity price data as well as the chosen capacity tariff, the heuristic will decide how much electricity to buy from or sell to the macrogrid for each of the upcoming 24 hours. The heuristic follows a multi-start best improvement strategy. To obtain information on the stability of our obtained simulation results, Monte Carlo methods are used. Under the assumption of real-time electricity pricing, different pricing strategies are investigated: (i) linear capacity pricing, (ii) two-tier capacity block pricing and (iii) no capacity tariff pricing.

Results

While both investigated capacity tariff designs provide incentives to the microgrid to smooth out demand, our results show that the two-tier capacity block pricing tariff performs markedly better in limiting demand peaks. Our results also show that capacity tariffs can have a large negative impact on consumers with intermittent generation but without storage: especially under the two-tiered design, any benefits accrued from selling generated electricity to the grid is offset by the penalties incurred from selling comparatively large volumes of electricity during peak production of the intermittent electricity source. Finally, our results show that capacity tariffs have a mixed effect on the owners of battery storage systems: on the one hand, capacity tariffs reduce the profits attainable from price arbitrage while on the other hand driving down the frequency of charge/discharge switches, reducing battery degradation.

Where the proposed heuristic method is concerned, our results show fast convergence within a simulation run, and little divergence between simulations under similar conditions. Additionally, we show that our heuristic search strategy converges to the optimal solution for the case of a continuous objective function.

Conclusions

We investigated the possible benefits accruing from the adoption of various capacity tariff pricing schemes using a novel heuristic approach. Capacity tariffs will drive microgrid owners with an intermittent generation component to include battery storage. For those microgrids that contain battery storage, we showed that capacity tariffs may smooth out the charge/discharge profile of battery storage, thereby prolonging its economic lifespan, and in doing so we also demonstrated the effectivity of our proposed method. Hence, these results show that in addition to the expected benefits, i.e. smoothed demand profiles, for the utilities, capacity tariffs can also be beneficial for battery storage owning consumers.