DYNAMIC AUCTION AND MATCHING MECHANISM FOR PEER-TO-PEER ELECTRICITY TRADING IN MICROGRIDS

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Overview

With increased deployment of distributed energy technologies, regular electricity consumers are now transforming into active prosumers. This, along with the advancement in Information and Communication Technology (ICT) devices, is setting the scene for a new paradigm where consumers can interact and trade their electricity with one another in community microgrids interconnected to the larger utility grid network. Peer to peer (P2P) energy trading models make renewable energy more accessible in the community while also making better use of prosumer decentralized generation. Efficient community microgrids offer win-win possibilities for participants where prosumers can benefit from increased efficiency and gains-form-trade, while at the same time, enhancing grid resiliency and reliability of local electricity delivery thereby potentially reducing the scope of large-scale power outages by providing isolated local power balancing capability.

Even though it appears that community-level P2P electricity trading can offer numerous benefits, the concept is relatively new (Lin, et. al., 2019). To reap the full benefits of community based microgrids, proper system architectures and clear market mechanisms need to be defined (Luth, et. al., 2018; Zhang, et. al, 2018; Xu, et. al., 2021). Successful functioning P2P trade requires both efficient price determination and energy allocation. While a number of mechanisms have been proposed to facilitate local electricity trade, most are based on Double Auctions (DA) and Vickey-Clark-Groves (VCG) mechanisms. Trade is often restricted to only those households wishing to trade, with various blockchain technologies enabling exchange. Low trading volume can make these mechanisms vulnerable to game play, inefficiencies, and increased price volatility. Further, many proposed mechanisms fail to incorporate important behavioral aspects of prosumers that can potentially enhance stability and efficiency.

This research proposes a novel approach to community-based microgrid P2P trade that builds on successful approaches used for auctioning divisible goods (Back & Zender, 2001; Wang & Zender, 2002; Ausubel, 2004; Ausubel, 2006). Our approach is based on a simultaneous clock auction augmented with a cost minimization algorithm that is preformed to match buyers and sellers and clear the market. Our auction contains several competition enhancing design elements to support welfare gains obtained through competitive pricing. An important feature of our auction is that it captures behavioral aspects of prosumers that can be easily implemented through autonomous agents to facilitate real-time pricing.

Methods

We develop a P2P auction that is administered through a community-based microgrid operator (CBMO). We assume that the microgrid is interconnected to a large regional grid allowing prosumers, through the CBMO, to purchase and sell power to the grid to maintain local supply-demand balance. The grid interconnect bounds local microgrid trading to prices between the grid import (P_I) and export (P_E) tariffs. In each trading period, the CBMO requests prosumers to submit a schedule of quantities corresponding to prices announced by the CBMO ranging from P_I to P_E. Prosumer bid and ask quantities are based on household utility/profit maximization decisions conditional on the announced price and other external factors. Importantly for potential real-time trading, this optimization that can be implemented through AI-based autonomous agents. Once bid-ask quantities are received, the CBMO executes a cost minimizing algorithm that efficiently matches nearby buyers and sellers. If local supply-demand balance can be obtained in the schedule of prices, that equilibrium is announced, and trades are completed. Otherwise, the local grid is balanced though the external grid linkage at P_f or P_p and that equilibrium is announced. In this way, the CBMO acts as a Walrasian auctioneer matching supply and demand at the equilibrating price, thereby maximizing welfare. To promote competition, all households (prosumer or consumer) are required to trade through the CBMO. Additional auction rules and information policies are proposed to reduce game play and promote competitive outcomes.

Results

We show that all households, prosumers, and consumers can benefit from our proposed auction design so that it is individually rational to bid truthfully. Further, though simulations we demonstrate the speed and accuracy of our auction matching algorithm and show that the proposed trades are within the transmission capacity and result lowest possible transmission costs. The results indicate the computational efficiency of this mechanism and highlight that with the proposed mechanism, the community can reduce its grid dependency by efficiently allocating its available surplus within the microgrid.

Conclusions

We develop a new P2P trading model that can enhance efficient utilization of decentralized prosumer produced renewable energy. Our results highlight important benefits that community microgrids can offer including increased efficiency and gains-from-trade obtained through enhanced trade among local prosumers. Further, we show how improved grid resiliency and reliability achieved through our microgrid design by providing isolated local power balancing capacity that can reduce the scope of large-scale power outages. AI-based autonomous agents can be readily incorporated into our microgrid exchange design offering the possibility of real-time trade within a microgrid.

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