Electricity, vol.6, no.4, pp.57-1-57-31, December, 2025.

Techno-Economic Analysis of Peer-to-Peer Energy Trading Considering Different Distributed Energy Resources Characteristics

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Abstract-

Peer-to-peer (P2P) energy trading has emerged as a novel approach to enhancing the coordination and utilization of distributed energy resources (DERs) within modern power distribution networks. This study presents a techno-economic analysis of different DER characteristics, focusing on the integration of photovoltaic (PV) systems and energy storage systems (ESS) within a community-based P2P energy trading framework in Aswan, Egypt, under a time-of-use (ToU) electricity tariff. Eight distinct cases are evaluated to assess the impact of different DER characteristics on P2P energy trading performance and an unbalanced low-voltage (LV) distribution network by varying the PV capacity, ESS capacity, and ESS charging power. To the best of the authors’ knowledge, this is the first study to comprehensively examine the effects of different DER characteristics on P2P energy trading and the associated impacts on an unbalanced distribution network. The findings demonstrate that integrating PV and ESS can substantially reduce operational costs—by 37.19% to 68.22% across the analyzed cases—while enabling more effective energy exchanges among peers and with the distribution system operator (DSO). Moreover, DER integration reduced grid energy imports by 30.09% to 63.21% and improved self-sufficiency, with 30.10% to 63.21% of energy demand covered by community DERs. However, the analysis also reveals that specific DER characteristics—particularly those with low PV capacity (1.5 kWp) and high ESS charging rates (e.g., ESS 13.5 kWh with 2.5 kW inverter)—can significantly increase transformer and line loading, reaching up to 19.90% and 58.91%, respectively, in Case 2. These setups also lead to voltage quality issues, such as increased voltage unbalance factors (VUFs), peaking at 1.261%, and notable phase voltage deviations, with the minimum Vb dropping to 0.972 pu and maximum Vb reaching 1.083 pu. These findings highlight the importance of optimal DER sizing and characteristics to balance economic benefits with technical constraints in P2P energy trading frameworks.

Index Terms- P2P energy trading; local electricity markets; energy communities; transactive energy; distributed energy resources; impacts on distribution networks; photovoltaic systems; energy storage systems; low-voltage distribution networks; time-of-use tariffs

Citation:
Nour, M.; Zedan, M.; Shabib, G.; Nasrat, L.; Ali, A.A. "Techno-Economic Analysis of Peer-to-Peer Energy Trading Considering Different Distributed Energy Resources Characteristics", Electricity, vol.6, no.4, pp.57-1-57-31, December, 2025.