Coordinating Distribution System Resources for Co-optimized Participation in Energy and Ancillary Service Transmission System Markets

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Abstract

The increasing penetration of distributed energy resources (DERs) within the distribution network (e.g., residential solar panels, electric vehicles (EVs), distributed storage and smart loads) brings new operational challenges to utilities. The inherent uncertainty associated with DERs can lead to increased day-ahead forecast error, reverse flows, and both over and under voltages. At the same time, the coordination of a wide range of DERs begets new opportunities to improve reliability and reduce operational costs by exploiting the additional flexibility provided by controllable demand and various energy storage resources (e.g., EVs, water heaters, and next-generation batteries). However, unlocking these potential benefits requires a paradigm shift wherein distribution system operators (DSOs) change from being inflexible energy consumers to become a dynamic resource that can adapt to changing system conditions and play an active role in energy and ancillary service markets. This work provides a means for a DSO to interact with these markets through a novel hierarchical coordination scheme for secondary distribution feeders –that geographically aggregate energy resources and controllable loads– over a radial primary network feeder. In particular, we design a Grid Market Layer (GML) that coordinates aggregate solar generation, demand response, and (virtual) storage to reduce the cost of energy procurement for a utility by strategic participation in real-time and ancillary service markets, while guaranteeing operational constraints. Using a test circuit from the operational territory of a New Jersey Utility, we illustrate the operation of this GML for the case of co-optimization of real-time and 1-hour reserve market participation. Results using real system data suggest that the procurement cost can be significantly reduced without violating operational constraints. Figure 1 demonstrates how the amount of energy procured from the transmission system, P_0, (net demand) varies with solar penetration levels and real-time locational marginal prices (LMPs) as well as the corresponding levels of virtual storage.

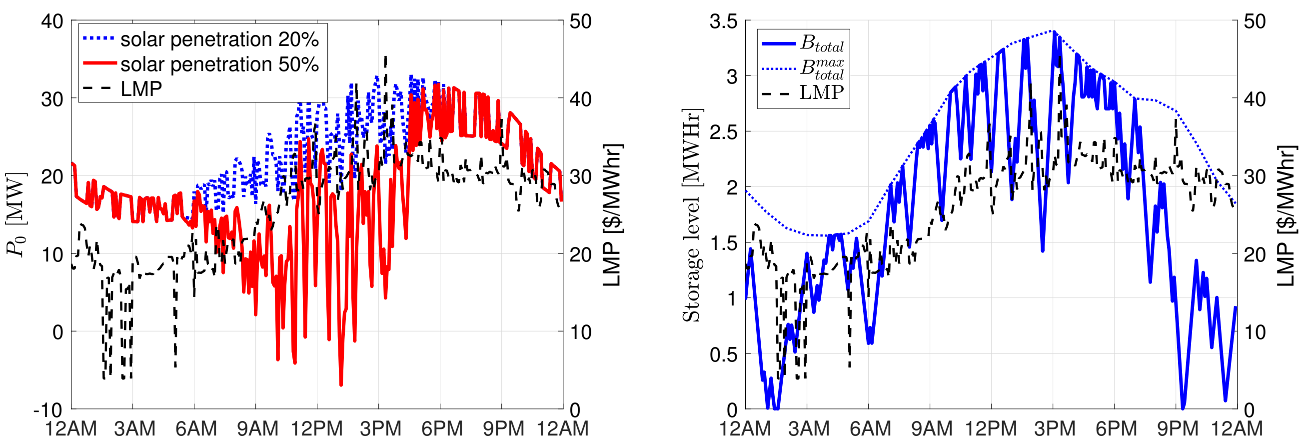

Figure 1: The time evolution of the net real power demand (left) and virtual storage level (right). The GML coordinates the virtual storage to reduce the cost of procuring energy. For example, the high LMP at around 3PM leads to storage discharge, whereas the battery charges with low LMP values (e.g., at 12PM).

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