Improving Distribution System Resilience Using Responsive Loads

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Aggregate response of these smart end-use loads could balance or improve the operational efficiency and resiliency of the grid. Particularly in distribution systems, a coordinated load management can improve the reliability and over all resiliency of the system. Employing residential loads in a scalable fashion requires four key advances. Firstly, develop end-use load control hardware that can be retrofit to the loads irrespective of the vendor and enable standardized control, communication, and data exchange to perform grid-responsive function while remaining with in safety and operational constraints. Secondly, a standards-based home energy management system (HEMS) that interacts with utility and serves as a platform for deploying intelligent algorithms to execute grid-responsive functionality of a collection of residential devices. The HEMS provides interoperability across multi-vendor devices and provides standard data exchange with utility systems. Thirdly, standards-based grid-service dispatch and transactive control architectures for scalable aggregation of residential loads in a timely fashion to provide variety of grid services. Finally, optimal distribution reconfiguration that utilize demand side resources and distribution-level distributed energy resources (DERs) to minimize outage and recovery times while reducing loss of load during extreme events.

We present a novel method to improve distribution resilience by accessing the flexibility in demand resources using decentralized transactive control along with intelligent distribution reconfiguration. The implementation of the decentralized control of residential DERs to provide grid services centers around the ability to do near-real-time estimation (of flexibility), optimization (guarantee response from DERs), and robust control (reliable actuation to affect the grid parameters of interest in a given use case). We present a system with two key components (1) a novel decentralized game-theoretic control with a utility-scale global controller and a residential level-local controller. The global controller utilizes the distribution-level information of a given topology to generate an incentive signal to influence the load shapes to maximize reliability and minimize disruptions. The local controller at residential level that forecasts device level performance to assess flexibility and communicates iteratively with the global controller to provide grid services while maintaining customer constraints, and (2) a method for online optimization of the distribution reconfiguration to minimize reliability impacts due to extreme event and maximizing resilience without breaking regulatory or cost constraints. An open-standards-based implementation architecture will be described. An open-source HEMS is developed to serve as an interoperability platform to interact with multi-vendor devices at home-level and utility-level interaction to provide grid services. The HEMS incorporates the ability to estimate demand flexibility and provide information to utility for optimizing distribution system resiliency. A linearized distribution flow algorithm is used online to periodically estimate the distribution state and drive incentive signal for customer participation in improving distribution resilience while minimizing cost constraints. We will present the preliminary results and discuss the impact of accessing flexibility on the short-term and long-term resiliency of the future distribution systems. Use cases driven by utility partners will be presented to evalaate resilience benefits provided by incorporating novel control formulation in future adaptive grid.