Implementing Real-Time Pricing in Smart-Grid with High Penetration of Renewable Resources and Plug-in Vehicles

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Abstract

The looming concerns of climate change and possible greenhouse gas regulation, coupled with excessive fuel price volatility, have all been contributing to the wide spread of renewable energy and new technologies, including wind, solar and electric vehicles (EVs). Smart Grid infrastructure is key to integrate the emerging technologies into the grid and to migrate to a clean, secure and sustainable energy system. Such infrastructure will also pave the way for demand participation in wholesale electricity markets, which will further help improve system efficiency and increase system reliability. Infrastructure alone, however, is not sufficient for reaching the full benefits of demand participation. The current prevailing fixed-electricity-rate structure needs to be replaced by dynamic rate structures.

The difficulty of consumers' behavior change towards electricity usage is a major barrier to the widespread application of dynamic pricing and demand response. As most consumers have been accustomed with a flat rate of electricity, it would take a long time for them to learn to track and respond to dynamic electricity rates, if they decide to do so at all. To overcome such a barrier, control automation devices (termed as energy management controllers, or EMCs) have emerged to help better enable demand participation in Smart Grid. Such devices can realize two-way communications between consumers and utilities (or even system operators) in terms of energy usage and electricity rates, and can be programmed to control certain household appliances, such as air conditioners, dishwashers and plug-in electric vehicles (PEVs).

In this talk we will present an approximate dynamic programming (ADP)-based economic dispatch model that can implement the real-time pricing rate structure and seamlessly integrate demand participation into the wholesale markets, with the aid of the EMCs. We will discuss and compare the market outcomes with different entities controlling the EMCs (namely, with a wholesale market operator or consumers themselves controlling the devices). Our numerical results using real energy market and household data from California indicate that compared to a flat-rate electricity market, the real-time pricing-based market with the energy management devices can both lower the expected values of wholesale electricity prices and increase the capacity factors of variable renewable resources, as the electricity consumption pattern can be better controlled to match the profile of renewable plants' outputs. In addition, with the higher utilization factor of renewables, more emissions reductions can be achieved under real-time pricing.