University of Victoria | Graduate Studies

Notice of the Final Oral Examination
for the Degree of Doctor of Philosophy

of

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"Market-Based Demand Response Integration in Super-Smart Grids in the Presence of Variable Renewable Generation"

Department of Mechanical Engineering

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12:30 P.M.
Engineering Office Wing
Room 106

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Abstract

Variable generator output levels from renewable energies is an important technical obstacle to the transition from fossil fuels to renewable resources. Super grids and smart grids are among the most effective solutions to mitigate generation variability. In a super grid, electric utilities within an interconnected system can share generation and reserve units so that they can produce electricity at a lower overall cost. Smart grids, in particular demand response programs, enable flexible loads such as plug-in electric vehicles and HVAC systems to consume electricity preferentially in a grid-friendly way that assists the grid operator to maintain the power balance. These solutions, in conjunction with energy storage systems, can facilitate renewable integration.

This study aims to provide an understanding of the achievable benefits from integrating demand response into wholesale and retail electricity markets, in particular in the presence of significant amounts of variable generation. Among the options for control methods for demand response, market-based approaches provide a relatively efficient use of load flexibility, without restricting consumers' autonomy or invading their privacy. In this regard, a model of demand response integration into bulk electric grids is presented to study the interaction between variable renewables and demand response in the double auction environment, on an hourly basis. The cost benefit analysis shows that there exists an upper limit of renewable integration, and that additional solutions such as super grids and/or energy storage systems are required to go beyond this threshold.

The idea of operating an interconnection in an unified (centralized) manner is also explored. The traditional approach to the unit commitment problem is to determine the dispatch schedule of generation units to minimize the operation cost. However, in the presence of price-sensitive loads (market-based demand response), the maximization of economic surplus is a preferred objective to the minimization of cost. Accordingly, a surplus-maximizing hour-ahead scheduling problem is formulated, and is then tested on a system that represents a 20-area reduced model of the North America Western Interconnection for the planning year 2024. The simulation results show that the proposed scheduling method reduces the total operational costs substantially, taking advantage of renewable generation diversity.

The value of demand response is more pronounced when ancillary services (e.g. real-time power balancing and voltage/frequency regulation) are also included along with basic temporal load shifting. Relating to this, a smart charging strategy for plugin electric vehicles is developed that enables them to participate in a 5-minute retail electricity market. The cost reduction associated with implementation of this charging strategy is compared to uncontrolled charging. In addition, an optimal operation method for thermostatically controlled loads is developed that reduces energy costs and prevents grid congestion, while maintaining the room temperature in the comfort range set by the consumer. The proposed model also includes loads in the energy imbalance market.

The simulation results show that market-based demand response can contribute to a signi_cant cost saving at the sub-hourly level (e.g. HVAC optimal operation), but not at the super-hourly level. Therefore, we conclude that demand response programs and super grids are complementary approaches to overcoming renewable generation variation across a range of temporal and spatial scales.