A Dynamic Equilibrium Framework for the Valuation of Demand Side Resources in Electricity Markets

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Overview:

With the ever increasing dynamics of modern power markets, the valuation of assets, initiatives and policies often requires a thorough understanding and characterization of the hourly interaction between supply and demand. To fully bridge the gap between supply and demand in such markets, and to fully assess the impact of both supply side and demand side initiatives, we have developed a dynamic equilibrium model of an electricity market that links the demand and supply sides of power market on an hourly basis. In this paper, we introduce the dynamic equilibrium model and use the modeling framework to analyze the value and market impact of various demand side resources.

When considering the various mechanisms that exist by which the demand side of the energy market can affect the overall market, it becomes more apparent how Demand Side Management (DSM) initiatives can make a significant, if not larger impact on system reliability than previous supply side solutions. Although new generation and transmission capacity is required to ensure sustainable growth in the market, any measures that can mitigate the load on the existing infrastructure during peak demand hours will significantly contribute to the long-term reliability of the system. A significant amount of pressure relief can arrive from the efficient use of demand side resources; however, these methodologies are laden with technological, social and economic uncertainty. On the supply side, the environmental advantages of renewable resources are great, but the policies required to encourage and properly value their potential contributions have not been fully assessed. Distributed generation resources can also be used to alleviate some of the load from the grid. The implications for the grid of an increasing fraction of residential power being self-generated, load shifted via DSM, or generated from an intermittent renewable resource are uncertain.

With the tremendous potential of such DSM initiatives established, the questions now becomes, which DSM strategy(s) to deploy, how will they be deployed, in what order and with what magnitude? The answers to these questions lie in the underlying economics of each strategy. The initiatives are designed to be deployed in a market that is stochastic in nature, and the mechanisms by which they work must interplay with the dynamics of the existing power markets. The framework presented in the paper will capture the underlying short-term time-dependent characteristics of each initiative, and will present a systematic analysis of the value of each strategy, which will be used as a benchmark for comparison. The initiatives that we will be addressing in particular include various end-use energy efficiency policies, incorporation of distributed generation resources and plug-in hybrids, demand response via load control, and real-time and time-of-use pricing schemes. The results are based on actual 2007 regional generation stacks and will highlight the system wide impact on load, energy value and environmental impact through emissions savings.

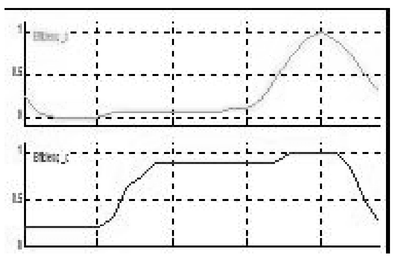
Method:

The model, which is built within the MATLAB/Simulink environment, may be used in a utility function independent manner to address various Demand Side Management (DSM) and market dynamics questions. The model will allow for the discovery of the key market parameters and characteristics associated with each strategy, while providing an objective standard by which to measure the effectiveness of each initiative. Moreover, the model allows for the assessment and valuation of market factors that are heavily dependent on the diurnal characteristics of such markets. We build regional generation stacks from a North American database to capture the supply side characteristics, which are used to assess the value of individual initiatives across different market settings and generation portfolios.

Results:

The incorporation of renewable resources, distributed generation, electricity storage and other traditional demand side management resources will have significant effects on the existing grid. The optimal operation strategy of each of these resources will dictate their overall impact on the traditional generation portfolio, and may lead to answers to questions such as: What happens to 'peaker' generators in light of reduced on-peak demand? What are the implications of adding load during off-peak hours? What are the net environmental and financial effects? How will the market react to a fleet of plug-in vehicles? What are the economic and environmental implications of various efficiency, load management and distributed generation initiatives?

We present several simulations results that aim to answer these and other questions. For example, we demonstrate the impact of energy efficient lighting in California. We use a residential lighting load over a 24 hour period where 20 lights at 100W each are replaced with more efficient lights ranging from 25 to 50W (peak savings range from 0.001 to 0.0015 MW). We also model a 50kW commercial building lighting load and a peak savings range of 0.0125 to 0.0375 MW. Simulation results show the non-linearity in the system impact, as the effect of increasing efficiency or equivalently the number of participants in this setting has increasing returns to scale impact on the system.



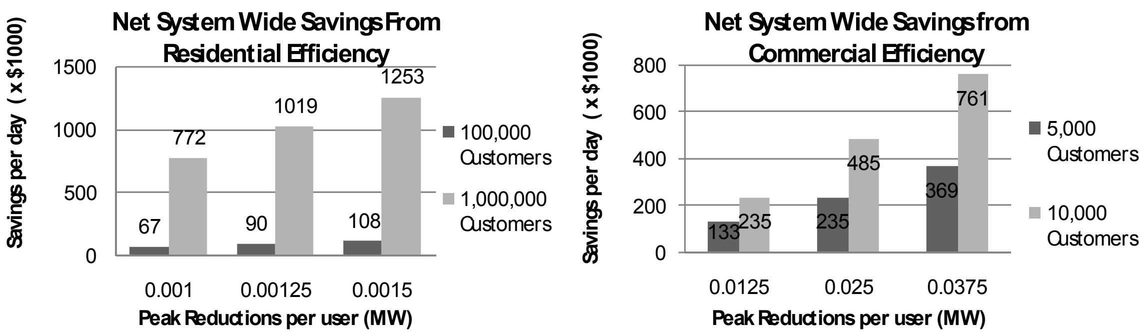


Fig 1: Daily system-wide savings as a result of energy efficient lighting in the residential and commercial sectors