The Future Grid

Examining Electricity Market and Power System Operation Interactions with Stochastic Distributed Resources

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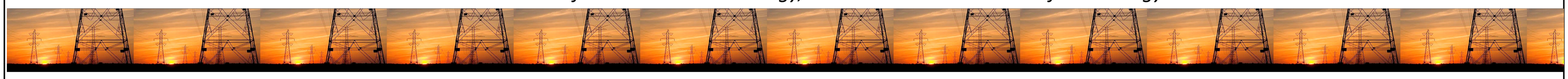


Project Objectives:

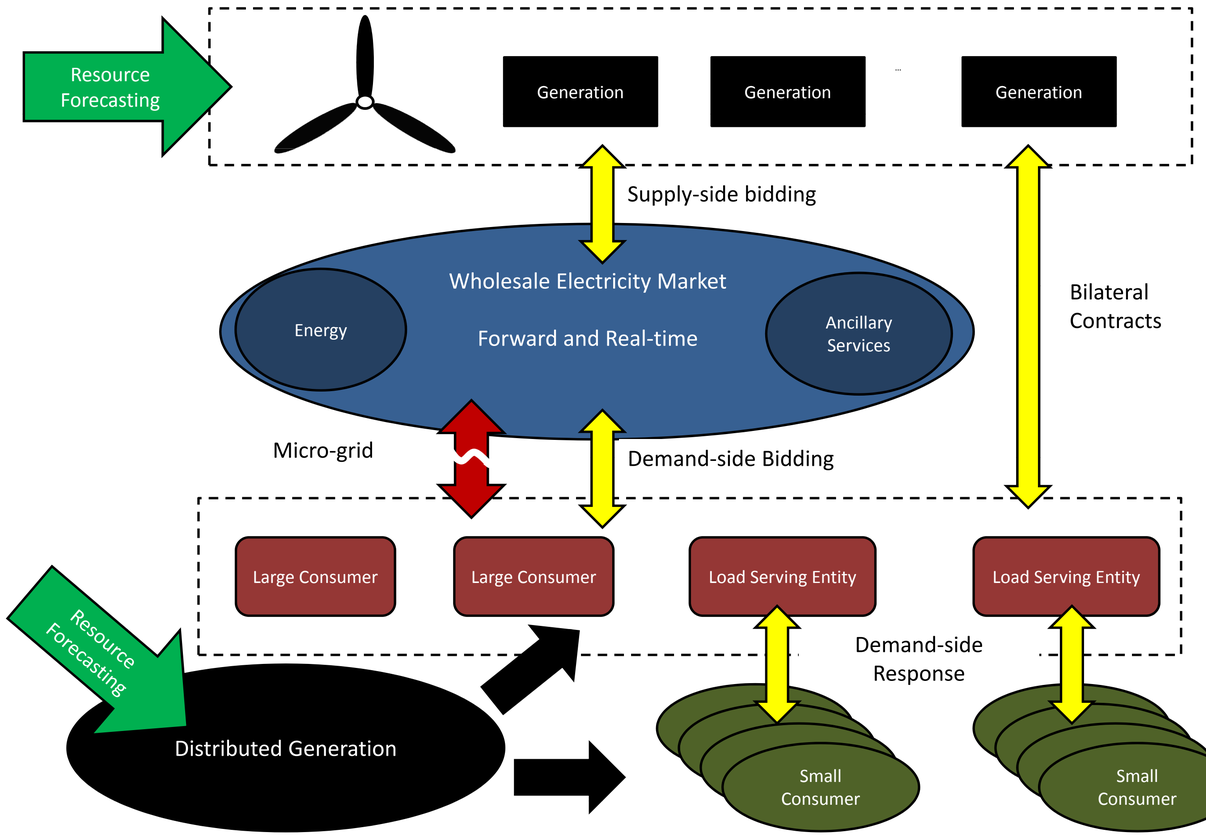
1) Model interactions between electricity market and power system operation for a grid with a high penetration of stochastic distributed generation, storage, and price-responsive loads;
2) Investigate the influence of stochastic renewable energy sources and price-elastic demand on investment choices in distributed generation, storage, and demand-response technology;
3) Assess the feasibility of meeting the rapid and uncertain demand growth in the UAE with a large share of distributed generation and price responsive technologies.

Background:

Advances in renewable energy technology and constraints on carbon emissions can potentially transform the electricity sector from a predominance of large centralized, fossil-fuel powered generating plants, to a more flexible, decentralized network with a high share of distributed renewable sources. In the UAE, the high growth rate of electricity demand provides an opportunity for rapid penetration of such new technology. In addition, the large uncertainty in future demand projections favors the deployment of smaller, more modular generating equipment, such as solar and wind power.

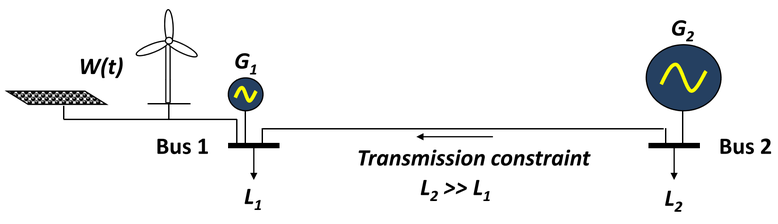
One significant challenge to the large-scale deployment of some renewable energy technologies is the stochastic nature of their availability. The present project will explore strategies for accommodating the intermittent nature of wind and solar power by enhancing the ability of electricity consumers to respond to variable electricity prices. Price-responsive measures include the deployment of commercial and residential energy management systems, distributed energy storage options, and new electricity market mechanisms that allow consumers and energy retailers to profit from adjusting their load to real time prices.

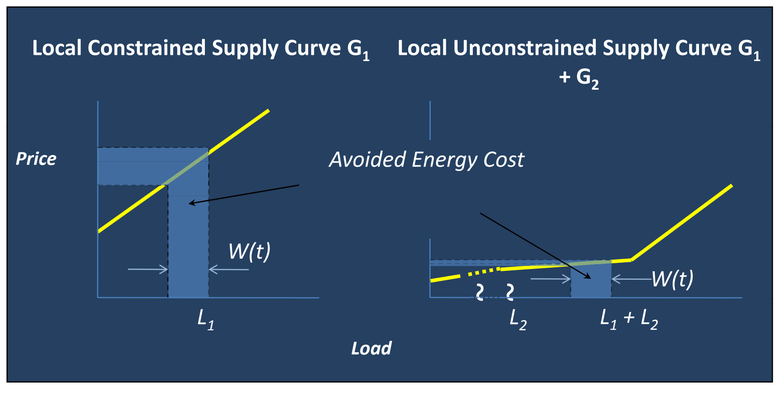
An important application of price-responsive technologies and demand response market mechanisms is in enabling more flexible operation of micro-grids. These "islands" within larger power systems maintain their own distributed generation and have the potential to increase reliability at the distribution level. Determining how power supply and load on a micro-grid are optimized in order to maximize power quality, financial returns, and reliability improvements, is currently a topic of active research and an important part of this project.



Price Generation with Stochastic Distributed Resources

Renewable energy resources tend to have very low operating costs as their "fuel" is often free (e.g. sunshine and wind). Due to this low marginal cost, large injections of wind or solar power can potentially reduce the real-time price of power relative to the daily average. This effect is even greater when the transmission system is constrained by line flow limits or high losses. The figure below shows a simplified example of a stochastic DG (e.g. wind and solar) separated from the main network by a transmission constraint. If there is no constraint, the price for power at both buses is set by the large and inexpensive generation (G_2) feeding into bus 2. When transmission is constrained, the price on bus 1 is set by the more expensive G_1. The avoided cost due to DG operation ($W(t)$) is much higher when the grid is constrained. Hence, the net value that DG provides to a network depends on: i) the operating cost of the DG source, ii) the stochastic resource correlation with system load (and hence, timing of constraints), iii) transmission and generation capacity limits, and iv) the operating cost of alternative local sources.



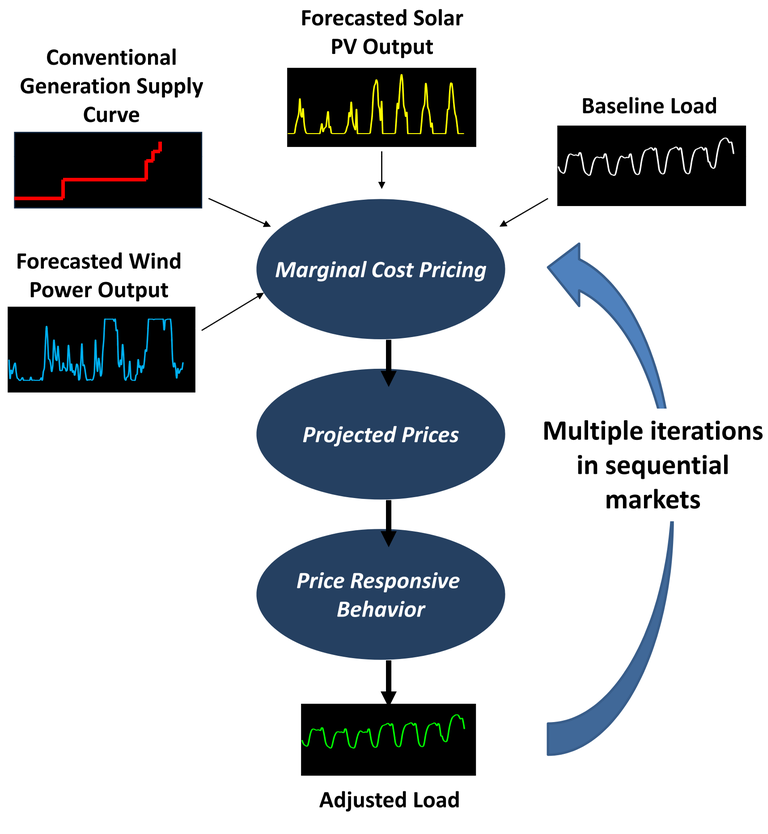


Price Responsive Demand to Mitigate Stochastic Supply

Pricing electricity based on the real-time marginal cost can improve the correlation between intermittent resources and the load, thereby overcoming some of the problems of their variability. There are a number of challenges of implementing this strategy:

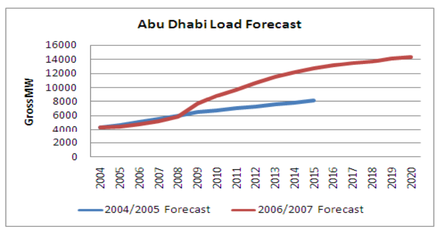
- Loads require knowledge of prices in advance in order to reschedule or activate energy storage devices;
- Future supply of stochastic resources is uncertain;
- Wholesale power markets may not allow participation of "non-firm" resources;
- Energy management devices may tend to synchronize their demand response if they see the same prices.

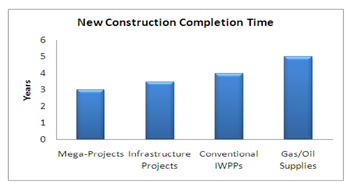
To resolve these issues, a market model is being developed that incorporates stochastic supply and distributed demand response technologies.



Meeting Rapid and Uncertain Demand Growth in UAE

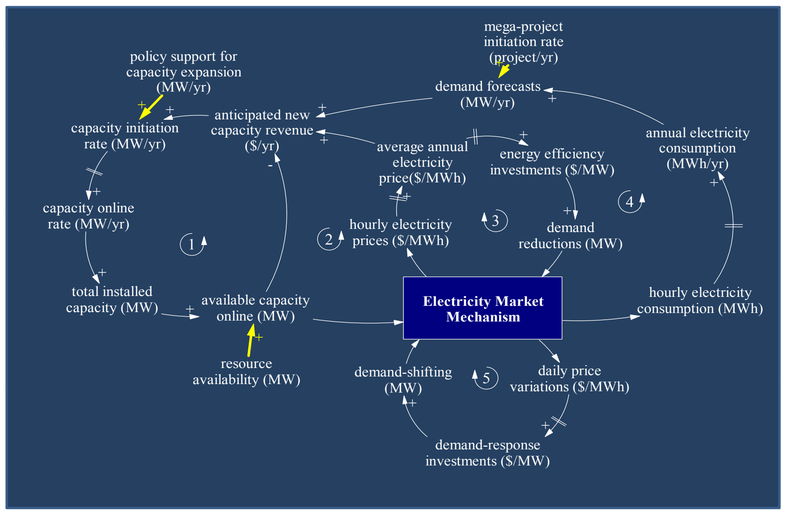
Electricity demand is growing very rapidly in the UAE. The Northern Emirates in particular are starting from a small base and showing very high annual growth rates. New mega-projects often increase local load significantly and often have a have a turn-around time that is shorter than the construction time for a new power and water plant. Hence, keeping pace with rapid demand growth is made even more difficult due to the uncertainty of new mega-projects.





Source: From Miller, K., MEED Abu Dhabi Conference, 2007.

A system dynamics model will be developed to examine the influence of demand forecast uncertainty on power system expansion and the potential for meeting new demand with distributed generation. Demand response mechanisms will be included to support a higher penetration of stochastic DG. The figure below shows a causal loop diagram that illustrates some of the primary feedback loops in such a system.



Causal loop diagram for a restructured electricity sector with distributed generation and price responsive demand. The diagram shows the dominant lags and feedbacks in the system and is useful for understanding its dynamic evolution.