# Developing Demand Response Programs and Markets

**Reza Ghorbani,**
**University of Hawaii at Manoa**

Where: Jakob-Haringer-Str. 2, Room T03

When: Wednesday, June 21, 2017, 10:15 s.t.

Demand Response (DR) programs and markets are being studied and developed to help increasing the efficiency of the generation especially with high penetration of renewable energies into the electric grid. This talk is divided into two main sections as they are being studied in the Renewable Energy Design Laboratory (REDLab) of the University of Hawaii at Manoa. First we present a theoretical framework of the DR market followed by a realistic testbed to verify the method.

The first section of this talk covers the initial steps of developing and understanding the DR in the developing electricity market. It covers scheduling the demand including water heaters, air-condition units and battery energy storage devices. A new market framework is presented as an alternative to the traditional vertically-integrated market structure, which may be better suited for developing DR and smart grid technologies. Game theory is used to justify the evolving market framework. The proposed market is cleared in each time interval of a day using a repeated game-theoretic framework. Two non-cooperative games are studied: one without considering market's constraints in an unregulated competition and the other one is a Stackelberg game which includes a leader to control the transaction price and power in a regulated competition. Effect of DR scheduling has been shown in both games for increasing the efficiency of the market. In a classical Cournot competition model, each firm tries to maximize its own payoff by deciding on the amount of production and only one market is shared among all firms. In recent economic models, different firms typically compete across a variety of markets simultaneously, i.e., each market might be shared among a subset of these firms. In this situation, a Networked Cournot Competition (NCC) graph models the relation between firms on one side and markets on the other side. Therefore, as the extension of the developed DR market in REDLab we have proposed a model of competition among demand response aggregators (as firms) which sell aggregated of stored energy in residential storage devices (as a homogeneous good) in a networked environment with a market maker. We call this game Networked Stackelberg Competition (NSC). The impact of strategic anticipative behavior in networked markets studied in our recent research will be presented. For each firm, the optimal bidding strategy and Nash equilibrium are obtained in an incomplete information game. Demand response aggregators submit quantity bids and the market maker (system operator) controls the transaction power and transaction price over the network subject to transmission constraints and other market policies. Existence of the Nash equilibrium, and efficiency of the game are also studied in the project and will be presented. The effect of DR scheduling has been shown in increasing the efficiency of the market.

Proper use of demand response requires that data be protected in real time so as not to affect performance. An increasing amount of communication, both wired and wireless, is required to enact accurate real-time control of a grid. However, due to the complexity of implementing this system to a large scale grid, a solution must be found where potential additions and changes to the grid can be tested to provide accurate real-life data that can be used by policy makers to inform their decision making process. To properly test the implementation of demand response in real world situations is extremely important and very challenging. A cyber-physical testbed has been developed at REDLab. The objective of the testbed is to test various simulated situations on a real microgrid system as well as testing various cybersecurity countermeasures. The benefit of this cyber-physical system is that the simulation can be tailored to any specific event or configuration, and the physical testbed can have multiple types of devices and control schemes implemented on it to test a variety of situations and conditions. This allows for the collection of data that is relevant to a real-world application and it does not endanger the greater grid as a whole, from both an operational or monetary aspect.

***Reza Ghorbani***
*Director, Renewable Energy Design Laboratory,*
*College of Engineering*
*University of Hawaii at Manoa, Honolulu, Hawaii 96822*
*E-mail:rezag@hawaii.edu; Office: (808) 956-2292*
*Website: http://manoa.hawaii.edu/me/redlab/*

*Reza Ghorbani (PhD, Mechanical Engineering, University of Manitoba), has over 10 years of experience in renewable energy, with an emphasis in the areas of smart grid, electronic hardware design, cyber security and optimization of energy systems. He joined college of engineering at the University of Hawaii at Manoa in 2008. As Director of REDLab he has initiated and led the development of innovative smart grid technologies, demand response and smart appliances, electricity market mechanism for renewable energy, cyber-security techniques for industrial control as well as data driven electricity grid control techniques. Current REDLab include the ARL funded "Cyber Security Testbed" focused on industrial control, ARL funded "Wave Energy Device" focused on powering remote sensors and drones; USDOE funded educational initiative in power systems; USDOT funded electric vehicle grid interaction study; as well as NSF funded optimization technique for operating electricity grid with very high penetration of renewable energy. REDLab also conducts transition to market of technologies for demand response, industrial control and cyber-security.*

UNIVERSITÄT SALZBURG

Software Systems Center
Colloqium Series

host: Wolfgang Pree