TCIPG

Trustworthy Cyber Infrastructure for the Power Grid

Smart Grid: Economics and Reliability

tcipg.org

Overview and Problem Statement

Renewable generation, energy storage, and demand response are key components of the Smart Grid vision. Effective use of these resources in future grids will require appropriate control architecture. This research focuses on investigations of control strategies for power grids with significant penetration of renewable generation, energy storage, and demand response resources. The goal is to understand how energy storage and demand response can provide ancillary services such as operational reserves and frequency regulation, thereby facilitating the use of volatile renewable generation in highly complex and constrained power networks. This understanding can lead to robust control schemes for future power grids.

Research Objectives

- Evaluate impacts of renewable generation, energy storage, and demand response on markets and operations.
- Investigate dispatch of energy storage and demand response resources to facilitate deployment of renewable generation.
- Explore the potential for storage and demand response resources to provide ancillary services in constrained power networks with high-penetration renewable generation.
- **Smart Grid Application Area:** Results can guide new policies, planning, and operations, thereby smoothing the transition towards the Smart Grid.

Technical Description and Solution Approach

- Questions of interest: How can energy storage and demand response be used in conjunction with renewable generation to provide services such as operational reserves, load following, and frequency regulation?
- Stochastic models for generation, demand, and storage that allow explicit consideration of impacts of volatility, dynamics, and uncertainty in both operations and markets are being used. Modeling abstractions for energy storage and flexible loads (e.g., HVACs and refrigerators), which explore similarities between both resources, have been developed.
- Operational tools for dispatch of power grids with renewable generators, flexible loads, and energy storage resources are being developed. Analytical techniques from approximate dynamic programming, reinforcement learning, and model predictive control are being used.
- Simplified models of flexible loads, such as HVAC loads of commercial buildings, are being developed for control synthesis in the context of extracting ancillary services from these loads.

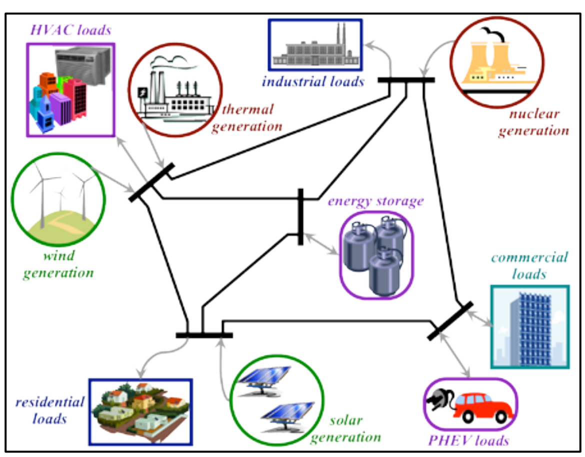

Figure 1: Conceptual illustration of the key Smart Grid resources considered in the analysis

Results and Benefits

- A conference paper detailing the control synthesis for energy storage and demand response resources with reinforcement learning techniques tuned with real world data has been presented at the IEEE PES General Meeting, July 2012.
- Computationally efficient control algorithms have been developed for operating power grids with renewable generators, flexible loads, and energy storage units. The proposed control algorithms are derived by combining reinforcement learning (RL) techniques with model predictive control (MPC). The application of the proposed algorithms to the dynamic economic dispatch problem has been extensively studied; simulation studies indicate that combining MPC with RL can significantly reduce the computational complexity of the dynamic dispatch problem.

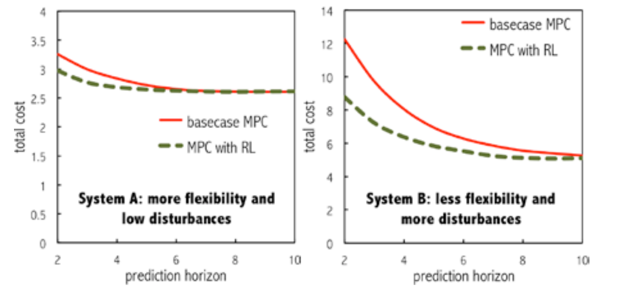

Fig. 2: Numerical studies demonstrate the effectiveness of the proposed algorithm in reducing computational requirements.

- The potential flexibility in the power consumption of heating, ventilation, and air conditioning (HVAC) loads of commercial buildings has been investigated to enable extraction of ancillary services from these loads. Simple control strategies, such as manipulation of the fan speed, have been studied in the context of regulation services. Simulation studies indicate that HVAC loads can be manipulated without discomfort to building occupants if the bandwidth of regulation is suitably constrained. Also, control of fan speeds of "suitable" HVAC loads alone can provide up to 6 GW of regulation reserves, which constitutes about 70% of the total requirements in the United States.

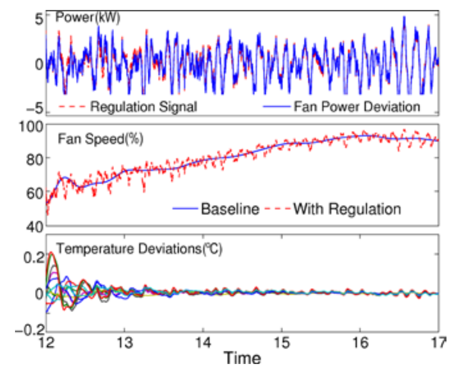

Fig. 3: Simulations on a high-fidelity model of a building and its HVAC demonstrate the impacts of fan speed control; the fan power consumption can be suitably modified to track the regulation signal sent by the grid operator.

- **Partnerships and External Interactions:** Anupama Kowli was a summer intern at PNNL.

Researchers

- Anupama Kowli, akowli2@illinois.edu
- Sean Meyn, meyn@ufl.edu

Industry Collaboration

- PNNL