# Game-Theoretic Methods for Distributed Management of Energy Resources in the Smart Grid

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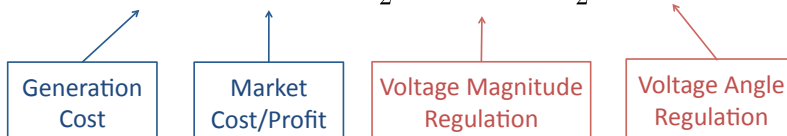University of Illinois at Urbana-Champaign, USA Email: {zhu31, basar1}@uiuc.edu

Introduction

- Game theory provides a versatile set of tools that can be used to analyze multi-layer and multi-agent strategic interactions in the smart grid.
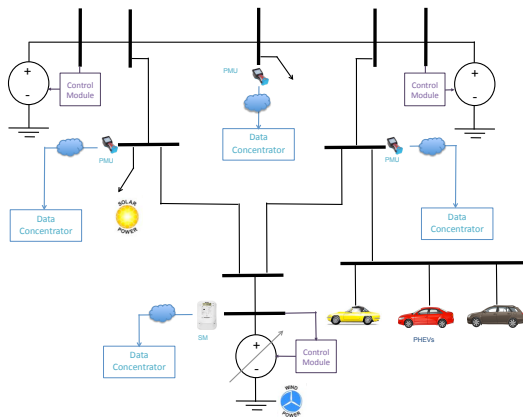
Distributed Renewable Energy Resources

- With deregulation, independent power providers can enter the electricity market and sell cheap power to the grid.
- A game-theoretic framework addresses how distributed renewable energy resources integrate into power grids for planning and operation.
- Each bus decides on the amount of power P_i to generate and a higher level player decides on rebate rates to incentivize the generation.

$$U_i(P_i, V_i, \theta_i) = c_i P_i + \alpha(P_i^l - P_i) + \frac{1}{2}\gamma_i^1 (V_i - \hat{V}_i)^2 + \frac{1}{2}\gamma_i^2 (\theta_i - \bar{\theta})^2$$

Generation Cost

Market Cost/Profit

Voltage Magnitude Regulation

Voltage Angle Regulation

Demand Response

- Users respond to supply and pricing information to balance the demand and supply.
- A risk-sensitive multi-resolution large population game is used to study optimal response and equilibrium as well as emerging phenomena in the large-scale system.
- Interactions among the players come from not only within the zone but also between the zones.
- The mean-field Nash equilibrium solutions are characterized by two coupled PDEs: Hamilton-Jacobi-Bellman (HJB) and Fokker-Planck-Kolmogorov (FPK) equations.

V2G Transactions

- The multi-layer and multi-resolution game is applied to optimal demand response of PHEVs in the smart grid.
- At each parking lot, the arrival and the departure of PHEVs follow a birth-death process.
- The framework enables cross-infrastructure study between power grid and transportation networks.

Arrival and Departure of PHEVs

Nash Equilibrium Power Flow

Multi-Layer and Multi-Resolution Game