TCIPG Smart Grid: Economics and Reliability

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Goals

- Evaluate impacts of renewable generation, energy storage, and demand response resources on markets and operations.
- Investigate use of energy storage and demand response to facilitate integration of volatile renewable generation.
- Explore control schemes for constrained power networks with integrated renewable generation, energy storage, and demand response resources.

Fundamental Challenges

- Existing models and tools do not capture the key underlying dynamics and uncertainties inherent to power systems.
- Tight coupling between market economics and physical operations is often ignored.
- Computational tractability, especially in planning and policy analysis, conflicts with the meaningful representations.

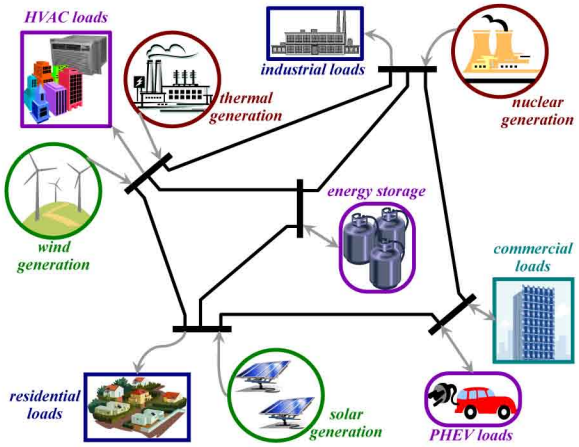

Fig. 1: Conceptual illustration of the key Smart Grid components considered in the analysis

Research Plan

- Questions of interest concern provision of services such as reserves, load-following, and frequency regulation when energy storage and demand response resources are used in conjunction with renewable resources.
- Focus on volatility, dynamics, and uncertainty: Use of stochastic models for generation, demand, and storage with explicit consideration of physical network constraints and environmental impacts.
- Simulation studies for single bus systems and extensions to realistic network settings.
- Tools: Markov decision theory, approximate dynamic programming, and reinforcement learning algorithms driven by real data.

Research Results

- Recent work [1],[2] demonstrates how demand response can reduce price volatility and facilitate use of volatile renewable generation.

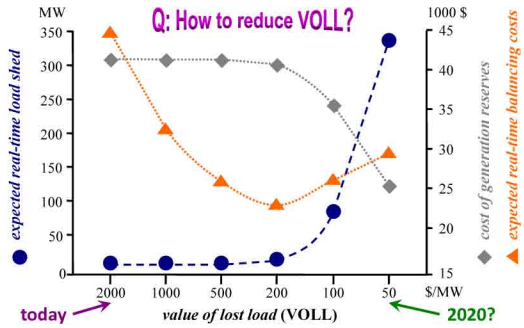

Fig. 2: Business case for load shedding, from [2]

- Reinforcement learning algorithm has been applied to solve the optimal control problem for smoothing variability of wind generation using energy storage.

Broader Impact

- Proposed techniques can lead to development of operational tools that do not use artificial models for system resources and environment.
- Results can guide new policies: incentives for ancillary services from buildings, new market mechanisms, and so on.

Interaction with Other Projects

- Research investigates the potential benefits of active load management: Greater demand-side participation will entail a secure communications and metering infrastructure.
- Some activities in the "Active Demand Management" cluster focus on the development of such frameworks and hence complement this research.

Future Efforts

- Impacts of cyber-attacks on proposed control algorithms need to be investigated.
- Robust control schemes that can tolerate cyber-attacks to a certain extent need to be explored.

References

[1] G. Wang et al., "Dynamic Competitive Equilibria in Electricity," in *Control and Optimization Methods for Electric Smart Grids*, A. Chakrabortty and M. Ilic (Eds.), Springer, 2011.

[2] A. Kowli and S. P. Meyn, "Supporting Wind Generation Deployment with Demand Response" in *Proceedings of the IEEE PES General Meeting*, 2011.