Smart-Grid-Enabled Distributed Voltage Support Framework

Hao Jan (Max) Liu, Hao Zhu, and Thomas J. Overbye

GOALS

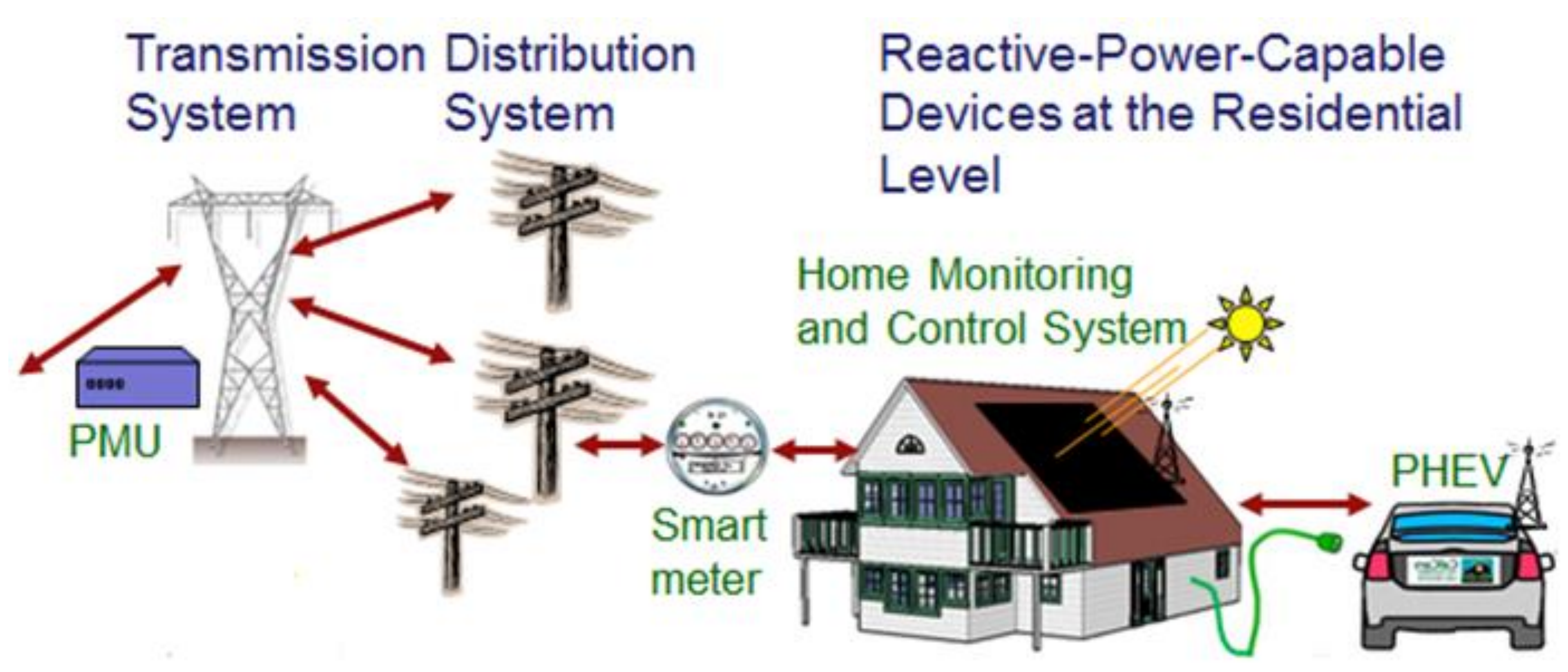
- Develop a system to enable the use of emerging smart grid devices, such as PHEV/EV and solar panel inverters, to participate in distributed reactive power support.
- Facilitate near-real-time reactive control at residential level.
- Devise ways to perform reactive control among distribution-level devices.
- Design effective ways to safeguard the required communications among devices.
- Validate simulated control algorithms in a laboratory setting with actual power system devices.
- Determine the cyber infrastructure needed to obtain that reactive power control.

FUNDAMENTAL QUESTIONS/CHALLENGES

- What is the best way to utilize the support from a power system perspective? Minimize system loss, maintain a preferable voltage profile, or reduce energy consumption?
- How far can the support go? How much is needed, and for how long, since the distribution system has low inertia and loading changes rapidly?
- How can we securely and reliably coordinate the control of a vast number of distributed resources to ensure a resilient power grid?
- What undesirable scenarios need to be considered, and how can they be prevented? For example, what if an adversary gained control of a neighborhood's distributed reactive power control system and caused all the fuses to trip at the same time? What can we do to prevent that?

RESEARCH PLAN

- Example power systems, such as distribution feeders, are modeled in OpenDSS via a control function in MATLAB to show the benefits of local injections of reactive power.
- Varying loading conditions and OLTC tap setting are being modeled.
- Algorithms are being developed to determine the validity of using distributed reactive power control with different assumptions about the cyber infrastructure and communication networks, such as local control versus global control.
- Examining the response of a distributed reactive power support system to events, such as short circuit analysis and relay coordination.
- The interactions between distributed reactive power support and conservation voltage reduction may result in the additional benefit of reducing energy consumption during the peak loading condition. Ultimately, we want to maximize the benefit to both utility companies and customers.
- Both the centralized and distributed minimization problems have been solved. An adaptive ADMM control algorithm has been developed to minimize the communication overhead.

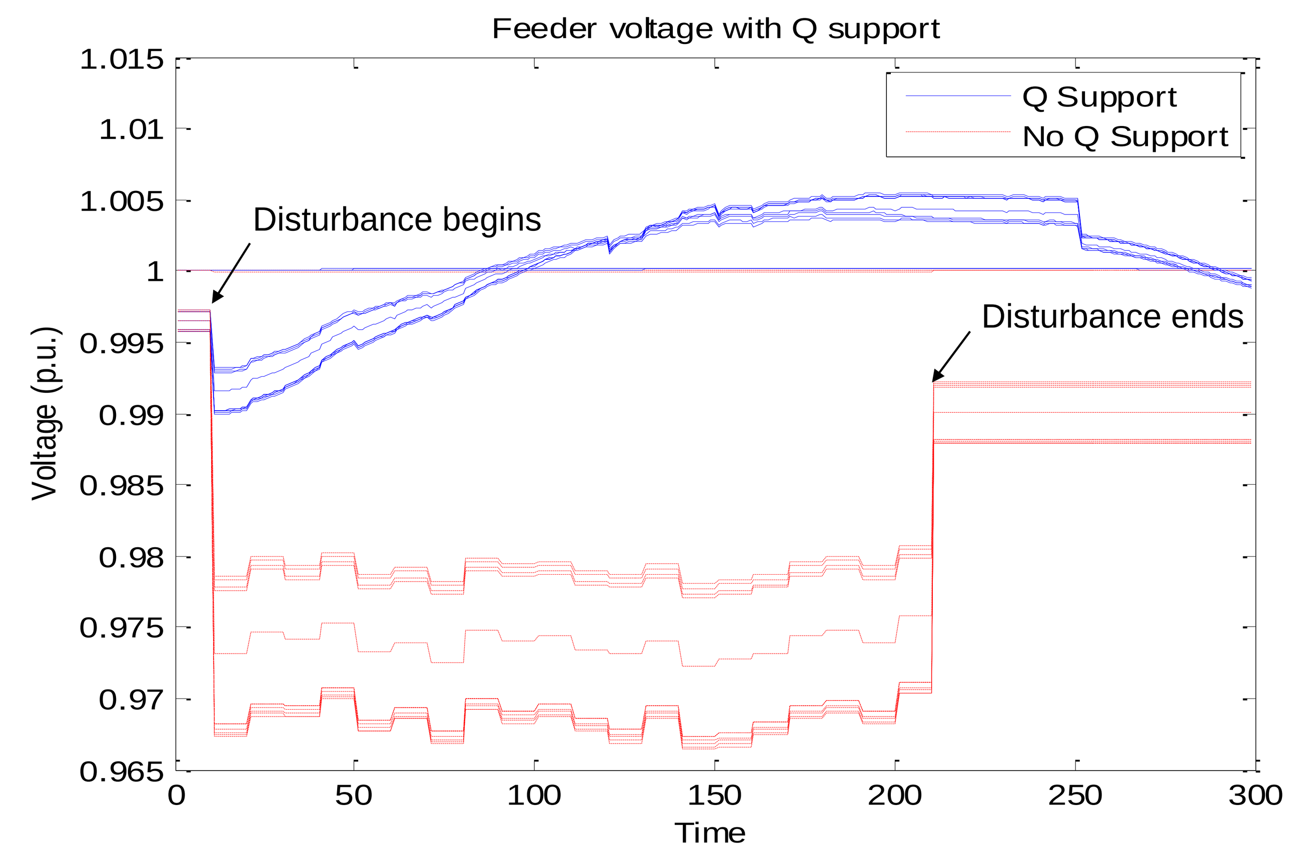


INTERACTION WITH OTHER PROJECTS

- Energy Dashboard project.

RESEARCH RESULTS

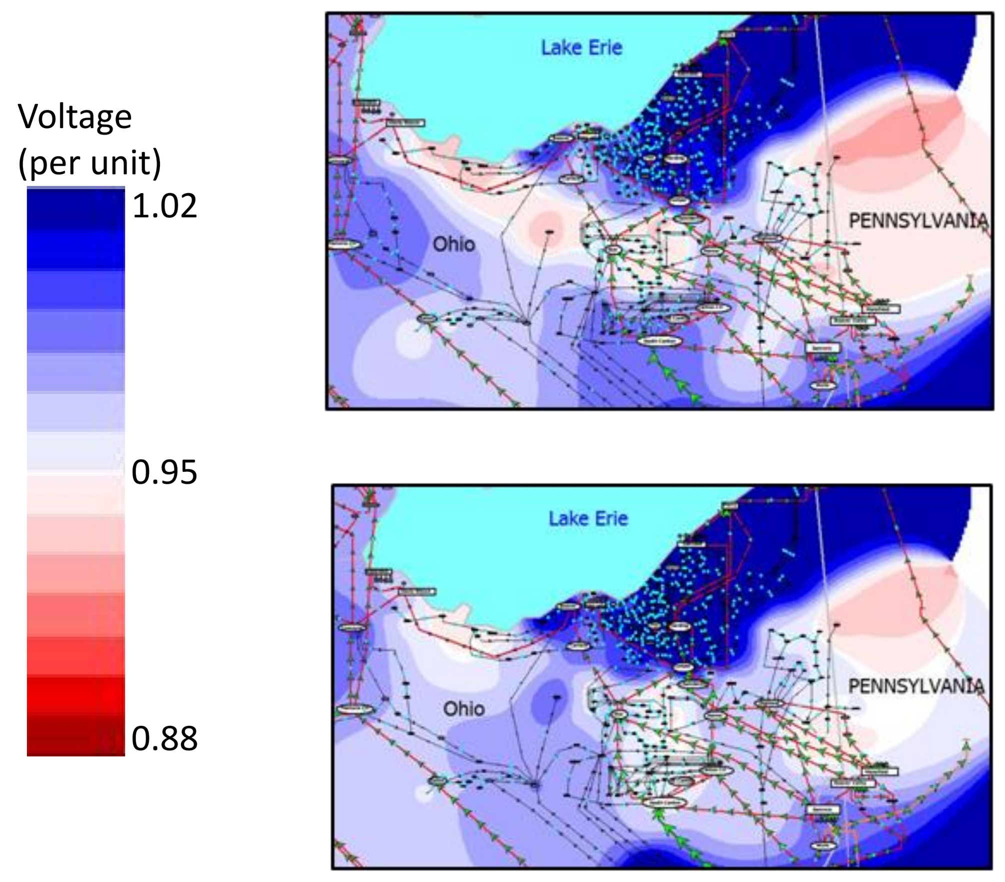
- Power loss sensitivity provides insight into effective locations for injecting the reactive power support. OpenDSS uses the idea to determine the next best location to inject reactive power.
- Centralized methods that solve for the amount of needed reactive power support and have full knowledge of system states require a communication network that may be prohibitively expensive. Therefore, a distributed optimization problem has been solved through use of the alternating direction method of multipliers (ADMM).
- A distribution feeder system has been modeled to show the benefits of reactive power support.
  - Possible to inject reactive power more evenly along radial feeder.
  - Lower distribution line loading and better power factor at substation.
  - More even voltage profile can be achieved.
  - Minimize distribution feeder losses.
  - Further energy reduction is possible with an even voltage profile and OLCT control.
  - Increase generator real power production while operating within same range.



BROADER IMPACT

- The additional reactive power potential from devices such as inverters is useful from a power system perspective, if it can be coordinated.
- By addressing the problem at the distribution level, it is possible to alleviate voltage problems at the transmission system level as well.
- The control framework, if enabled in a timely manner, could help prevent problems such as voltage collapse.

Power factor correction at just 5 buses results in appreciable voltage improvement



© Rogers, K: An Authenticated Control Framework for Distributed Voltage Support on the Smart Grid. *IEEE Transactions on Smart Grid*, **2010**, *1*, 40-47.

FUTURE EFFORTS

- Quantify benefits associated with an autonomous as compared to a networked system with different levels of control.
- Optimize the control scheme to minimize the loss of the system or maintain the voltage profile.
- Use simulation to assess the impact of different types of attack with different levels of control.
- Long-term goal: test in real feeder system, e.g., the campus distribution system.

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