Smart-Grid-Enabled Distributed Voltage Support Framework

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Goals

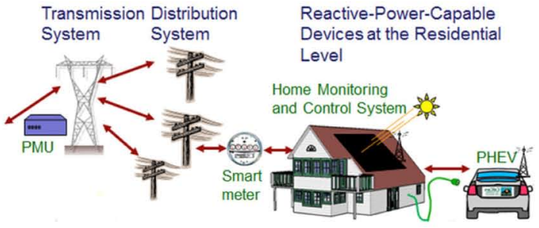
- Develop a system to enable the use of emerging smart grid devices, such as PHEV/EVs and solar panels, to participate in distributed reactive power support.
- Facilitate near real-time reactive control at residential level.
- Devise ways to perform reactive control among distribution-level devices.
- 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 this reactive power control.

Fundamental Questions/Challenges

- What is the best way to utilize the support from a power system perspective: minimize the loss of the system, or maintain a preferable voltage profile?
- How far can this support go? How much is needed, and for how long?
- How can we securely and reliably coordinate the control of a vast number of distributed resources?
- 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 to show the benefits of local injections of reactive power.
- Varying loading and supply voltage conditions are modeled.
- Algorithms are being developed to determine the validity of using distributed reactive power control with different assumptions about the cyber infrastructure, such as local control versus global control.
- Examine the response of a distributed reactive support system to events.
- Impacts of cyber disruptions are being studied.
- "Q-C Bus": a bus providing controllable reactive power.



Interaction with Other Projects

- Energy Dashboard project.

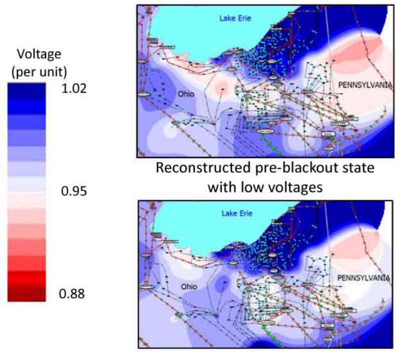
Research Results

- Sensitivities provide insight into effective locations for injecting the reactive support.
- Optimization methods solve for the amount of support needed.
- A power system has been modeled to show the benefits of reactive power support.
  - It is possible to inject reactive power more evenly along radial load buses.
  - Transmission line loading is lower and there is a better power factor at each load bus.
  - There is a more even voltage profile in subnetworks and higher up the network.
  - Generators face reduced reactive power demand.
  - Generator real power production can be increased while operating within the same ratings.
- A control system has been proposed that would allow a battery-inverter device, representing an EV, to inject reactive power; it has been modeled in Simulink prior to implementation.

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 also.
- This control framework, if enacted in a timely manner, could help prevent problems such as voltage collapse.

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



Reconstructed pre-blackout state with low voltages

After power factor correction of 5 buses

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 campus distribution system.