Smart-Grid-Enabled Distributed Voltage Support Framework

Overview and Problem Statement

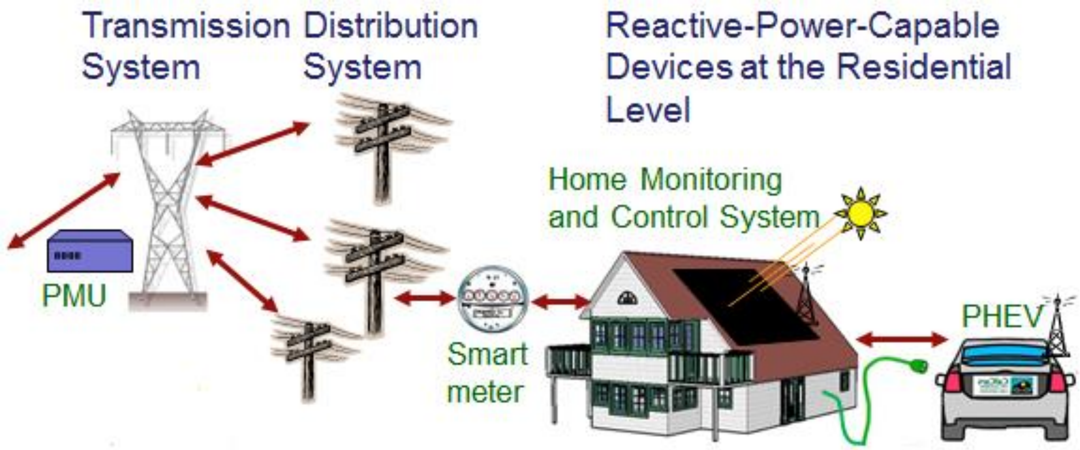
The motivation for this research lies in the use of emerging smart grid technologies, such as smart inverters, to supply reactive power as a means of distributed reactive power support. Power factor compensation closer to the load improves transmission line loading and efficiency. In the distribution networks, reactive power support not only minimizes the system losses, but also improves the feeder voltage profile. The focus of this research is on developing a smart-grid-enabled control algorithm that will determine the amount of reactive power injection or absorption required at each location to minimize the deviation from the control voltage level. Once the voltage level has been achieved, implementing conservation voltage reduction further benefits the system by increasing energy savings and extending equipment lifespan. We examine requirements for a secure communication framework to interact with the large number of devices that would be present. In general, reactive power support occurs at the substation level, whereas the communication advantages and system feedback provided by smart-grid technologies, such as smart meters, facilitate an extensive reactive power support scheme that reaches all the way to the end users.

Research Objectives

- The project seeks the ability to utilize large amounts of distributed resources, so there are major challenges to ensure high security to prevent adverse effects on the system.
- Information received by the devices must be trustworthy so they will respond only in an intended way.
- Availability of the resources is important, and the capabilities of the system at any time should be known, since having wrong or out-of-date information about resource availability may cause the control scheme to be unsuccessful; therefore, the communication between the control center and the end users is important.
- There are also questions about the best way to utilize the support from a power system perspective. For example, should the system operate so that it receives the distributed support all the time to match the voltage profile, or just operate so that it minimizes the loss in the system?
- Another challenge is that of investigating the implications for potential contingencies of the system, so that the system can be designed to avoid them. For example, if an adversary were to gain control of the system and command all the distributed reactive power devices to maximize their output, could a sudden voltage rise damage the equipment along the feeder or cause the fuse to burn out? If so, what can we do to prevent that situation?
- **Smart Grid Application Area:** This project is developing a framework to allow secure control of distributed resources in an intelligent manner.

Technical Description and Solution Approach

- Example power systems, such as distribution feeders, are being modeled to show the benefits of local injections of reactive power. Varying load and supply voltage conditions are being 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.
- Algorithms combining reactive power support, conservation voltage reduction, and on-load tap changer (OLTC) control are being developed in OpenDSS and MATLAB to find the optimal voltage profile for the feeder system in order to minimize system losses and save energy consumption.
- Both centralized and distributed minimization problems have been solved. An adaptive alternating-direction method of multipliers (ADMM) control algorithm has been developed to minimize the communication overhead.



Results and Benefits

- Reactive power support is most effective when provided locally, and voltage problems tend to start in the distribution system. By addressing the problems at the distribution level, we can also alleviate voltage problems at the transmission system level.
- A framework utilizing distributed reactive resources is important, because an increasing number of inverter devices that can potentially provide this support are being placed in the power grid, and this additional reactive power capability is useful from a power systems perspective.
- As noted in the 2003 blackout report, a commonality among most previous major North American blackouts was that the system was experiencing inadequate reactive power support. With a smart-grid-enabled reactive power support scheme, such problems could possibly be prevented.
- Reactive power support tends to lower feeder losses and flatten the voltage profile. By implementing this control algorithm, further load reduction is possible through OLTC coordination.
- **Technology Readiness Level:** The researchers plan to model a distribution feeder in the Real Time Digital Simulator (RTDS) to implement the control algorithm when the devices are ready.

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funded by the U.S. Department of Energy and the U.S. Department of Homeland Security