# Integration of Smart Grid Enabling Technologies within Power Distribution Systems

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Electric power distribution systems typically encompass the power delivery systems with voltage levels from 115kV and below. These systems include the branches, nodes and components up to the meter outside customer buildings. Historically, strict assumptions with respect to network topology and network power flows have been made. Consequently, physical design and construction have followed suit. Now, with the desire to integrate large numbers and large amounts of alternative energy sources and other technologies, it comes to pass that the power distribution system itself is a limiting factor [1].

This talk will discuss some of these factors. Open challenges for system analysis and control for both planning and operation will be identified. To push beyond the limits, enabling technologies for system operations are needed. These include not only components such as automated switches, voltage controllers, etc., but also integrated distribution energy management systems with advanced distribution analysis and automation techniques.

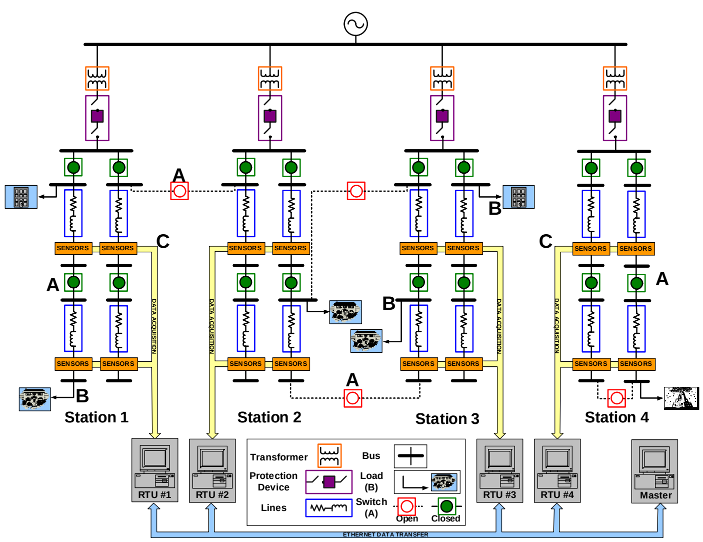


Figure 1: One-line diagram of a multi-phase power distribution system: with control and network inputs (A,B) (e.g. switch, load & faults) and sensed outputs (C)

Advanced control devices have long existed within components connected to power distribution systems, e.g. smart appliances, direct load control, co-generation, etc. Their potential benefits have been demonstrated with a relatively small number of participants or with pre-set control schemes. As the push for new technologies continue, the scale of active devices within the power distribution systems will increase to previously unplanned for levels. In addition, in the US, the regulatory structure often requires owner separation of the sources (generation and load control/demand response) from the distribution of the energy. Yet, achieving optimal or near-optimal system conditions would require tighter coupling (beyond energy pricing) between system characteristics and individual component behaviors.

Thus, identifying modeling and analysis techniques appropriate for system integration studies of smart-grid enabling devices is needed. Since distribution system measurement systems are evolving, finer model resolution can be achieved. For example, it has been shown that simplified models and analysis tools adopted in bulk power transmission systems yield unsatisfactory results for power distribution system analysis and control. The talk will illustrate significant differences in solutions to the system state found using three-phase and unbalanced models. In addition, these differences can subsequently lead to unsecure/infeasible control selections in desired grid functions such as service restoration after a fault [2].

Furthermore, in order to identify limits to the amount of allowable power from distributed energy resources within a given distribution system, new control algorithms and instrumentation and measurement systems need to be developed. With respect to network reconfiguration and voltage control, adaptive control systems would be required to handle varying operating environments presented by the decentralized control of power injections (e.g. renewable energy sources and demand response.) This is not standard practice. Also, under current industry standards, if a fault is detected within the system, distributed resources are electrically isolated from the grid. While standards are under consideration to allow for electrically isolated microgrids/islands to form, traditionally, optimal control functions within distribution systems did not include dynamic constraints. With the inclusion of large-numbers of energy resources (both storage and generation) physically and thus electrically close to one another, interactions between individually-owned and operated, multiple devices via the system become a concern. Thus, varying time-scales with respect to data exchange would be required to coordinate new control schemes.

Within this talk, the impacts and some proposed analytically-based solutions to integrating new technologies will be discussed. Examples on actual power distribution systems will be presented. Finally, the need for judicious integration of new technology and control schemes will be shown in order to balance maximizing benefits of the new technologies with its utilization.

[1] P. Djapic, C. Ramsay, D. Pudjianto, G. Strbac, J. Mutale, N. Jenkins, and R. Allan, "Taking an Active Approach," *IEEE Power and Energy Magazine for Electric Power Professionals*, July/August 2007: 69-77.

[2] M. Kleinberg, K. Miu, H.-D. Chiang, "Service Restoration with Load Curtailment,"*to appear in IEEE Transactions on Power Systems*.