Architecture and Distributed Management for Reliable Mega-scale Smart Grids

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The objective of this research is to establish a foundational framework for smart grids that enables significant penetration of renewable DERs and facilitates flexible deployments of plug-and-play applications, similar to the way users connect to the Internet. The approach is to view the overall grid management as an adaptive optimizer to iteratively solve a system-wide optimization problem, where networked sensing, control and verification carry out distributed computation tasks to achieve reliability at all levels, particularly component-level, system-level, and application level.

Under the common theme of reliability guarantees, distributed monitoring and inference algorithms are being developed to perform fault diagnosis and operate resiliently against all hazards. PMU measurements from multiple locations, are used for learning, characterizing and classifying event-specific spatial signatures, and probabilistic models are developed to subsume measurement data. To attain high reliability, a trustworthy middleware tailored towards smart grid design, is being studied to shield the grid design from the complexities of the underlying software world, using automatic generation of invariants for software validation. Further, the PIs are investigating realistic/tractable models for wind generation forecast, and leveraging them to devise efficient algorithms for demand response and adaptive reserve requirements. Another major effort of this project is on exploring the CPS architecture that is capable of providing reliable operation and good performance of smart grid, even in face of an uncertain, error-prone, and dynamic environment.

The smart grid is an outstanding example of the CPS technology. Built on this critical application study, this collaborative effort will pursue a CPS architecture that enables embedding intelligent computation, communication and control mechanisms into physical systems with active and reconfigurable components.