Model-based Integration Technology to Enable Resilient Next-Generation Electric Grid

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The national electric power grid is going through transformational reform to be efficient, reliable and secure smart electric grid in line with the national energy security mission. The electric power grid constitutes the fundamental infrastructure of modern society and utilizes communication, digital information and control technology to improve efficiency and reliability of the system.

The scale and complexity of the electric grid has increased over the years with ongoing smart grid activities employing a range of advanced technological solutions while being confronted with changing load profile, integration of renewable energy sources, and an ageing infrastructure. A number of recent blackouts and natural catastrophes have exposed the power grid's vulnerabilities and emphasized the need for resiliency to be embedded into the smart electric grid infrastructure. Achieving a '*resilient*' smart electric grid requires monitoring the interactions between the power grid and the communication and control infrastructure, as well as the ability to assess integrated performance. By integrating adequacy, security and reconfigurability of cyber and power network in a single metric, we will address all the requirements of resilient cyber-power network. Both physical and cyber issues must be well understood, identified, and mitigated to ensure continuous reliability of the bulk power system. There remains a lack of computational tools to study interdependencies of such a complex system over any reasonable scale and to assess the system performance against a metric.

Simulation-based evaluation of the behavior of the electric grid is complex, as it involves multiple heterogeneous, interacting domains. Each simulation domain has sophisticated tools, but their integration into a coherent framework is a very difficult, time-consuming, labor-intensive, and error-prone task. This means that computational studies cannot be done rapidly and the process does not provide timely answers to the planners, operators and policy makers. Furthermore, grid behavior has to be tested against a number of scenarios and situations, meaning that a huge number of simulations must be executed covering the potential space of possibilities. Designing and efficiently deploying such computational 'experiments' by utilizing multi-domain tools for integrated smart grid is a major challenge.

Our vision is to develop a computational framework by integrating modeling tools from diverse domains into a single coherent framework for integrated modeling and simulation of 'smart' electric grid. The one practical solution is a multi-model simulation approach that facilitates the precise integration of heterogeneous, multi-model simulations. Feasibility of the proposed approach largely depends on the pervasive application of advanced software technology in modeling and model integration, heterogeneous multi-model simulation and information management infrastructure. We envision achieving plug-and-play capabilities with minimal effort required to replace any of the domain specific simulation tools in an integrated simulation by an alternate tool. Examples of such domain specific tools are: Real Time Digital Simulator, Power World, Network Simulator, OPNET. Our goal is to analyze electric grid systems against a set of resiliency metrics which will lead to a better understanding of the trade-offs in adopting a specific algorithms and control mechanism to design resilient power grid.