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Title:

Smart Grid Integrated Modeling Hubs Linked to Tradeoff Analysis and Validation

Abstract:

Despite intensive efforts towards modeling of smart grids we do not have todate a methodology and associated tools that allow easy and modular creation of accurate models of smart grids at various space-time scales and which are expandable. Furthermore, the testbeds that exist do not link easily to tradeoff and decision making tools for design and operation. Finally, and this is the weakest component of the overall modeling and synthesis and performance evaluation environment we do not have a rigorous representation of requirements and metrics that can be easily linked to such modeling environments for the purpose of testing and validation of requirements and performance metrics. In this paper and presentation we will present our on-going methodology and framework for developing integrated modeling hubs for smart grids that can accommodate heterogeneous physical and cyber components, at various spatial and temporal scales. The hub utilizes a modern and rigorous model-based systems engineering methodology that we have recently developed and utilizes SysML to represent the various structure and behavior components of a smart grid. We show how this environment links easily to popular tools like OpenModelica and Matlab (or SciLab) and COMSOL to model the heterogeneous physics involved. We will describe how these models are supported by distributed hybrid systems analytics and port-Hamiltonian formalisms for built-in composability. The part of the latter theory that covers hybrid systems is new.

We next describe our efforts to move towards open source tools and libraries of components and discuss the significance of large collaborative efforts towards this end. We describe the FMI metamodeling and open environment for linking heterogeneous models and show that it is very compatible with ur proposed overall methodology in smart grid modeling and model validation. We develop new methods for tracking uncertainties in these complex hybrid systems and show how they can be effectively used to track validation of requirements and performance metrics. We develop new methods for linking this integrated modeling hub with dynamic tradeoff analysis tools that are based on the integration of multi-criteria optimization and constraint based

reasoning. We demonstrate the utilization of the modeling hub and the tradeoff tools on a smart grid example.

We next describe a framework for representing requirements and methods for validating such requirements and performance metrics using a combination of model-checking, contract-based design and operation and automatic theorem proving. We describe a simple such system and discuss the challenges remaining towards full development of such a framework.

We describe hierarchical methods for scaling the overall framework to very large scales. We show how the proposed framework can incorporate dynamic pricing, dynamic load management, evaluation of new technologies, overall economic analysis and tradeoffs, smart grid security and trust evaluations. We describe how results and experimental test outcomes can be formally integrated within the proposed modeling and evaluation framework.