

Federated Smart Grid Testbed

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Marija Ilic pulls together various groups building major smart grid testbeds at the 10th Carnegie Mellon Conference on the Electricity Conference. We propose that she discuss with the community the possibility of a concerted effort to create a federated testbed connected over the Internet and available for the research community at large.

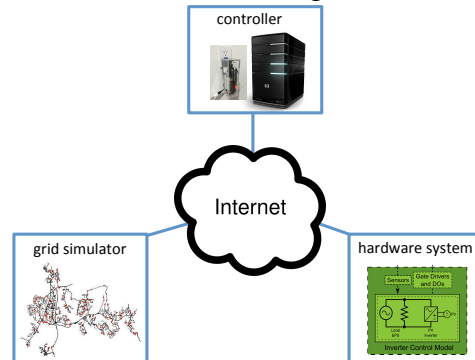
Motivation. Power systems research and development make use of all tools at our disposal, from mathematical theory to software simulation to hardware-in-the-loop (HIL) testbed to field test to commercial deployment. These tools differ in their realism, flexibility, portability, and cost, but are all indispensable to the R&D enterprise. At one end of the spectrum, mathematical modeling and analysis is the most flexible and portable tool that allows us to expose the underlying structure of a complex system and experiment with first-order designs. Sometimes it is the only tool for understanding fundamental limits or macroscopic properties at the extreme end of scalability where field tests or even software simulation is not feasible. On the other hand, mathematical models inevitably ignore many critical details in order to remain analytically tractable. As we transition to software simulation to HIL testbed, we zoom into these details. HIL represents an intermediate step between software-only simulation and field implementation. It allows the simulation of multi-domain, large-scale systems that include hardware, and to efficiently evaluate the proposed solution in a variety of system configurations and operational scenarios. Particularly, controller HIL (CHIL) techniques can be leveraged to connect hardware controllers to real-time software models of power and communications networks, while power HIL (PHIL) techniques can be utilized to test physical devices at-power. This not only allows us to test and refine our mathematical theory and algorithms, it also brings to the fore a new set of technical hurdles that must be overcome in order to build deployable products and services. Ultimately, these products and services must go beyond laboratory and be tested in the field before they can be deployed at scale.

This set of tools complements and reinforces each other. Software simulations and HIL testbeds occupy a unique position in their portability and cost in the spectrum from mathematical theory to commercial deployment. It is therefore highly feasible and desirable, though nontrivial, to connect simulation tools and

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HIL testbeds over cybernetworks and make them available to the whole research community. This will speed up innovations by a large segment of the community that will have no access to realistic testbeds otherwise, amplify the investment and impact by all testbed efforts, and strengthen the community.

Example. A configuration is shown in the diagram below as an illustration.



In this example, a grid simulator (e.g., OPAL RT, GridLab-D, PSS), a hardware system (e.g., synchronous generator, inverter, EV charger), and a piece of controller software are connected through the Internet. Suppose we wish to test a piece of controller software that optimizes EV charging, inverter reactive power, HVAC and pool pumps on a distribution feeder. The grid simulator simulates the feeder as well as distributed generation, behind-the-meter loads, including all controllable devices. Our controller software reads state information from the grid simulator over the Internet, solves OPF to compute a control decision, and dispatch them over the Internet to all the controllable devices in the grid simulator, thus closing the loop. Suppose some hardware such as EV chargers or inverters can be inserted into the testbed. These pieces of hardware in the loop will interact with the grid simulator as well as the controllable software over the Internet. The goal is to create a platform that allows different research groups to develop grid simulators or controller software or various hardware independently and be able to plug into a federated smart grid testbed to test their individual pieces.

Questions. This seems quite ambitious in its full generality, but even a modest version can be very useful to the community. A few issues must be addressed to pursue such an effort.

Can one define interfaces and management middleware that will allow a plug-and-play experimental platform? What is the right balance of generality, complexity, and cost? Besides development of such an infrastructure, its operation and maintenance will involve nontrivial amount of time, effort and expertise. Are there incentives for different groups who build their own testbeds to share their facilities? Do we need research groups whose research focuses on building and operating smart grid testbeds for the community? Who will fund such a community infrastructure?