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RESEARCH

Large-Scale Test Bed

Overview

The Large-Scale Test Bed is a computer software-based platform to simulate cyber-physical power systems with emulated communication networks, energy management systems, and measurement-based control applications. LTB features real-time continuous operation, closed-loop controls, and online visualization of power systems under small or large disturbances. While the traditional power system simulators only focus on the power system dynamics, LTB integrates power system components, EMS and measurement-based control systems into one platform through data streaming to address emerging challenges, such as, renewable energy integration and cyber-physical security under innovative measurement-based technologies.

Technology Pathway

The LTB platform is designed with a decoupled architecture based on the concept of "module". With the data interfaces properly defined, each module runs its own routines independently and communicates with other modules through data streaming. Modules are categorized into four categories based on functionality: grid simulators, measurement devices, EMS, and controls. These modules, the underlying communication network, and the large-scale system models make up the LTB system.

Fig. 1 shows the overall architecture and the structural organization in LTB. The CURENT North America systems with 50% wind scenarios are created for different seasons. The grid simulator produces algebraic and state variable data from time-domain integration on a large-scale grid model. The measurement system receives the raw state, imposes measurement errors and delays, and sends the measurements to the state estimator. The state estimator sends the estimated states to control modules for further processing. Control signals from the control modules are sent back to the grid

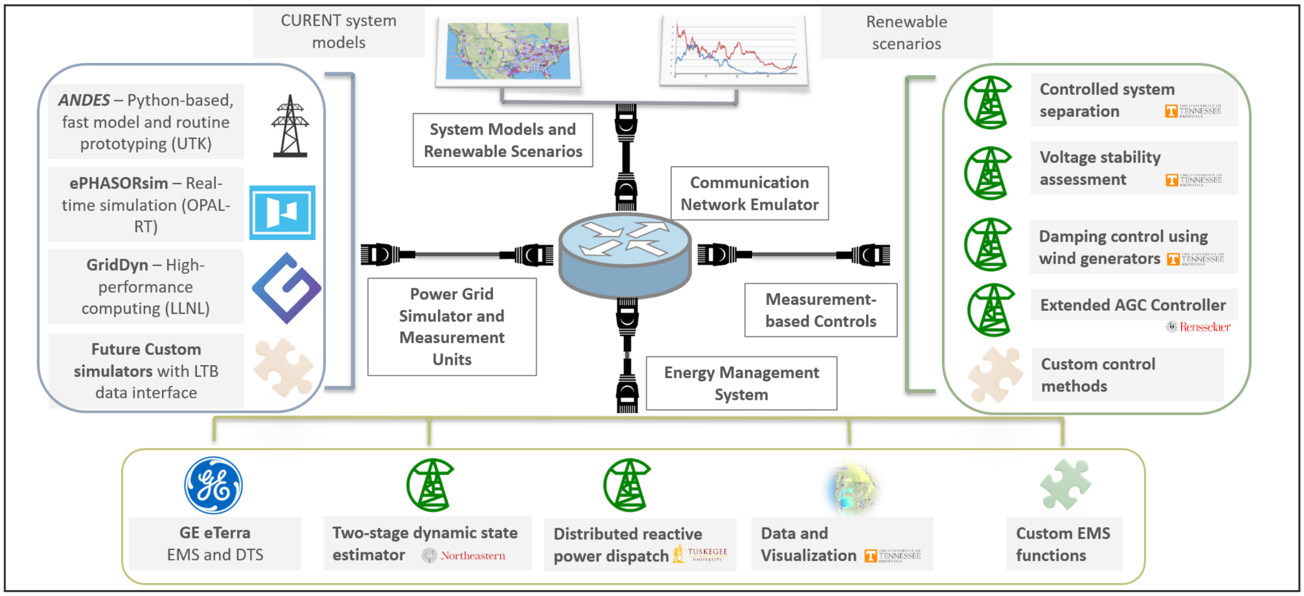

Fig. 1: Overview of the Large-Scale Testbed architecture and components

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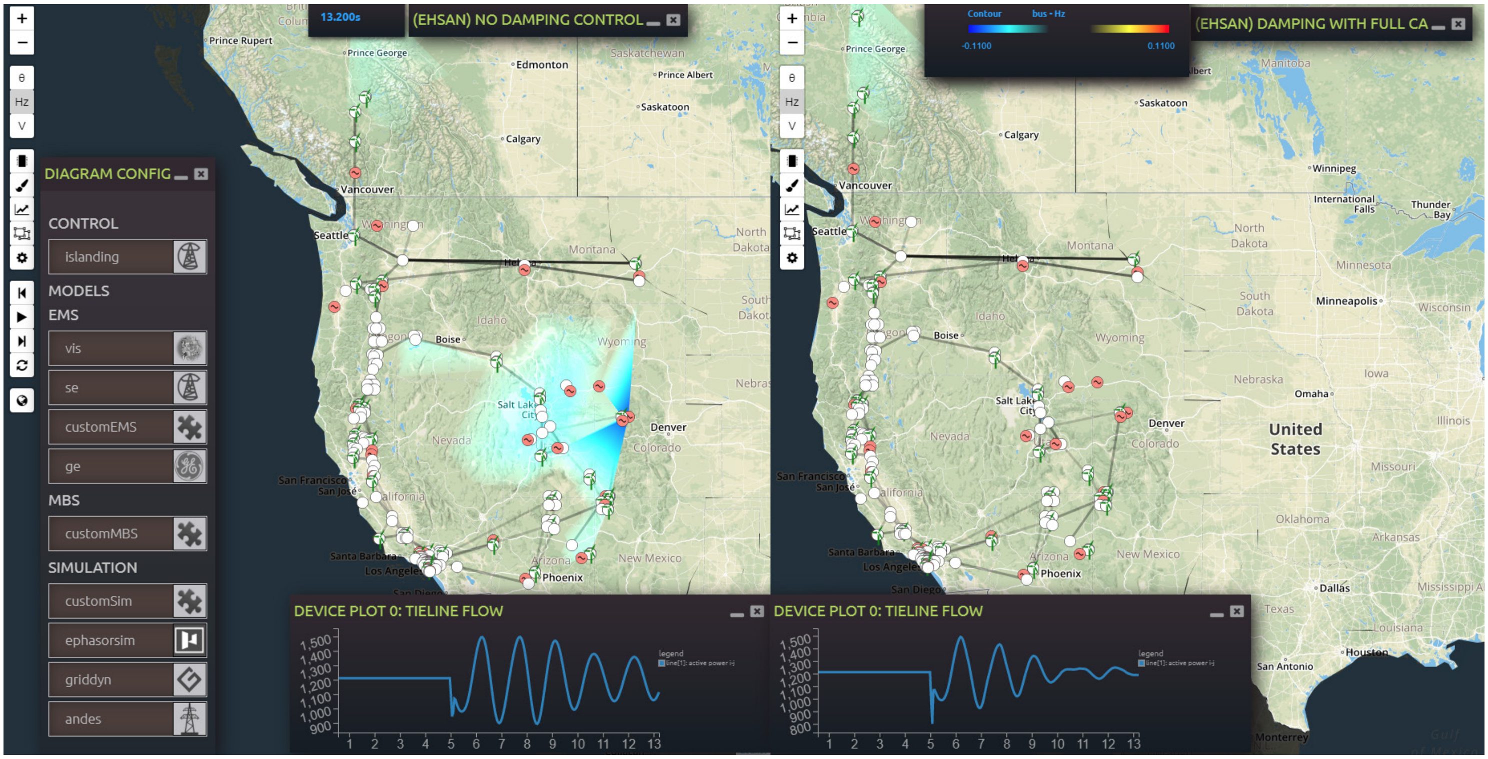

Fig. 2: Visual comparison of the WECC damping control effects

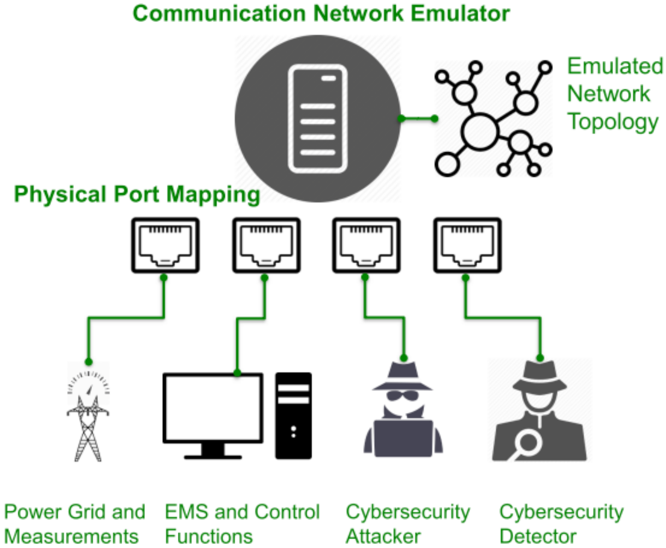

Fig. 3: LTB for cyber-physical event simulation

The control system consists of wide-area measurement-based control methods developed in the CURENT thrusts. Over the years of development, several control methods have been implemented on the LTB, including controlled system separation for the WECC system, voltage stability assessment, damping control and frequency control. The control methods were developed in standalone mode with the simulation data dumped from the simulators. When the methods are mature, they are interfaced to the LTB platform via data streaming, which provides the inputs to the methods are mature, they are interfaced to the LTB platform via data streaming, which provides the inputs to the control methods. Fig. 2 shows a visual comparison of damping control using wind turbines on the WECC system.

LTB also links the emulated communication network to physical network interfaces that enables real-time cyber-attack, attack detection and mitigation simulation, as shown in Fig. 3.

Impact

LTB provides a testing platform to validate and verify new models and control technologies developed in CURENT. It also serves as a driver of research since it allows fast prototyping of new models and grid infrastructures, direct access to simulation and measurement data, and instant feedback of the wide-area control signals. Thus, it is of critical importance to the success of the CURENT research visions.

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