

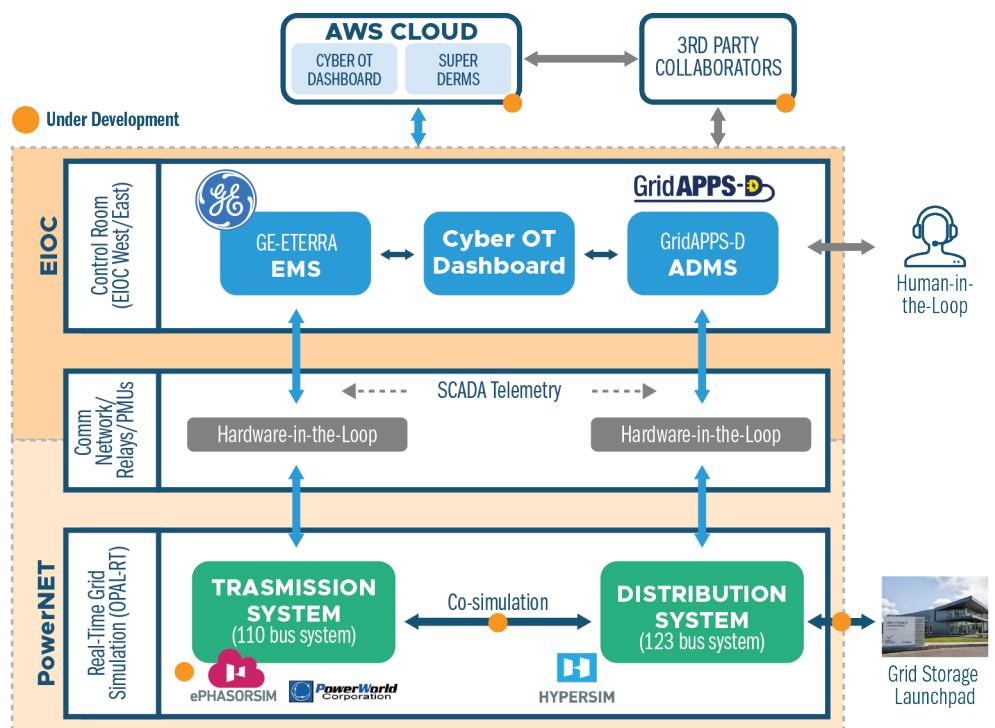
PRIME TESTBED FOR TRANSMISSION AND DISTRIBUTION CO-SIMULATION

The PRIME Testbed brings together synthetic transmission and distribution grids with advanced energy and distribution management systems in a single platform. By combining hardware, software, and human interaction, it enables evaluation of operational strategies spanning the transmission and distribution boundary. PRIME supports real-world simulations and innovative use cases, helping researchers and operators explore and optimize grid operations.

Layered Architecture

- 1. Cloud Applications:** Cloud-based applications can be deployed in the AWS cloud, which can stream data from the control center applications including energy management system (EMS), advanced distribution management system (ADMS), and Operation Technology Cybersecurity Visualization Dashboard (OTVD).
- 2. Control Center:** The control layer can represent a variety of control hierarchies ranging from a distribution utility all the way up to an independent system operator (ISO)-level control center. It also hosts other control center-level applications like the visualization dashboard for OT cybersecurity (OTVD).
- 3. Communication Network:** The hybrid communication network with virtual and real networking capabilities uses cyber and power-hardware-in-the-loop (C-PHIL) components including Relays, PMUs, and RTACs.

- 4. Real-Time Grid Simulation:** PRIME performs transmission and distribution (T&D) system co-simulation using real-time simulators OPAL-RT and PowerWorld Dynamic Studio.



Key Features

- 1. Fidelity:** The real-time T&D co-simulation of the grid models provides high fidelity, with phasor domain simulation at the transmission level and electromagnetic transient (EMT) domain simulation at the distribution level.
- 2. Flexibility:** The simulation tools and the control applications can be chosen from different vendors, making PRIME flexible for a variety of research applications.
- 3. Modularity:** The layered architecture enables modular design of the PRIME Testbed where tools, models, and applications used in each layer can be changed based on compatibility with the interface interactions.
- 4. Scalability:** The T&D models can be scaled up to a few thousands of buses supported by the control applications without losing fidelity.
- 5. Accessibility (under development):** Access to the EIOC by 3rd party collaborators is being accommodated by creation of a master scope of work (master CRADA) that helps streamline the contracting process.

Use-Cases

- 1. Technology Validation and Demonstration:** The PRIME Testbed provides a platform for development, validation, and demonstration of novel tools and technologies across the T&D boundary, providing higher TRLs in addition to generating realistic co-simulation datasets.
- 2. Operator Training:** The EIOC rooms emulate a real-world control center environment with real-time data streaming from the PRIME Testbed, which can serve as a platform for training grid operators, engineers, and cyber analysts at all levels including Distribution, Transmission, Balancing Authorities, and Regional Coordinators.
- 3. Human Factors Testbed:** In addition to technical validation and demonstration, the PRIME testbed allows for human-in-the-loop evaluation of novel tools across the T&D boundary. The real-time data streaming generated by the PRIME Testbed helps create the high fidelity simulated environment required to assess the effects of tool design operator adoption and performance.
- 4. Testbed Federation:** The PRIME testbed can be federated with other testbeds at each layer including cloud applications, control and cyber layer, and hardware-in-the-loop. grid simulation. These include internal (PNNL) and external federations such as with PowerNET Testbed and PNNL-National Laboratory of the Rockies hardware-in-the-loop Testbed Federation.

References

Becejac, T., et al. 2020. "PRIME: a real-time cyber-physical systems testbed." IET Cyber-Physical Systems: Theory & Applications 5(2): 186–195. <https://doi.org/10.1049/iet-cps.2019.0049>



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