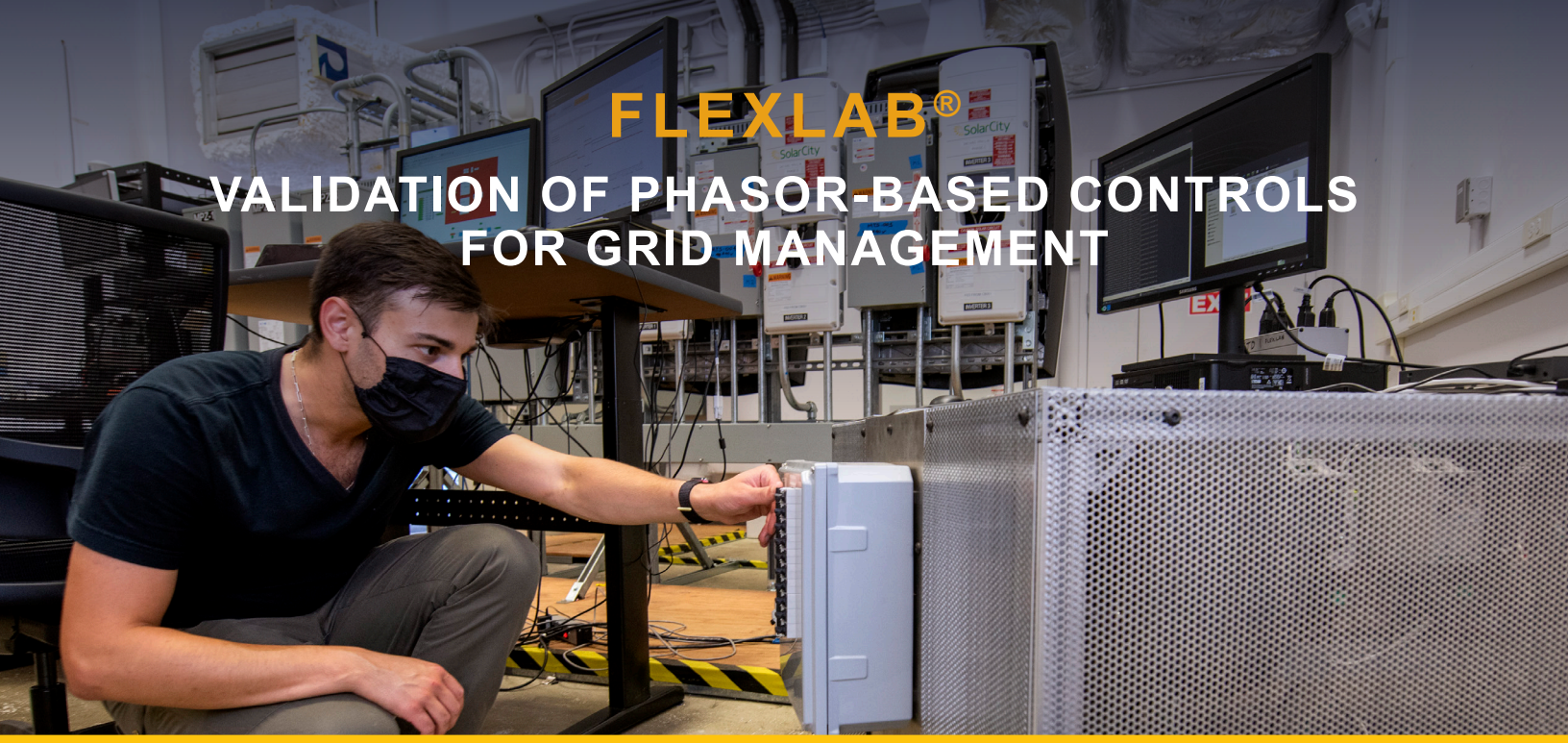

FLEXLAB®

VALIDATION OF PHASOR-BASED CONTROLS FOR GRID MANAGEMENT

This FLEXLAB project demonstrated the ability to use phasor-based controls for more granular control of strategic nodes of the electrical grid.

THE CHALLENGE

Advancing the use of distributed energy resources to improve grid operation

As the use of distributed energy resources (DERs) such as solar photovoltaic (PV), wind power, and battery energy storage systems grows and evolves, they are creating a new paradigm where power flows both to and from the electric power grid. While this advancement creates exciting opportunities for managing electricity, these bi-directional power flows sometimes can result in new grid constraints on grids that were not originally developed for such flows.

THE SOLUTION

Fortunately, DERs can also improve grid operation, by deploying new, more advanced and granular control algorithms to relieve constraints. Flexible phasor-based control (PBC) frameworks can control the voltage phasor (i.e., the voltage magnitude and angle) at strategically chosen nodes of the electrical grid, recruiting DERs to help remedy the problem. The University of California developed such a system and turned to the U.S. Department of Energy's FLEXLAB® facility at Lawrence Berkeley National Laboratory to validate it in a hardware-in-the-loop (HIL) system.

> **"Berkeley Lab's FLEXGRID facility provided a perfect platform to experimentally verify our novel Phasor Based Control scheme for future smart electric grid operations."**

Sascha von Meier, California Institute for Energy and Environment (CIEE), Director of the Electric Grid Research Program

THE BOTTOM LINE

The University of California's PBC system demonstrates successful grid support.

The FLEXLAB test setup was able to coordinate multiple DERs to execute real and reactive power commands. The testbed, including smart inverters, PV and battery systems, controllable loads, and micro-phasor measurement units (μPMU) enabled researchers to encounter and overcome several practical challenges, including real-world control delays of devices and duplication of fast-paced (120 samples per second) μPMU datastreams.

THE EXPERIMENT

- The setup at FLEXLAB allowed comparison and validation of PBC schemes that used different algorithms. It could be remotely configured to be used in all the desired configurations of both sensor and actuator locations.
- Three HIL μPMUs provided measurements at the reference, performance, and actuation nodes. Internal grid simulator switching mechanisms enabled mapping of each μPMU to different nodes of the grid models. A phasor data concentrator (PDC) server forwarded the measurement streams to the PBC controller.
- The experiment considered two types of validation: (i) HIL where physical actuators (a set of fans with variable-frequency drives and three Flexgrid inverters using batteries and PV panels) were controlled, and (ii) a controller-in-the-loop (CIL) setup that bypassed the physical actuators of the setup. In both cases the PBC prototype was connected to the real-time grid simulator over a digital link using MODBUS.
- The experiment evaluated electric distribution models with varying complexity, including a 33 node, 13 node unbalanced, and 13 node balanced models.
- The setup allowed both CIL and HIL experiments in a seamless configuration that featured several grid models, a set of remotely configurable sensors, and up to six separate DERs to act as actuators in a common control scheme, enabling tests in a wide array of scenarios.

THE RESULTS

- Multiple DERs were successfully coordinated to execute real and reactive power commands for tracking phasor setpoints through μPMU measurements.
- A comparison of the software simulations to CIL and HIL tests showed similarly effective performance, with reasonable differences in settling time and amount of noise.
- The test results exhibited effective phasor tracking, where DER actuators and load racks overcome solar PV and load demand variations.
- The CIL setup was used to finalize the development of the controller remotely during the Shelter In Place order during the COVID-19 outbreak.

flexlab.lbl.gov
flexlab.lbl.gov/publications/hardware-loop-benchmarking-setup

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