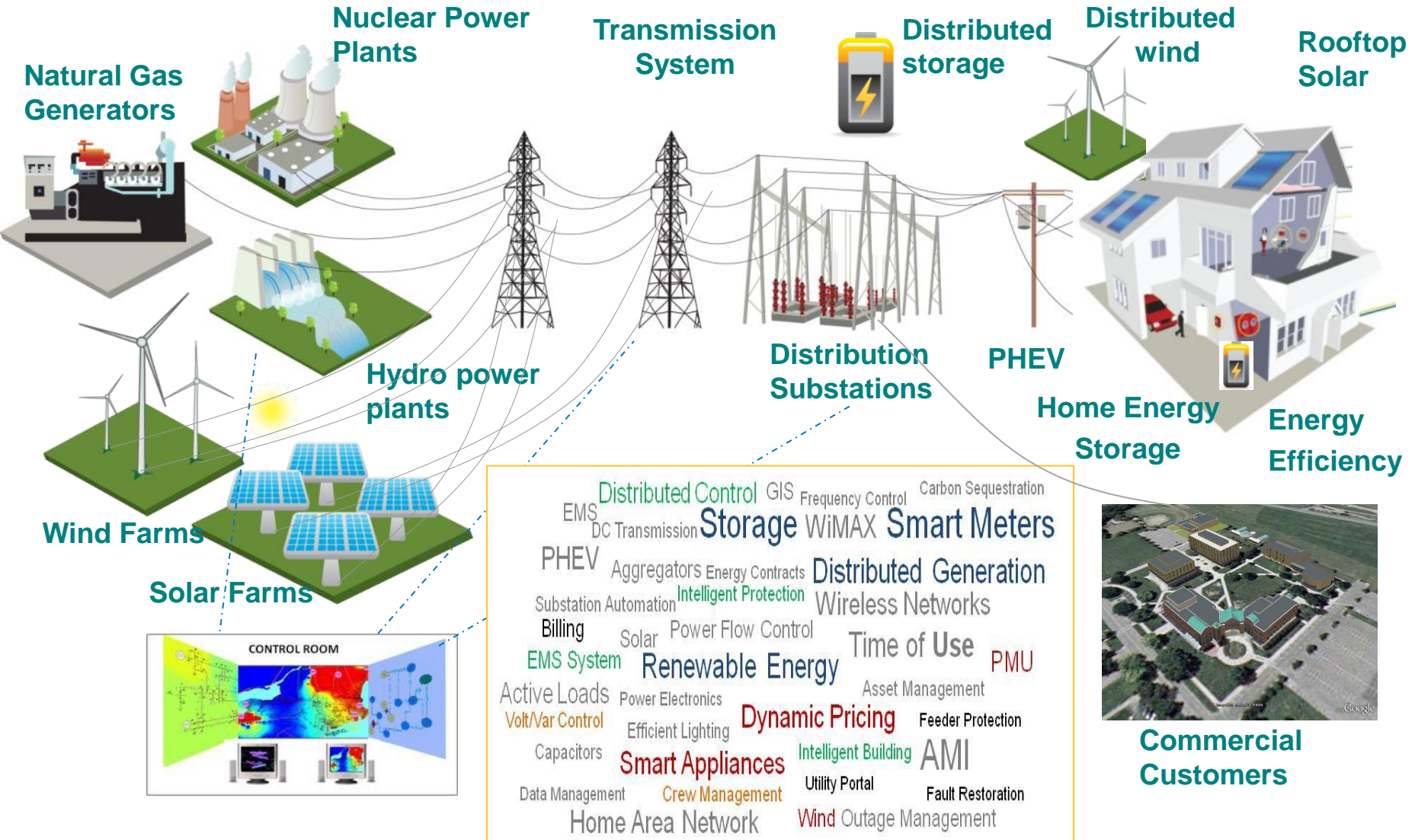


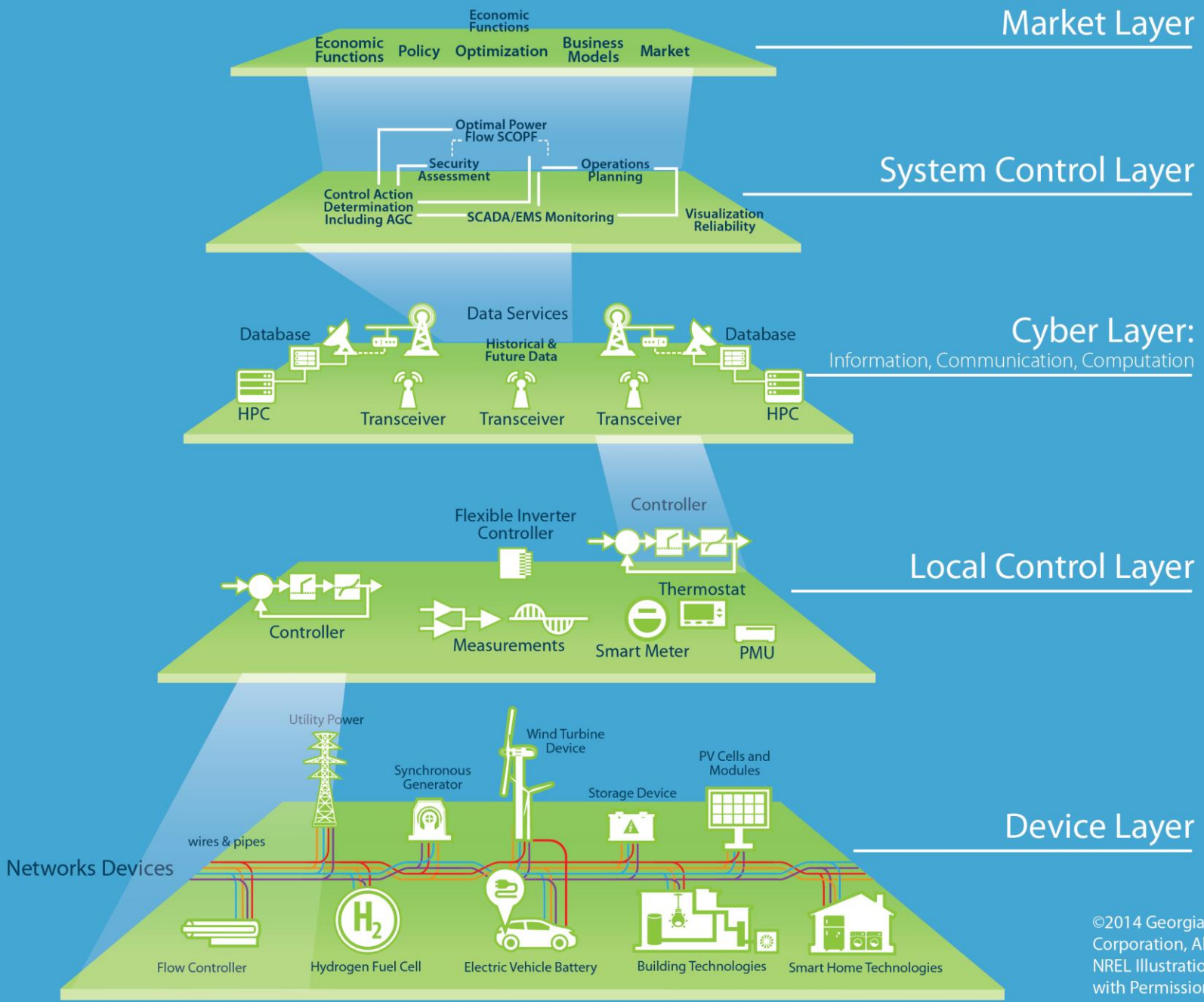
Research in Virtual Oscillator Controls for Microgrids at NREL

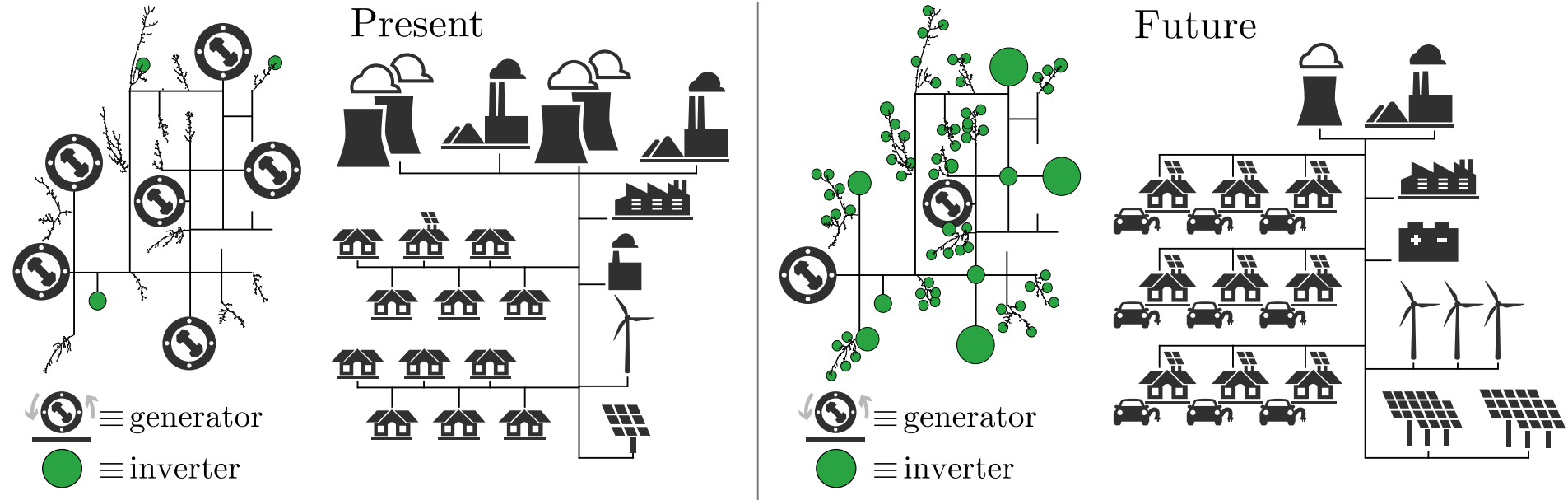


James Cale, Ph.D., Group Manager
Distributed Energy Systems Integration (DESI)
Power Systems Engineering Center
National Renewable Energy Laboratory

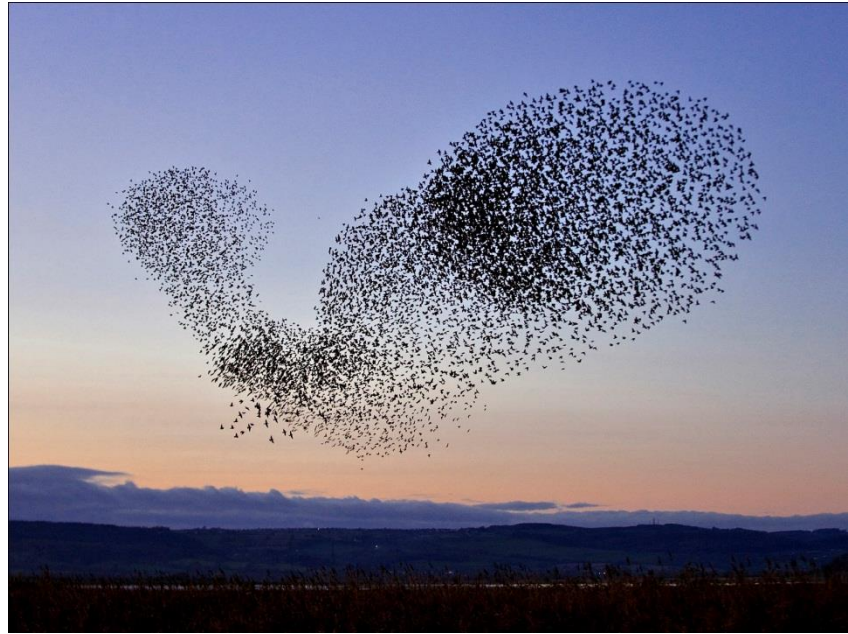
The Emerging Grid







Synchronization in Nature



Control for Distributed Energy Resources

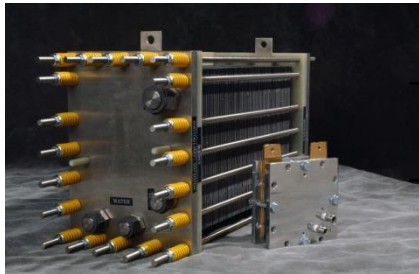
Dc Sources



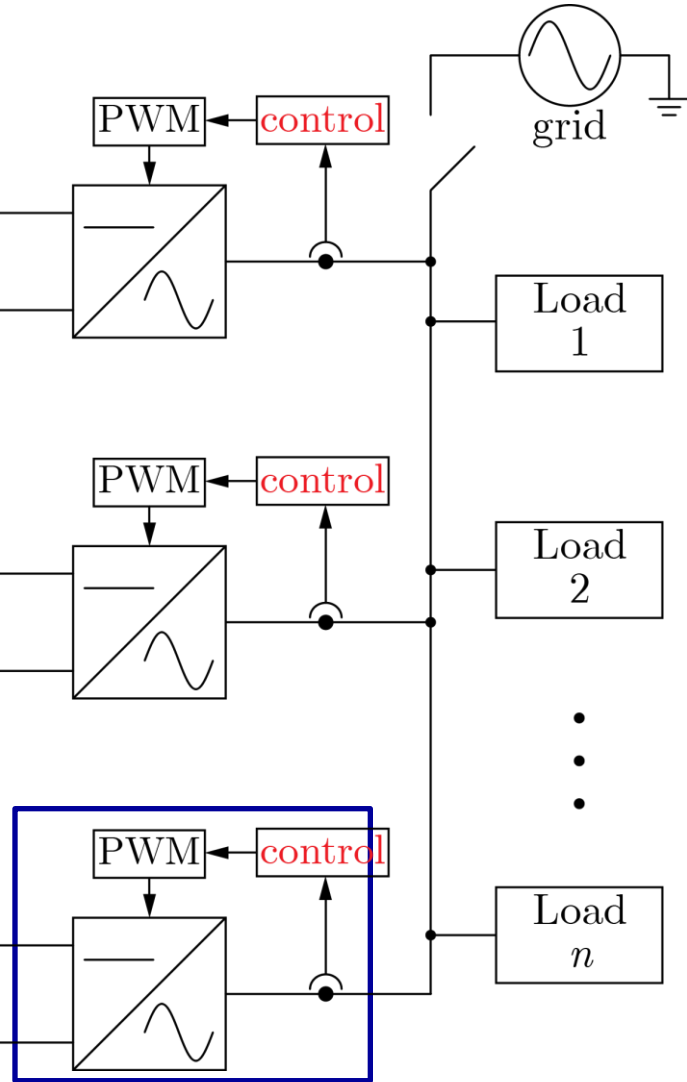
PV



EV Battery



Fuel Cells

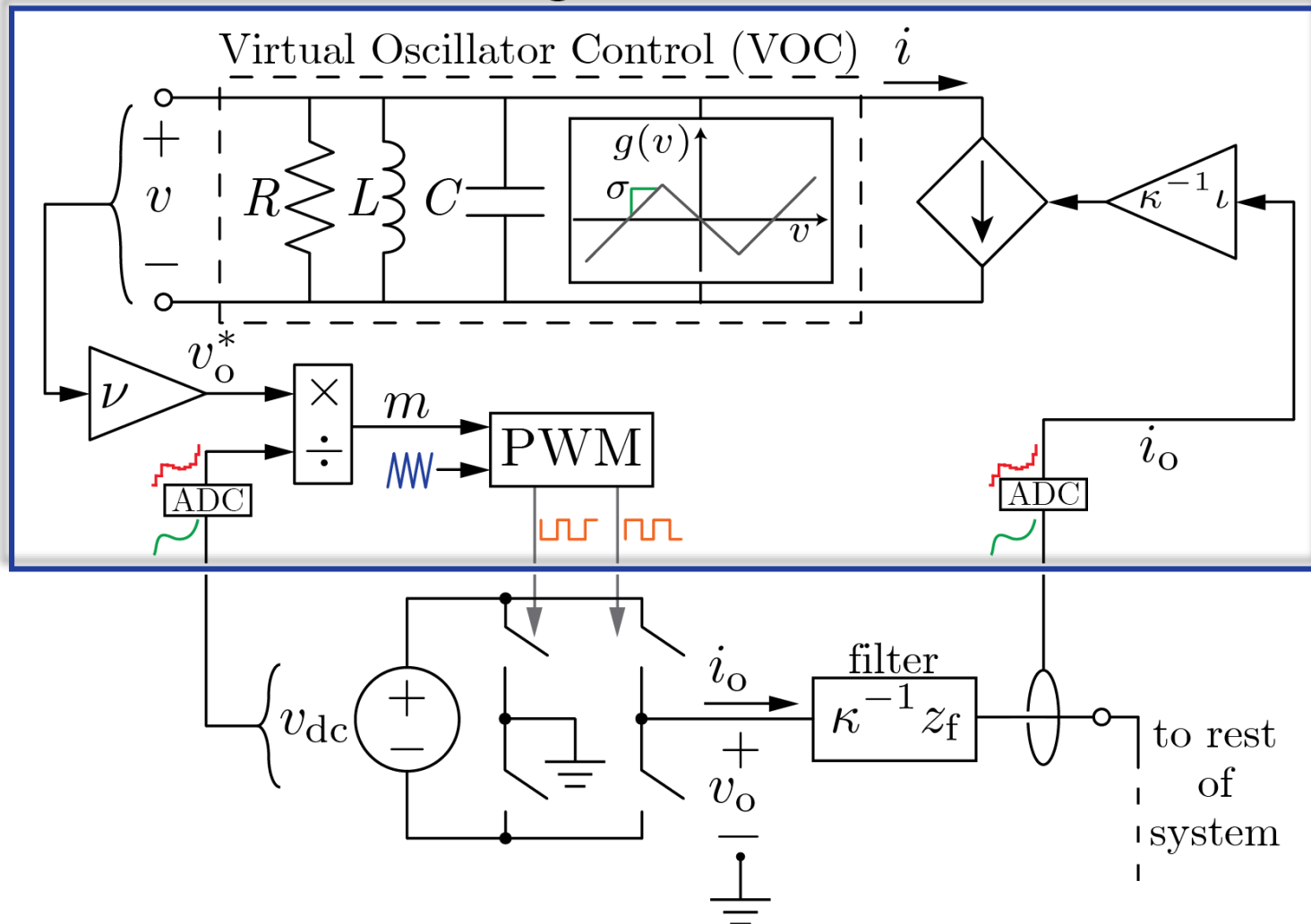


Challenges:

- Low-inertia
- Minimize communication
- Plug and play
- Intermittency
- Reliability
- Multi-mode operation

Building Block:
Inverter

Digital Control

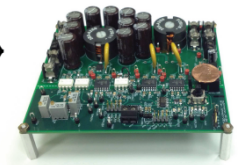


micro-
controller

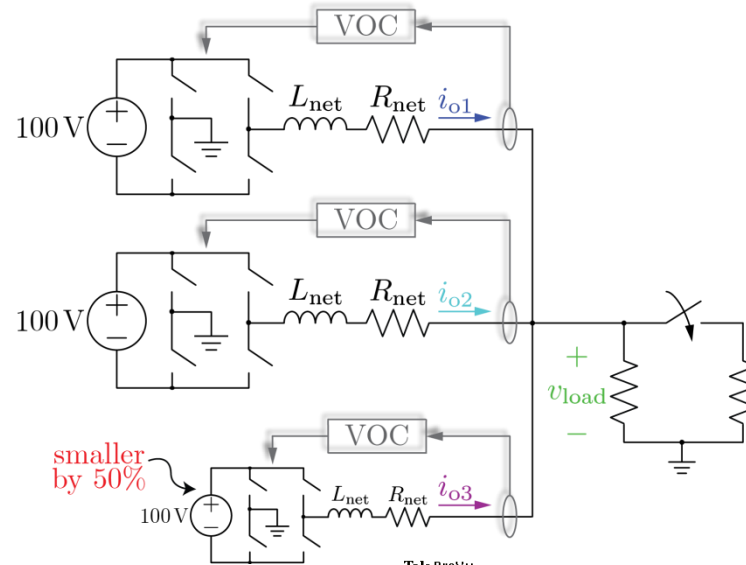


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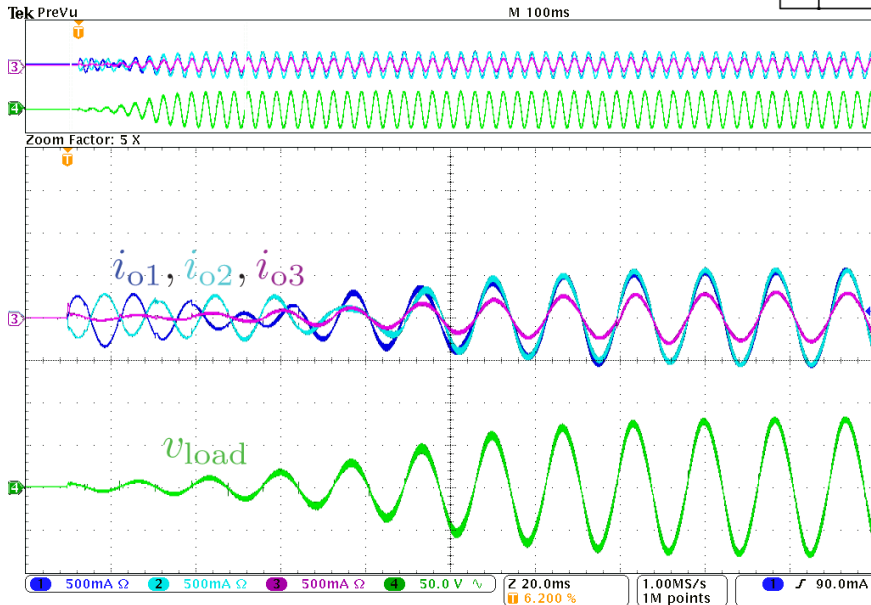
power
electronics



Experimental Results



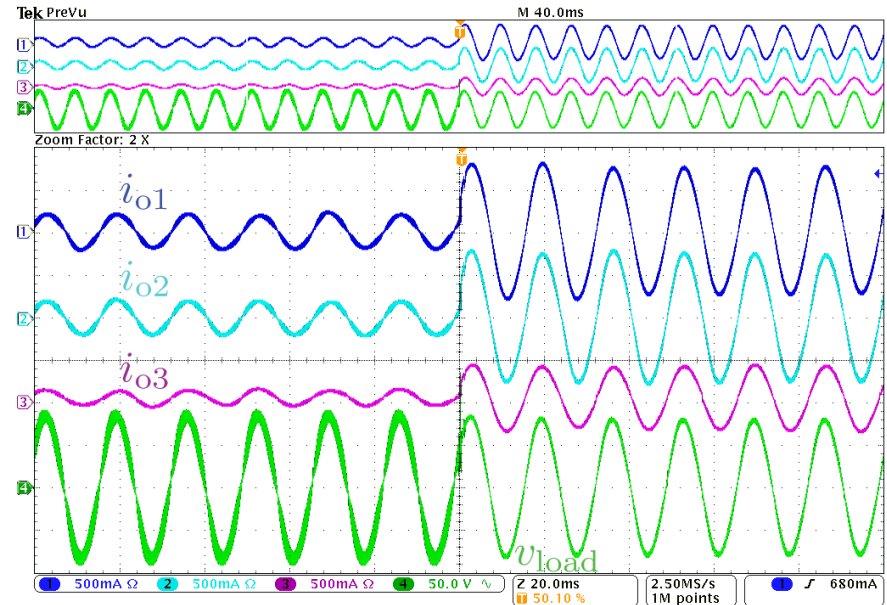
experiment



Startup

14 Dec 2012
10:15:50

experiment



Load Step Up

13 Dec 2012
10:48:17

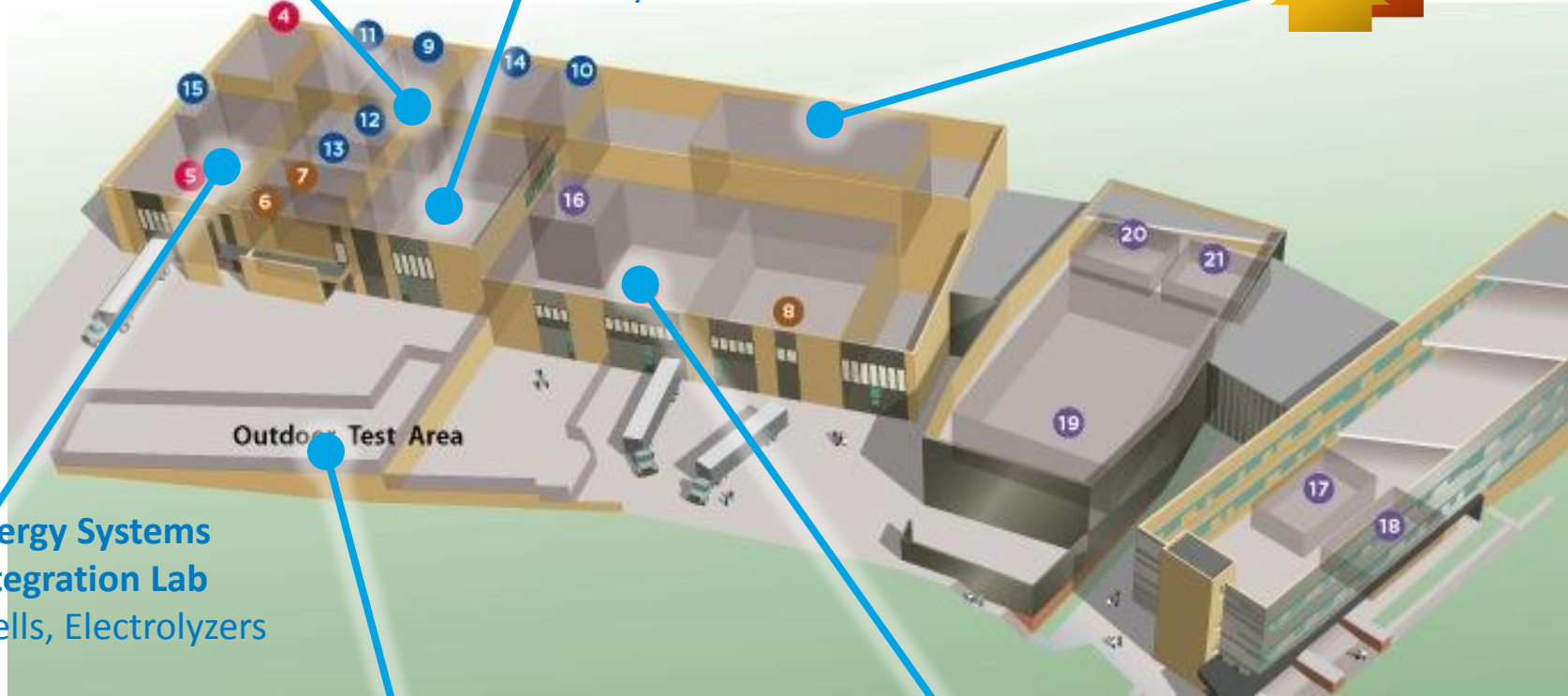
Replication at Scale: Microgrid at ESIF

Rooftop PV & Wind



Energy Storage Lab
Residential, Community
& Grid Battery Storage,
Flywheels & Thermal

Smart Power Lab
Buildings & Loads



Energy Systems
Integration Lab
Fuel Cells, Electrolyzers

Outdoor Test Area

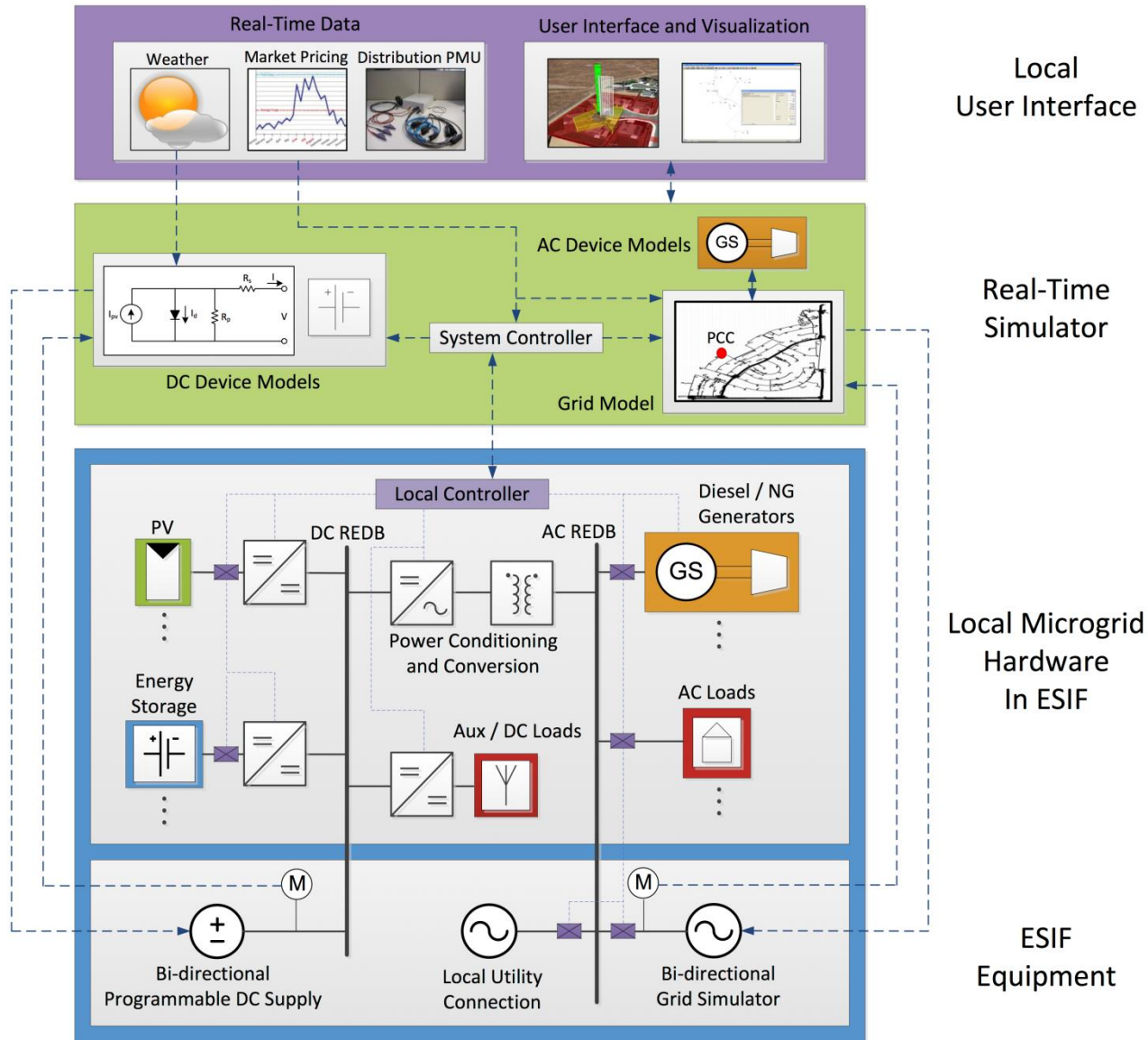
Outdoor Test Area
EVs, Power Transformers



Power Systems
Integration Lab
PV Simulator



MW Scale Hardware-in-the-Loop



Thank You!!

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