Pacific Northwest
NATIONAL LABORATORY

PE@PNNL:
Power Electronics for a Better Future Grid

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U.S. DEPARTMENT OF ENERGY BATTELLE

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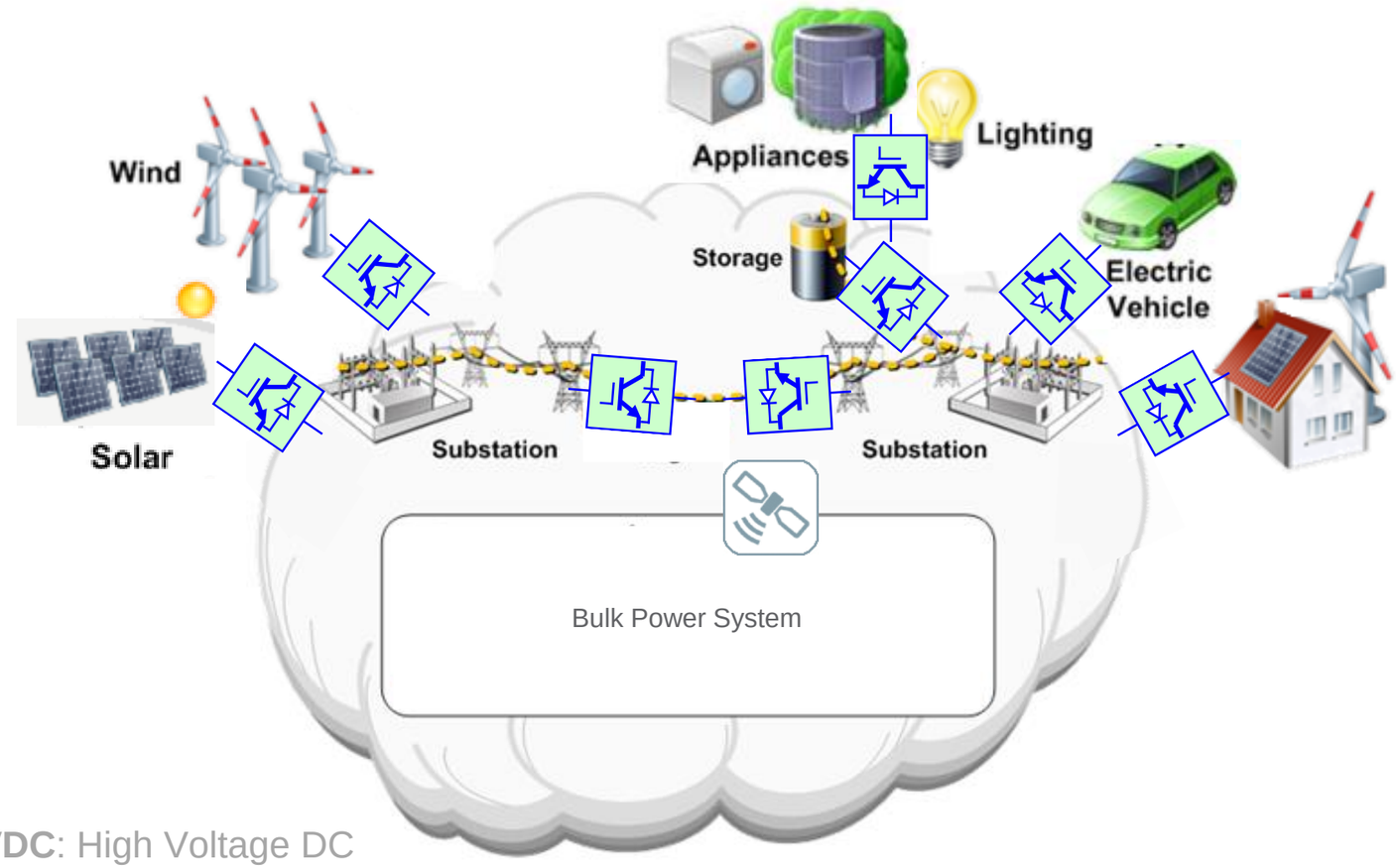
Ubiquitous power electronics at all levels



HVDC: High Voltage DC
MVDC: Medium Voltage DC
LF-HVac: Low-Frequency High Voltage AC
LVDC: Low Voltage DC

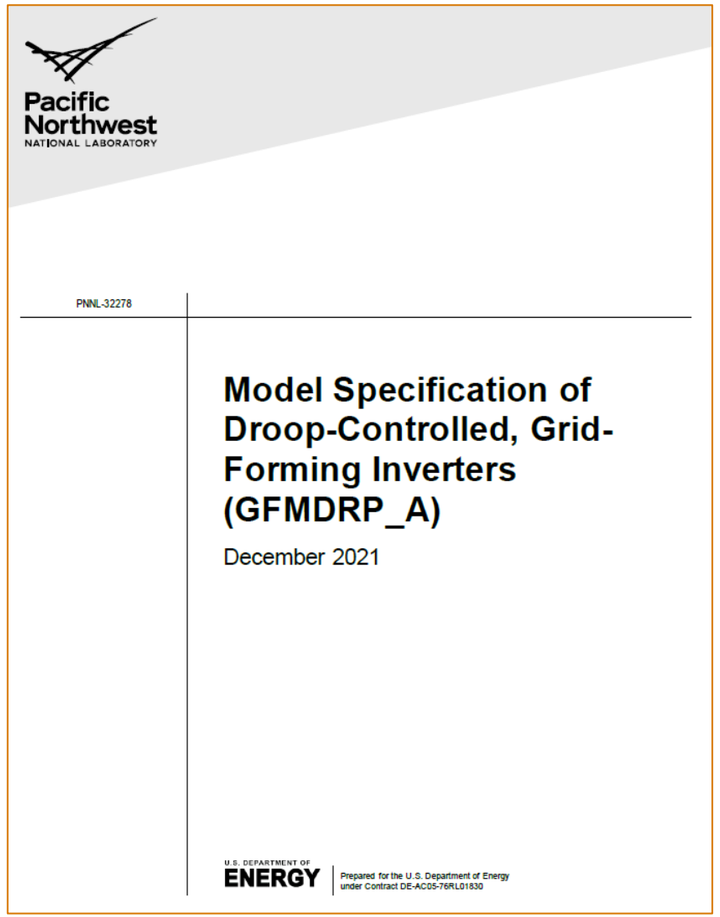
HVDC: National transmission upgrades
MVDC: Offshore wind and regional transmission
LF-HVac: Offshore wind integration and reconductoring
LVDC: Inverters for renewables, EVs, storage, …

Challenge: low inertia ➔ new dynamics ➔ new control

Opportunity: higher controllability and flexibility

WECC adopted the grid-forming inverter model (REGFM_A1) led by PNNL

- Grid-forming inverters are vital for renewables and energy storage to maintain the stability of power grids
- PNNL-developed model specification of droop-controlled, grid-forming inverters was approved by WECC [1]
- This is the first grid-forming inverter model spec adopted by WECC
- *The beta version of REGFM_A1 model has been included in the model libraries of PSS/E, PSLF, PowerWorld, and TSAT*



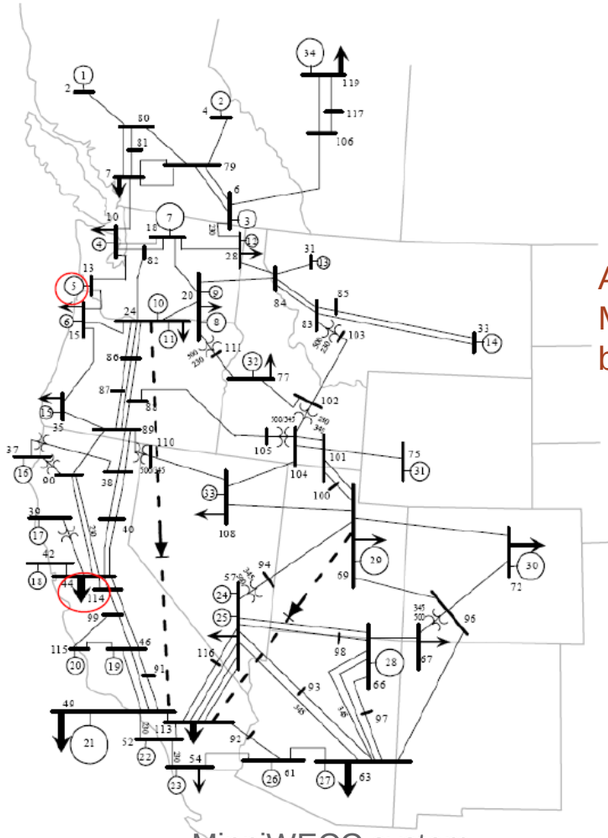
Twittered by Secretary of Energy Jennifer M. Granholm

This work is funded by the UNIFI consortium under the DOE SETO Award Number 38637, the PNNL Laboratory Directed Research and Development (LDRD) Program, and the OE Microgrid program

Integrated T&D Co-Simulation Platform

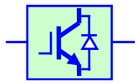
- Developed a T&D co-simulation platform leveraging DOE invested open-source tools GridPACK, HELICS, and GridLAB-D
- System size: ***10,000+ IBRs***, and ***160,000+ nodes***
- The platform can be used to investigate the impact of grid-following (GFL) and grid-forming (GFM) IBRs on the system dynamic stability at any penetration levels (up to 100%)

GridPACK™ + HELICS + GridLAB-D

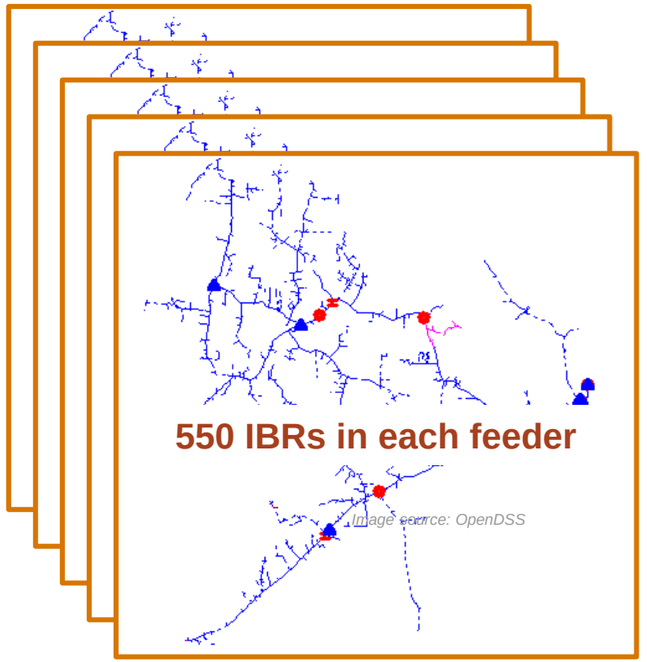


MinniWECC system

All 19 load buses of the MinniWECC system are replaced by detailed feeder models



10,000+ IBRs



Modified IEEE 8500-Node Test Feeder

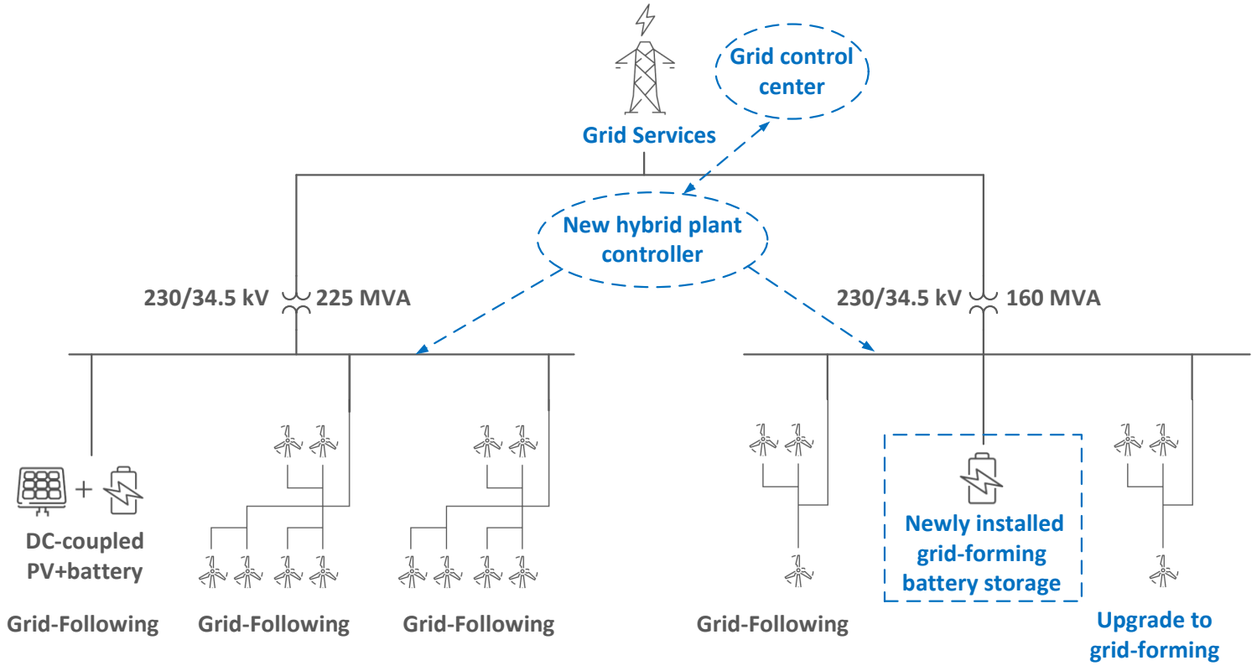
This work is funded by the PNNL Laboratory Directed Research and Development (LDRD) Program.

Yuan Liu, Renke Huang, Wei Du, etc., "*Highly-Scalable Transmission and Distribution Dynamic Co-Simulation with 10,000+ Grid-Following and Grid-Forming Inverters*", in IEEE Transactions on Power Deliver, 2023. (Accepted)

Demonstration of Grid Services by a 380 MW Wind, Solar, and Battery Storage Combined Power Plant

- Wheatridge Renewable Energy Facility is ***North America's first energy center to combine wind, solar, and battery storage in one location***, with 300 MW of wind, 50 MW of solar, and 30 MW of energy storage systems
- This will be ***the first time that grid forming IBRs, including both wind and battery storage, are connected to the US bulk power systems,*** and demonstrated at the same site for grid services

380MW Wheatridge wind, solar and battery storage power plant

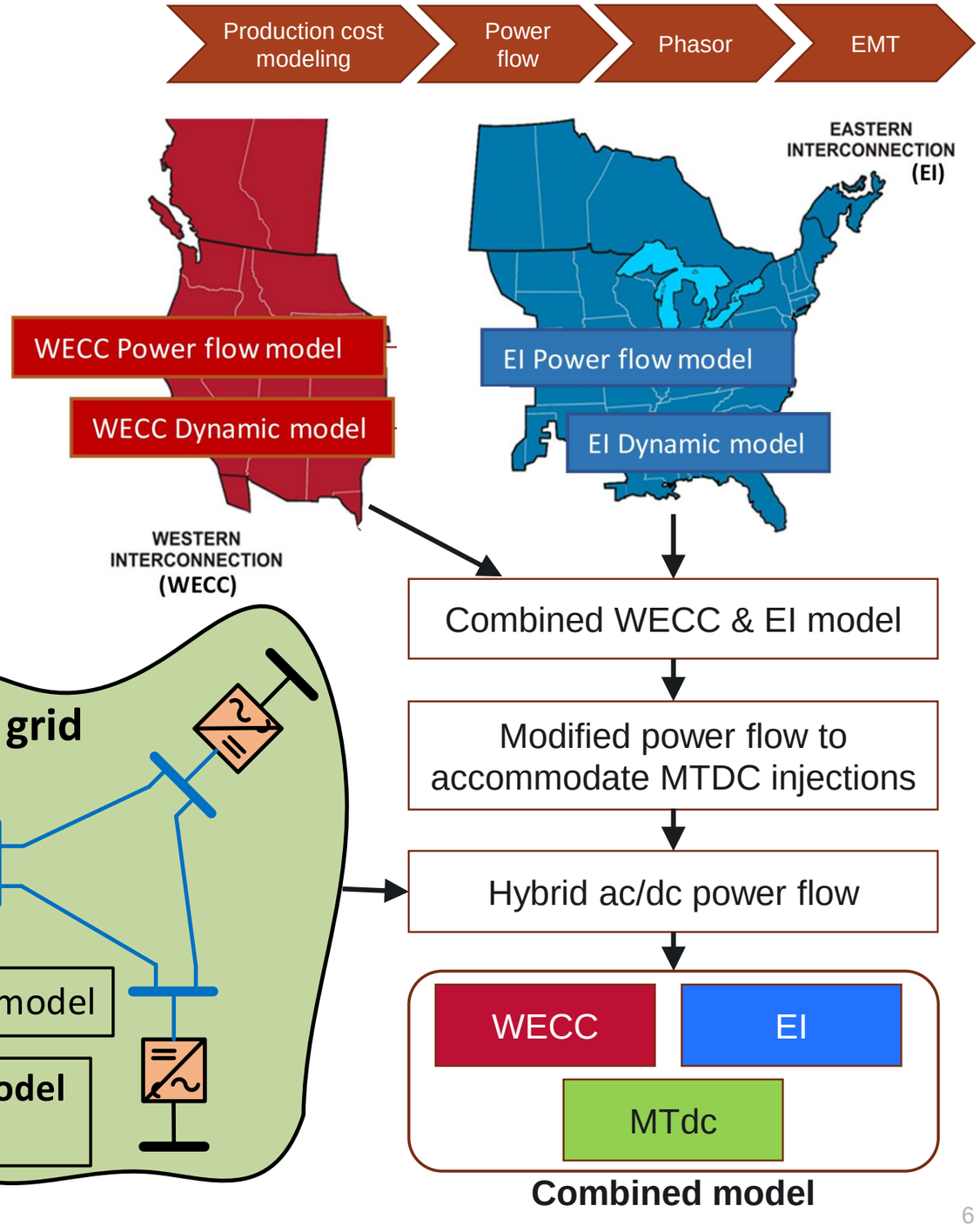


One line diagram

The project is funded by the solar and wind grid services and reliability demonstration funding program by the DOE SETO

Interconnection-level TS Dynamics for HVDC Grids

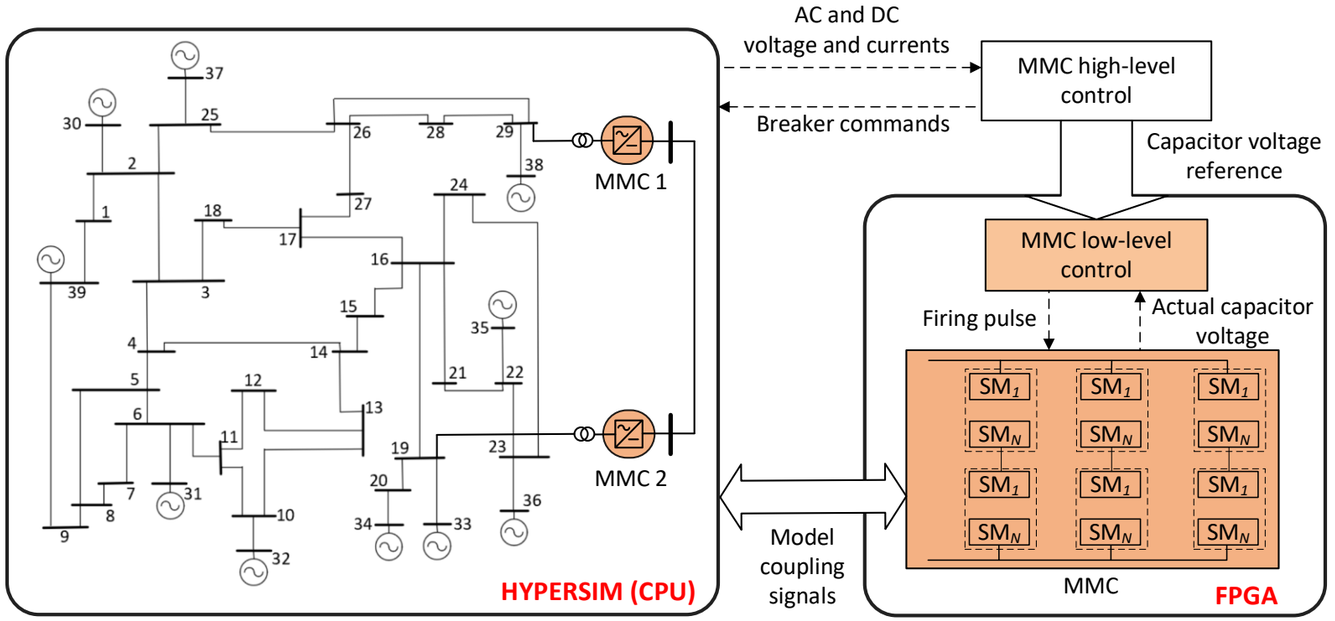
- **Full steady-state and TS model of an MTdc grid at interconnection level**
  - Able to model different MTdc grid topologies (monopolar/bipolar) and number of terminals
  - Flexible to develop and study different converter controls (grid forming, grid following), and grid supporting functions (voltage and frequency support)



This work is funded by the OE TRAC program

Real-Time Simulation/HIL Testing Capability at PNNL

- **Physical Process Emulation**
  - 3 Opal-RT simulators with I/O capabilities
- **SCADA Capability and Automation**
  - SEL RTAC, OPC Server, and support for Modbus, DNP3, and many other protocols
- **Multi-vendor power devices (RTU, relays, meters, microgrid controllers, PMUs)**
  - 11 SEL, 7 ABB, 5 GE, 4 Siemens, and 3 others
- ***Newly purchased HVDC MMC emulators***
  - *Currently allow simulation of a two-terminal HVDC system with each value having 256 units*
  - *Will further expand for a multi-terminal HVDC system in the next year*



Grid simulator

HVDC MMC extended box

Real-Time Simulation Platform for MTDC

We need a national scale hybrid platform to study power electronics at all levels

This work is supported by the Energy System Co-Design with Multiple Objectives and Power Electronics (E-COMP) Initiative, the Resilience Through Data-Driven, Intelligently Designed Control (RD2C) Initiative, and other LDRD programs at PNNL

Thank you

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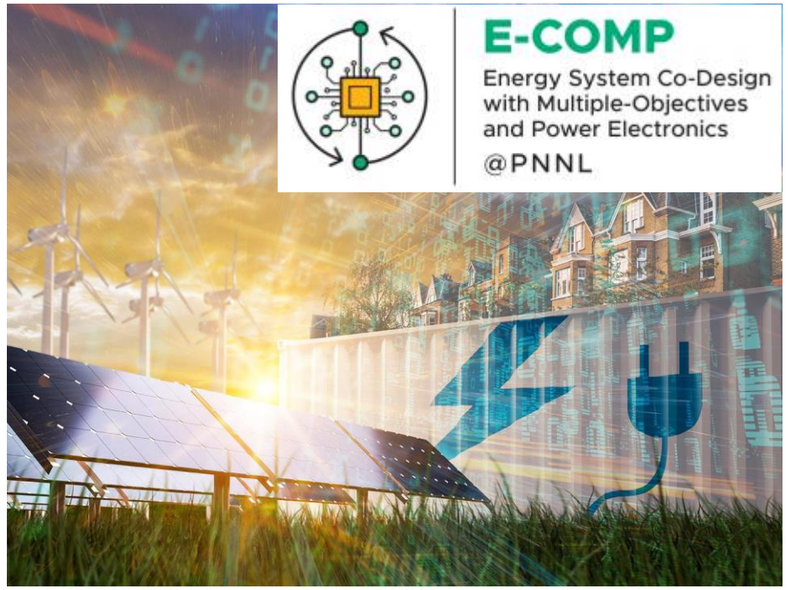
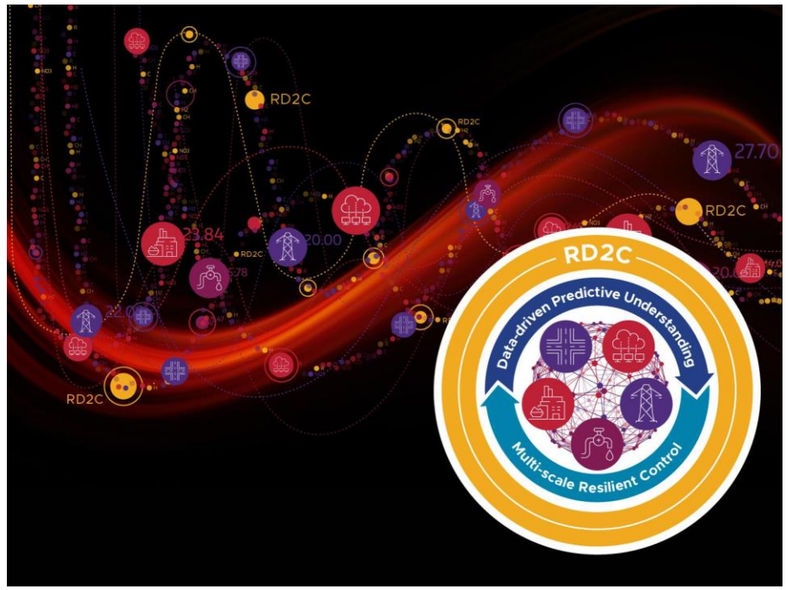
More Information for Ongoing PNNL PE Work

- E-COMP: The Energy System Co-Design with Multiple Objectives and Power Electronics (E-COMP) Initiative
  - Creating new capabilities that enable the optimized design and operation of energy systems subject to multiple objectives and with high levels of power electronic (PEL) driven devices.
- RD2C: Resilience Through Data-Driven, Intelligently Designed Control (RD2C) Initiative
  - advancing scientific understanding of cyber-physical systems and seeking to develop novel sensing and control approaches that will advance the resilience of our critical infrastructures.





[*] PNNL E-COMP Initiative: https://www.pnnl.gov/projects/e-comp
[**] PNNL RD2C Initiative: https://www.pnnl.gov/projects/rd2c-initiative