Pacific Northwest
NATIONAL LABORATORY

Power Electronics for a Better Grid

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2024 Power Electronics & Energy Conversion Workshop
Hosted by Sandia National Laboratories

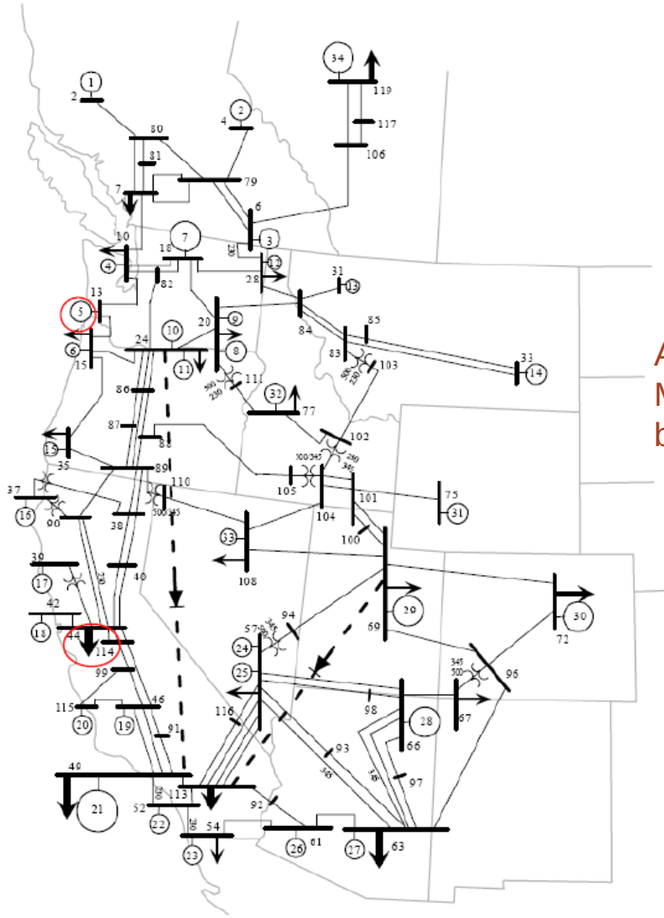
U.S. DEPARTMENT OF ENERGY BATTELLE

PNNL is operated by Battelle for the U.S. Department of Energy

PNNL Developed Integrated T&D Co-Simulation Platform to Study the Impact of 10,000+ inverters on the System Stability

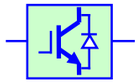
- System size: ***10,000+ inverters*** and ***160,000+ nodes***

GridPACK™ + HELICS + GridLAB-D

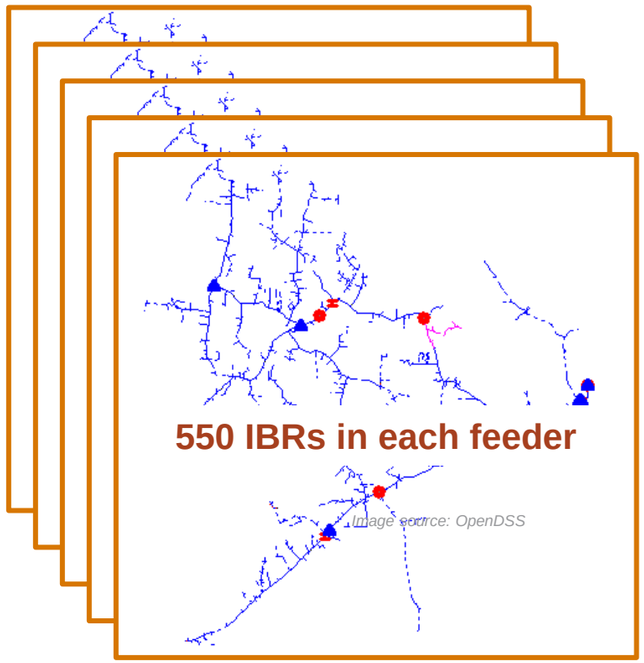


MiniWECC system

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



10,000+ Inverters

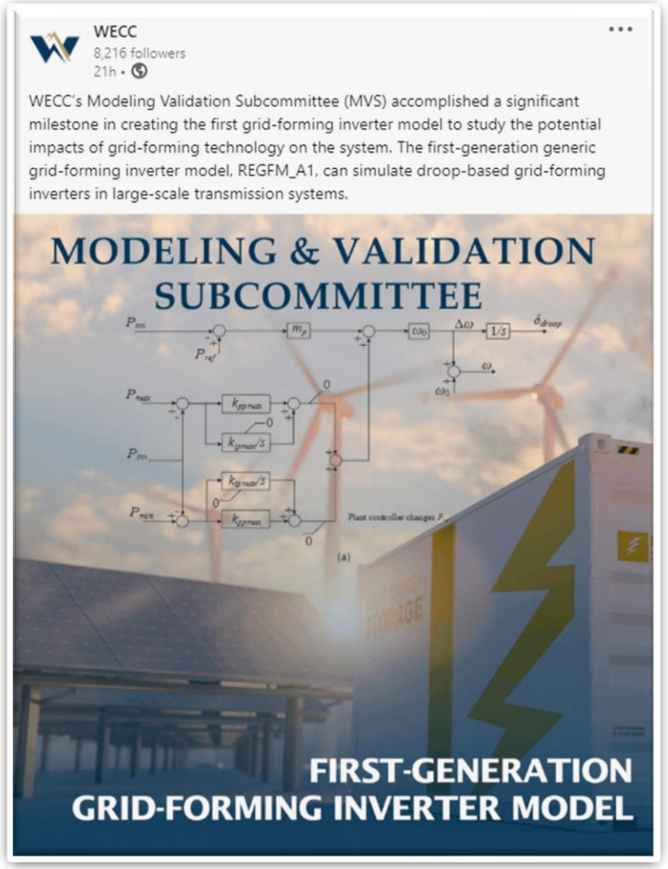


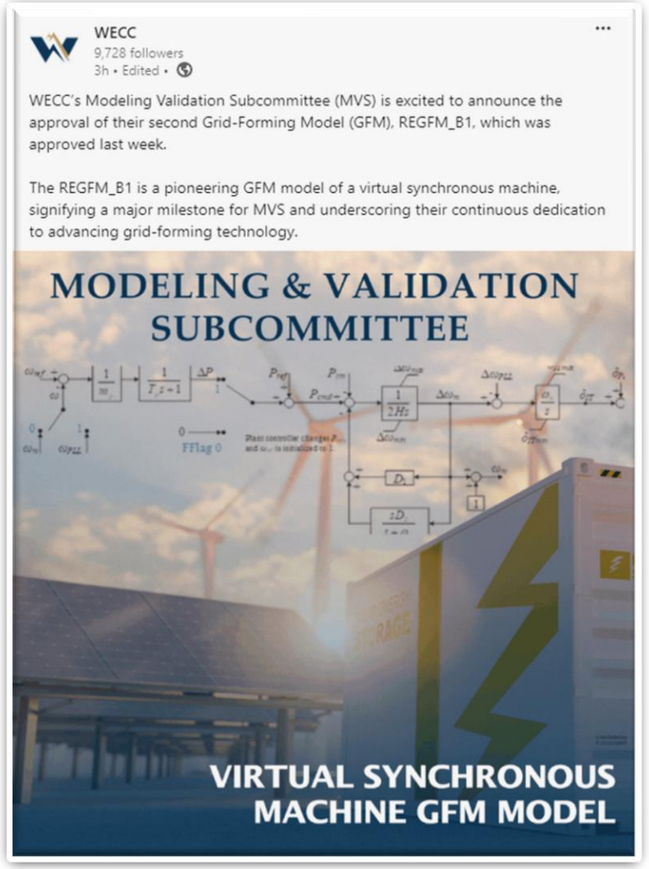
Modified IEEE 8500-Node Test Feeder

[1] Yuan Liu, Renke Huang, Wei Du*, *et al.*, "Highly-Scalable Transmission and Distribution Dynamic Co-Simulation with 10,000+ Grid-Following and Grid-Forming Inverters", in IEEE Transactions on Power Delivery, 2023.

PNNL is a Part of UNIFI Grid-Forming Consortium and Developed WECC-Approved Standard Library Grid-Forming Inverter Models

- The WECC Modeling and Validation Subcommittee (MVS) recently approved two GFM models: ***REGFM_A1*** (*approved on 9/27/2023*) and ***REGFM_B1*** (*approved on 5/23/2024*) proposed by UNIFI members
- These models represent two mainstream GFM controls used in industry: ***droop control*** and ***virtual synchronous machine control***
- These two models become the first generation of WECC-approved GFM models, and have been integrated into the simulation tools used by transmission planners worldwide, including PSS/E, PSLF, PowerWorld, and TSAT

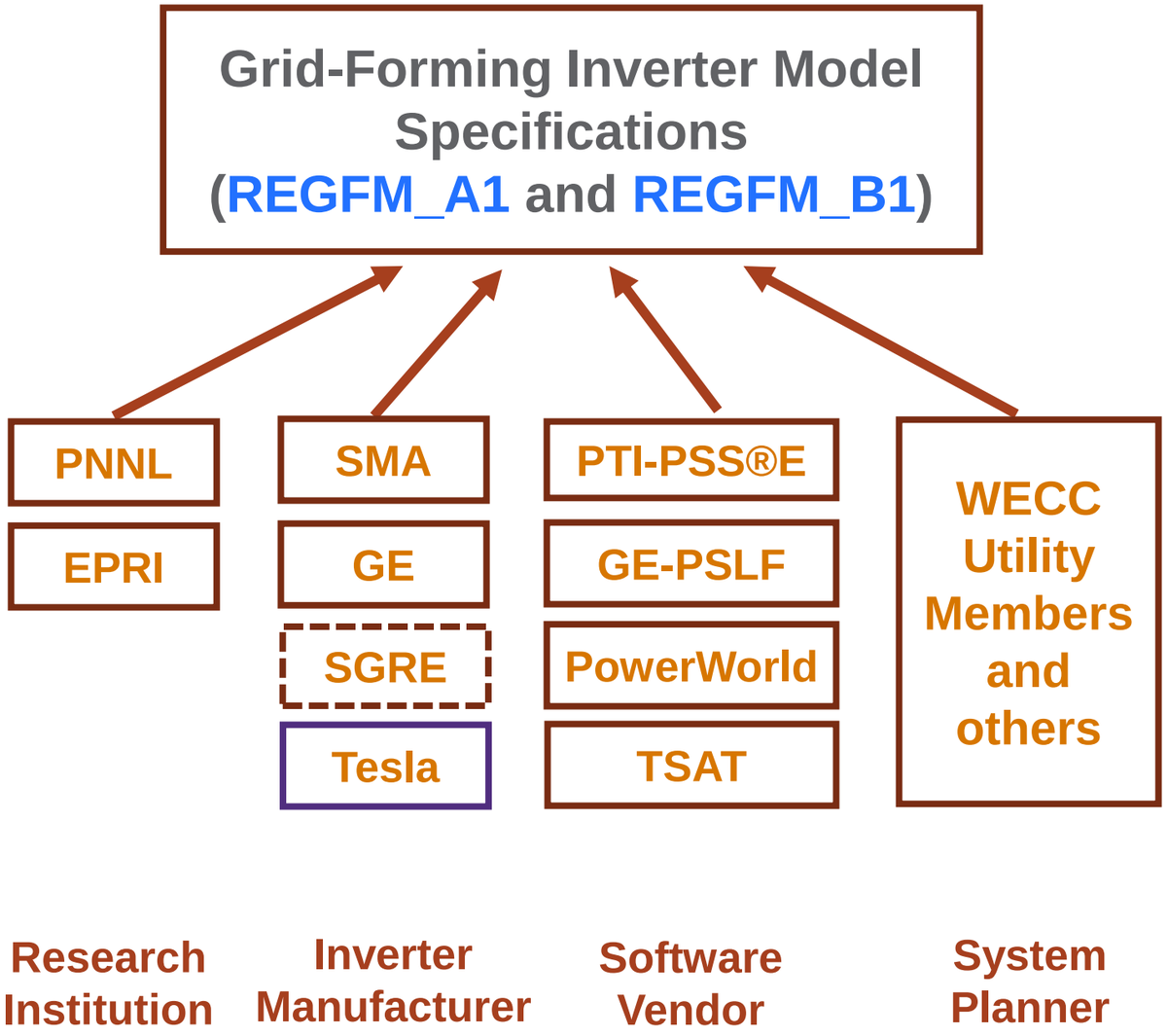




WECC Announcements of REGFM_A1 and REGFM_B1 Model Approvals

This work is funded by the UNIFI consortium under the DOE SETO Award Number 38637

PNNL Continues Leading Standard Library Grid-Forming Inverter Models Development in Collaboration with Industry Partners under UNIFI

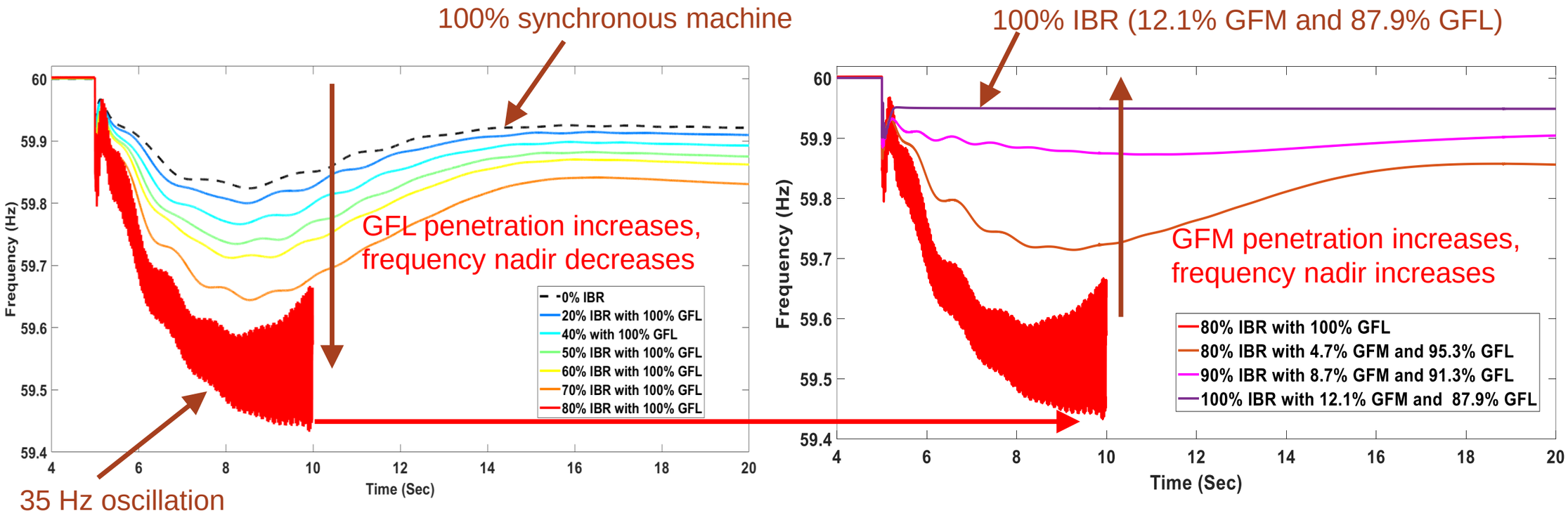


PNNL bridges the gap between utilities and inverter manufacturers for addressing challenges of low-inertia systems

This work is funded by the UNIFI consortium under the DOE SETO Award Number 38637

Grid-Forming Inverters Improve the Frequency Response of Power Grids

- As the penetration level of grid-following inverters (GFLs) keeps increasing in the system, the system frequency response becomes worse, and the system eventually becomes unstable
- As the penetration level of grid-forming inverters (GFMs) keeps increasing in the system, the system frequency response is significantly improved

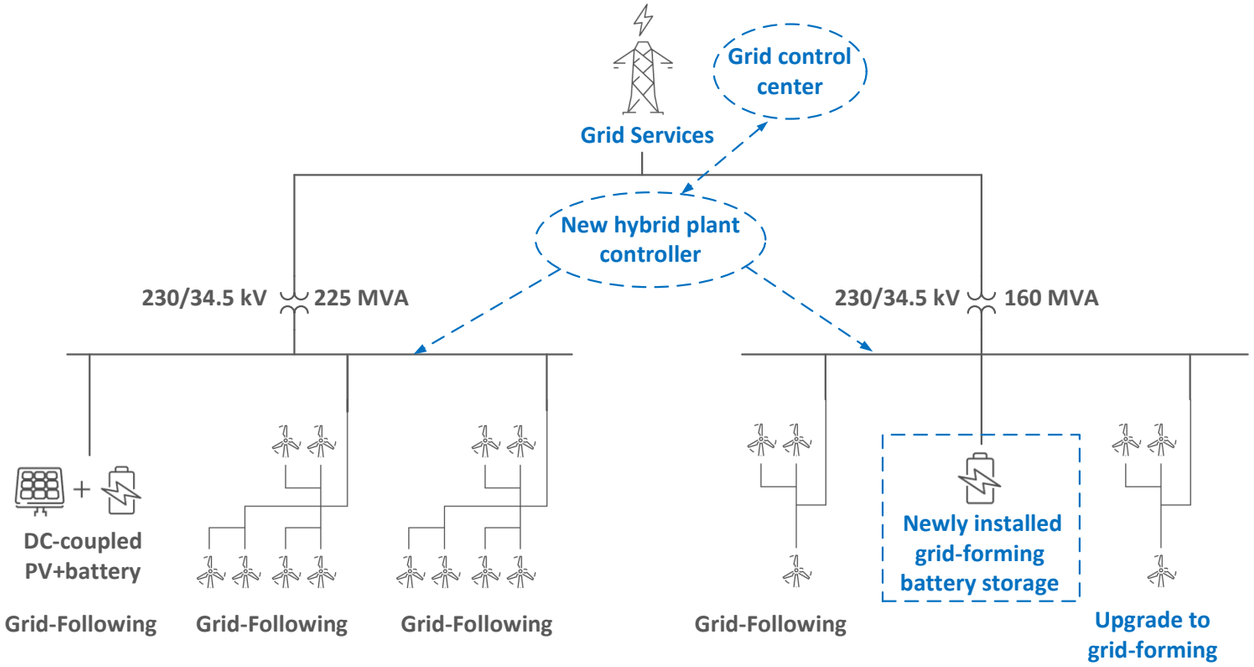


[1] Wei Du*, Frank Tuffner, Kevin Schneider, Robert Lasseter, *et al*., Modeling of Grid-Forming and Grid-Following Inverters for Dynamic Simulation of Large-Scale Distribution Systems." IEEE Transactions on Power Delivery, 2021
[2] Yuan Liu, Renke Huang, Wei Du*, *et al*., "Highly-Scalable Transmission and Distribution Dynamic Co-Simulation with 10,000+ Grid-Following and Grid-Forming Inverters", in IEEE Transactions on Power Delivery, 2023.

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
- If successful, this will be ***the first time that grid forming inverters, 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

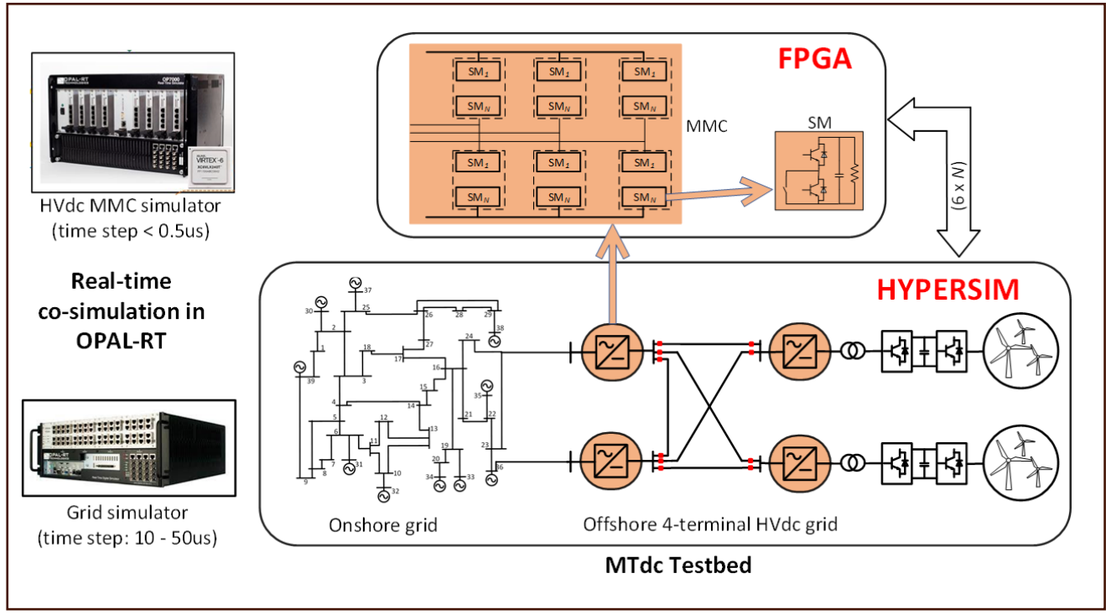
Project Lead

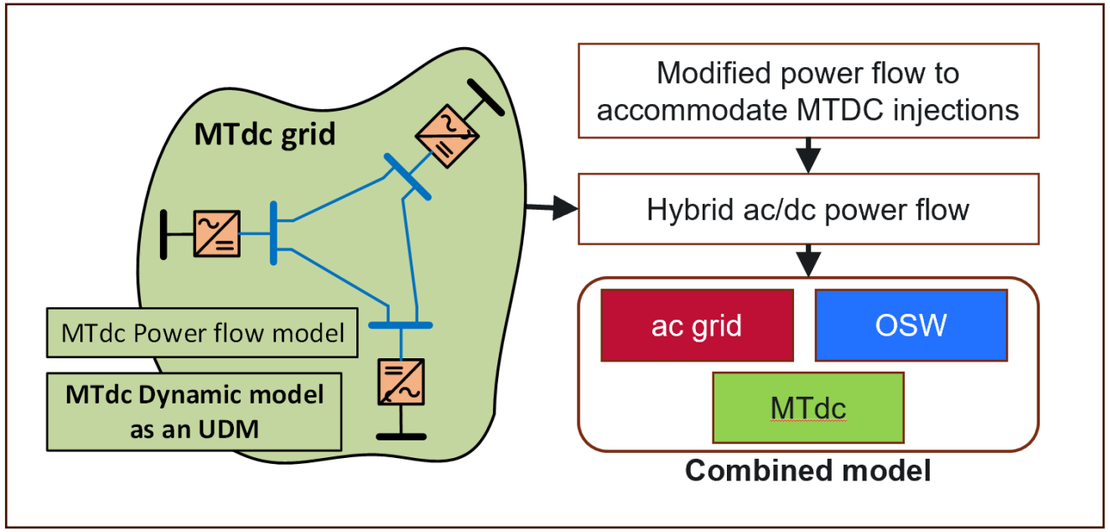
The project is funded by the solar and wind grid services and reliability demonstration funding program under the DOE SETO Award Number EE0010651

Multi-Terminal HVDC for Offshore Wind Planning Studies

- Develop electromagnetic transient multi-terminal HVDC grid for offshore wind integration in real-time simulator OPAL-RT
  - Grid-forming and grid-following control
  - Fault analysis and protection
  - Grid services (black-start, V-f support)

- Develop large-scale steady-state and positive-sequence models of a multi-terminal grid for offshore wind planning study
  - Able to model different multi-terminal HVDC grid topologies (monopolar/bipolar) and any number of terminals
  - Flexible to develop and study different converter controls and grid services





The HVDC work at PNNL is funded by the DOE Office of Electricity, Wind Energy Technology Office, and the PNNL Energy System Co-Design with Multiple Objectives and Power Electronics (E-COMP) Initiative

GMLC Medium Voltage Resource Integration Technologies (MERIT)

National Lab Partners: ORNL(Lead) , NREL (Co-Lead), Sandia, PNNL

- **Technical objective** :design, develop, and demonstrate foundational technologies and capabilities for scalable, modular and cost-effective subsystems and systems and provide performance targets and metrics.

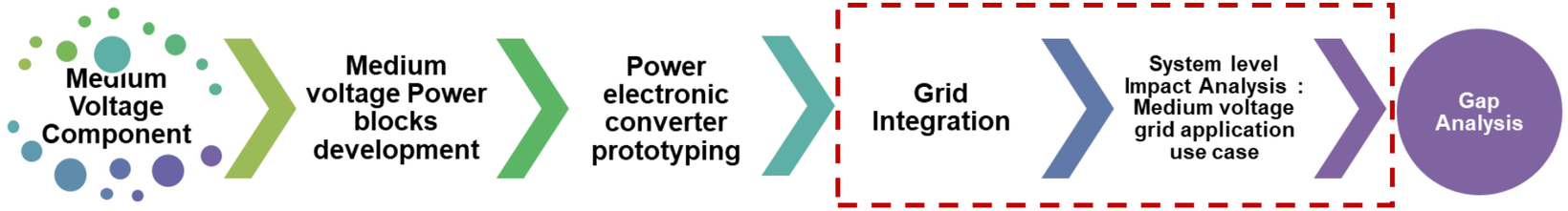
- MV Solid-state transformers have the potential to have significant system-level benefits from the resource integration level to system-control level.

- PNNL is focusing on using high-fidelity modelling platforms and techniques to model MV SSTs, study their control challenges and characterize their system impact, vulnerability and value.

Resources

Advanced Components and Power Stages	Advanced Converter Systems	Resource Integration& Management Systems	Grid Integration and Demonstration@scale
Materials & Components, Embedded Controllers	Power Stages & Sub-System Prototypes	Auxiliary Systems, Software Platforms, Algorithms, System Prototypes	Demo Use Case
VALLEY OF CHALLENGES	VALLEY OF CHALLENGES	VALLEY OF CHALLENGES	VALLEY OF CHALLENGES
Sandia National Laboratories, Wolfspeed, SEMIKRON innovation+service, Microchip, HITACHI	OAK RIDGE National Laboratory, Virginia Tech, University of Colorado Boulder, University of Arkansas, Sandia National Laboratories, Florida State University	OAK RIDGE National Laboratory, Viridi Parente, EATON, NREL Transforming ENERGY	NREL Transforming ENERGY, Pacific Northwest National Laboratory, Southern Company, OPAL-RT TECHNOLOGIES
TRL 2–7	TRL 3–7	TRL 4–7	TRL 5–7
Advanced Components	MV PE Subsystems Inverters converters	Software platforms, Real-time Optimization	**Novel multi-port Medium Voltage PE System: Future pilot**

PNNL



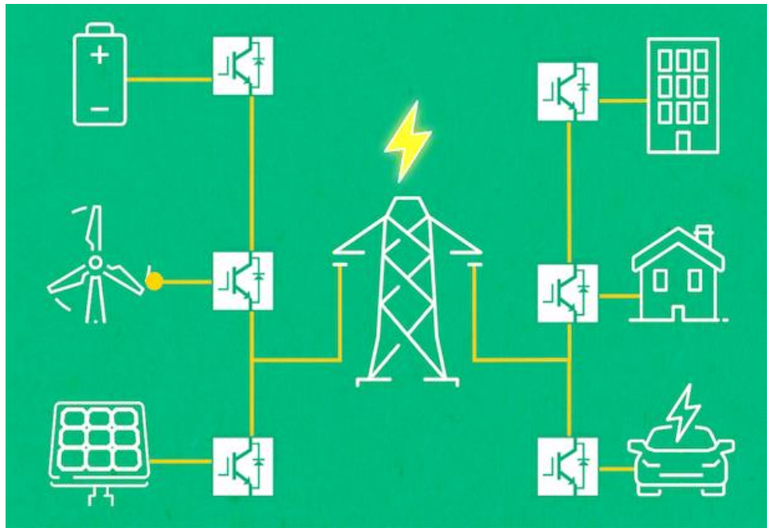
Leverage Existing Technologies: Identify Opportunities & gaps for power electronics systems

PNNL Energy System Co-Design with Multiple Objectives and Power Electronics (E-COMP) Initiative

- The PNNL E-COMP Initiative aims to create new capabilities that enable the optimized design and operation of energy systems subject to multiple objectives and with high levels of power electronics

E-COMP
Energy System Co-Design with Multiple-Objectives and Power Electronics
@PNNL

Energy System of the Future



E-COMP = smart decision making to support the energy system transition

Aspirations

New characterization and modeling to understand the stability of interacting devices and systems.

Co-optimization of design and operation (aka co-design) to meet multiple objectives across multiple time scales.

Multi-entity simulation platform to enable value modeling, energy policy evaluation, and techno-economic approaches for future energy system operation.

Prototypical use cases.

Why PNNL

World class multi-disciplinary capabilities in optimization, controls, power systems engineering, modeling and simulation, energy economics, and computational science.

State-of-the-art test facilities, high performance computing, libraries of data sets, and network of stakeholders

Proven system-level expertise to tackle large-scale problems driving toward affordable, clean, and reliable energy systems

https://www.pnnl.gov/projects/e-comp

Thank you

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