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WECC

MVS GFM Model Development and PGE DOE Project Update

November 14, 2024

Song Wang, MVS Chair

MVS

- Committee Purpose
  - The purpose of the MVS is to review, recommend, develop, and validate system models used to support reliability assessments and other modeling tools that advance the mission of WECC
  - Working with industry experts, academia, and stakeholders to incorporate the latest research and technological advancements into our models
  - Providing guidance and support to the broader community to enhance the understanding and application of power system models

Grid-Forming Inverter Modeling

- There are mainly three types of grid-forming controls: droop control, virtual synchronous machine control, and virtual oscillator control.

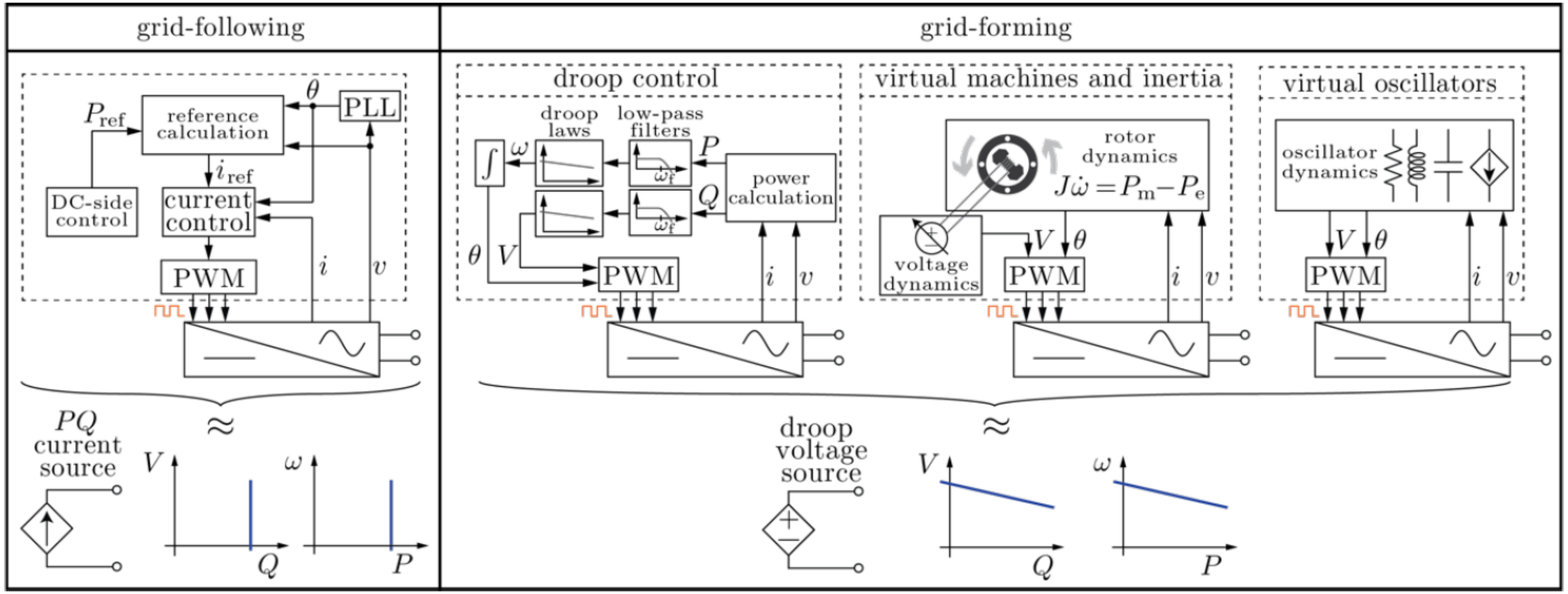


Figure 4. Functional diagrams of grid-following and grid-forming inverters. Grid-following inverters mimic current sources at their output terminals, whereas grid-forming inverters act like voltage sources whose output abides by droop laws.

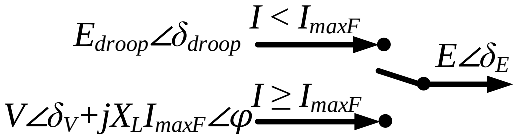
WECC-Approved GFM Models

- These models encompass two prevalent GFM control strategies in the industry: droop control and virtual synchronous machine control
- They mark the first generation of WECC-approved GFM models, now integrated into simulation tools used globally by transmission planners, such as PSS/E, PSLF, PowerWorld, and TSAT

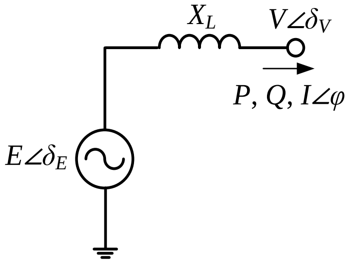
Grid-Forming Inverter Modeling

- Grid-Forming Inverter (REGFM_A1)

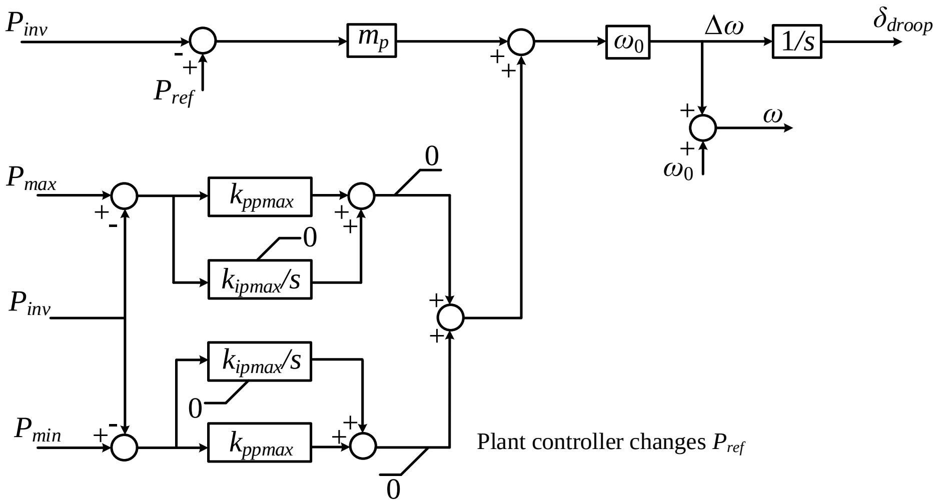
https://www.wecc.org/Reliability/Model%20Specification%20of%20Droop-Controlled%20Grid-Forming%20Inverters-REGFM_A1.pdf



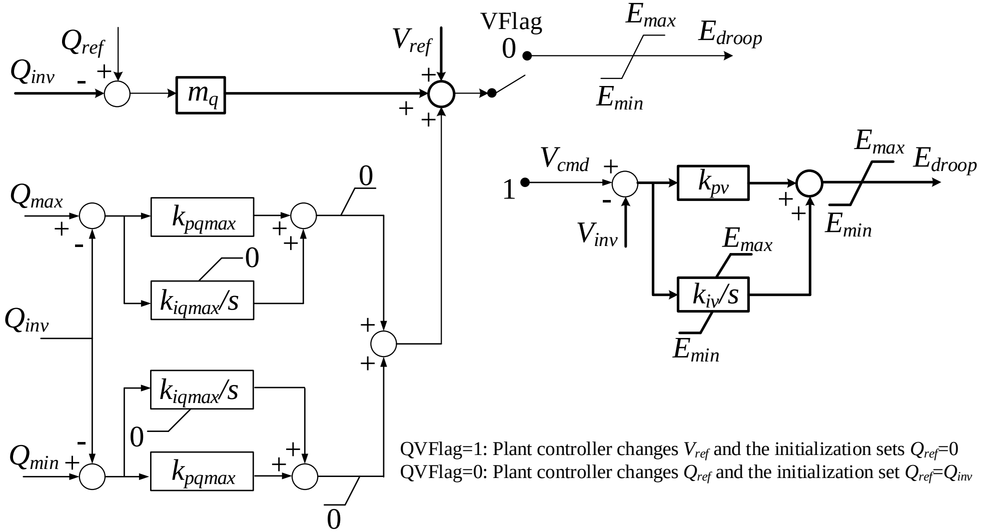
Fault current limiting



Voltage source behind impedance



P-f droop and P Limiting



Q-V droop and Q Limiting

Grid-Forming Inverter Modeling

- Timeline for the REGFM_A1 Model development

2021.12 – Model spec approved (GFMDRP_A)

2021.12 – NREC sent the model spec to GFM OEMs

2022.1 – GFM vendor SMA provided detailed suggestions

2022.5 – Updated model spec to include Q_{max}/Q_{min} control block

2022.9 – Updated model spec to include Vflag

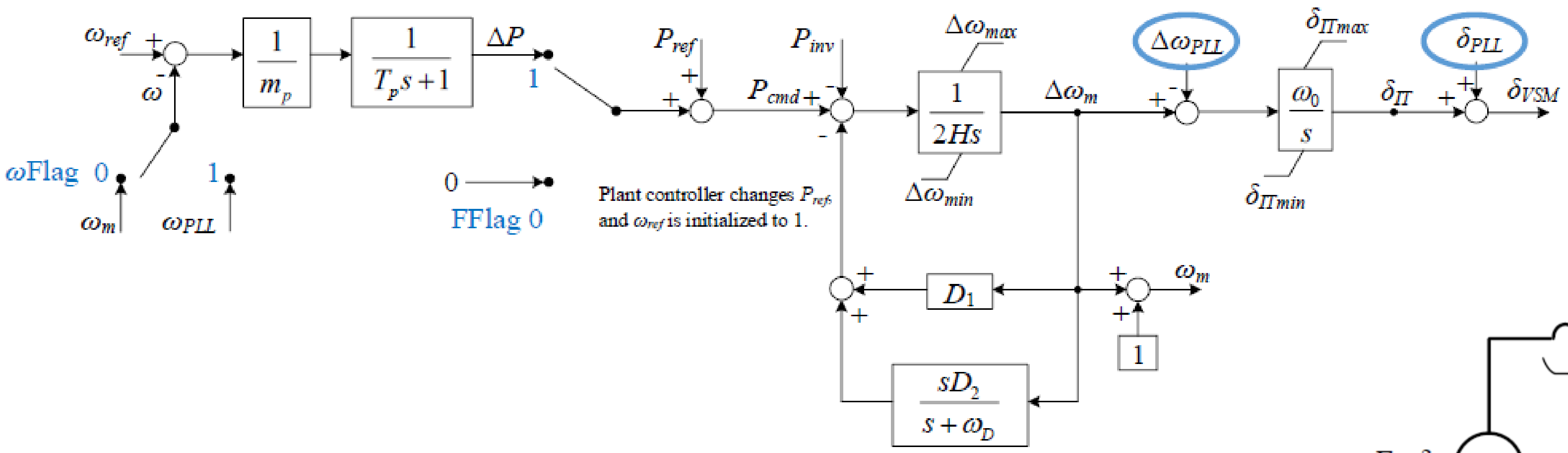
2023.2 – Model renamed to REGFM_A1. Software vendors started to implement

2023.5 – Model benchmarking completed. A few concerns were raised at MVS meeting.

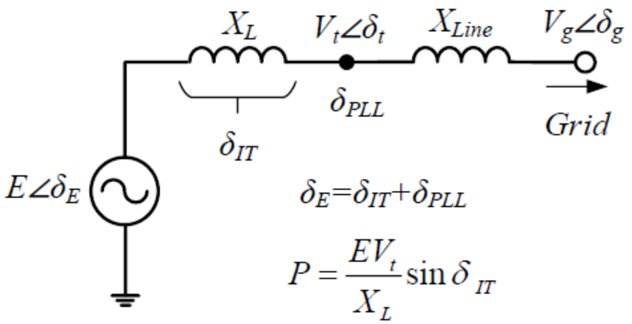
2023.9 – REGFM_A1 approved.

Grid-Forming Inverter Modeling

- Grid-Forming Inverter (REGFM_B1)



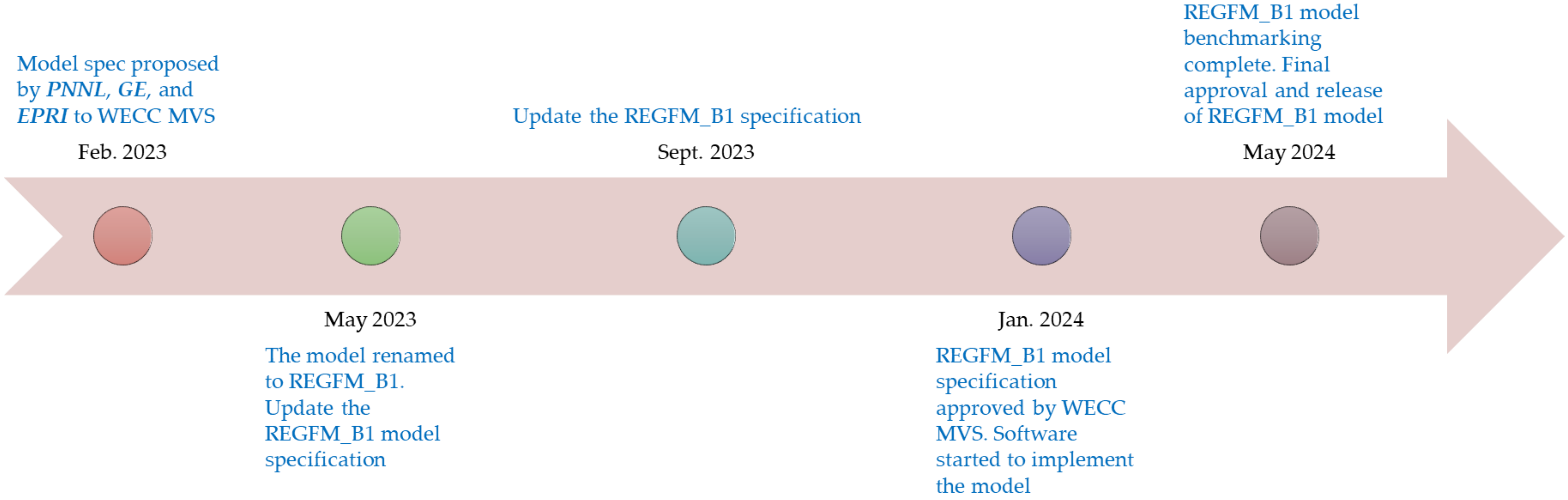
VSM/inertial control block



Voltage source behind impedance

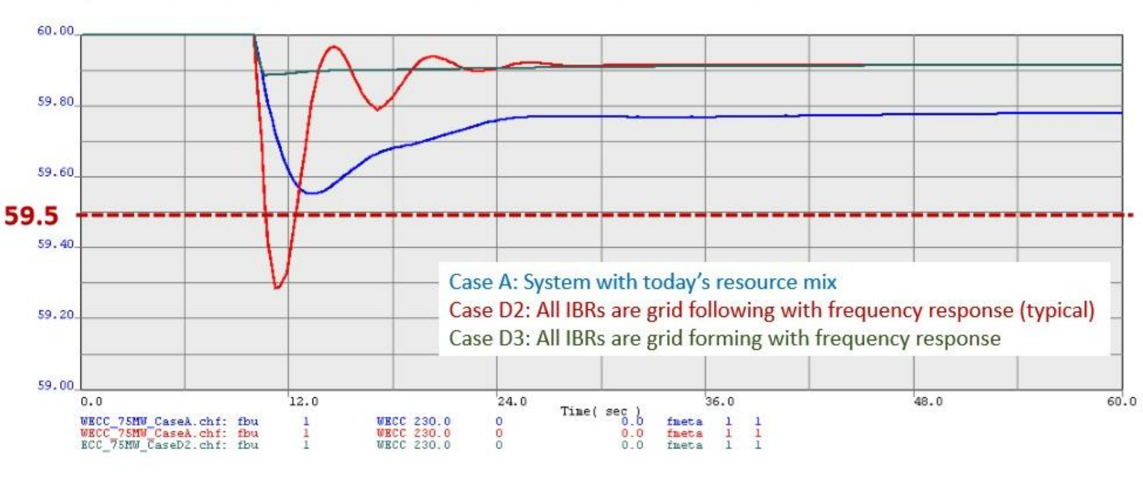
Grid-Forming Inverter Modeling

- Timeline for the REGFM_B1 Model development



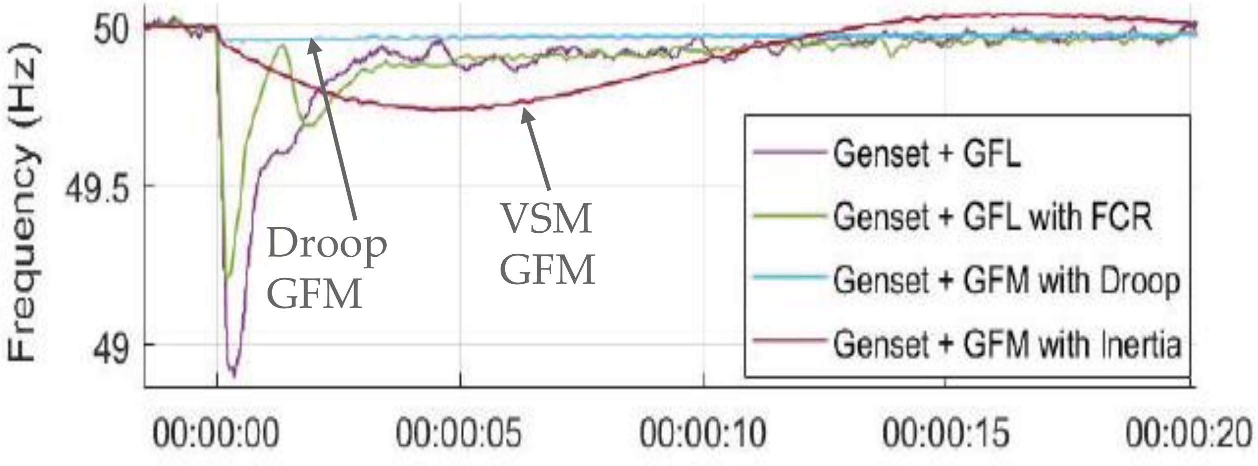
Grid-Forming Inverter Modeling

- Comparison between the SMA Test and the Simulation Results



(Simulation credit: BPA)

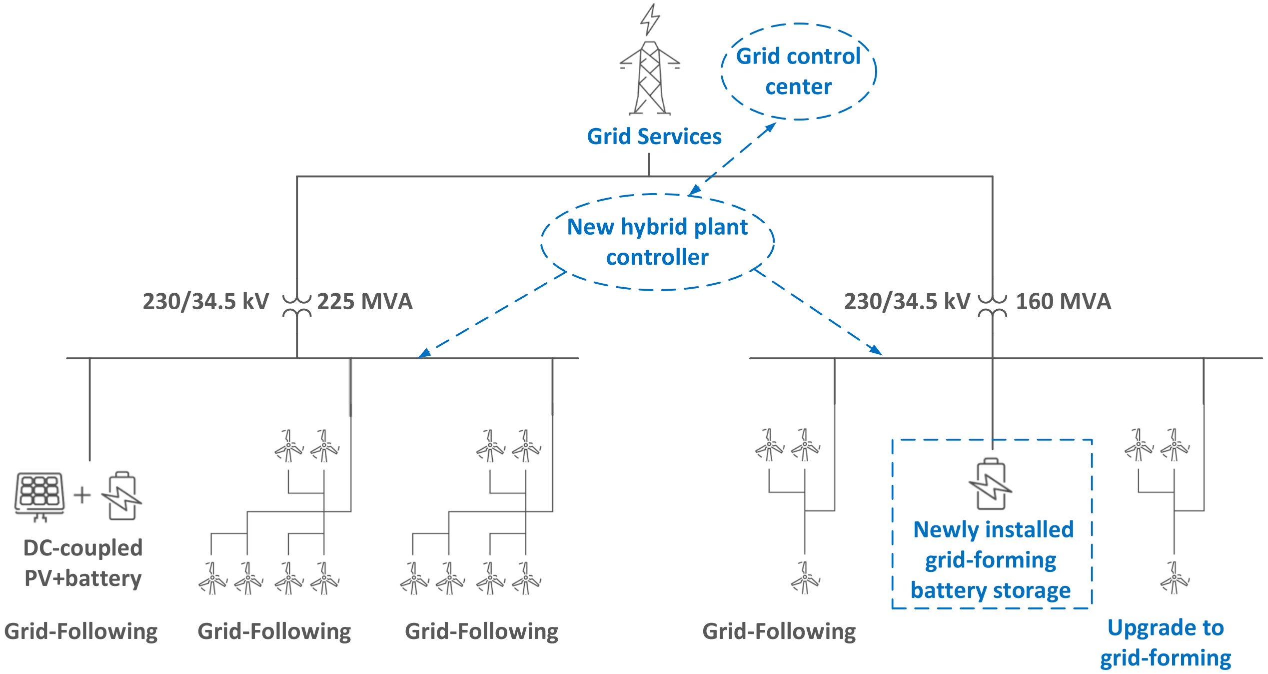
SMA Hardware Test Results on a Small System



PGE Led DOE Grid-Forming Demonstration Project

- 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

Photo of 380MW Wheatridge wind, solar and battery storage power plant

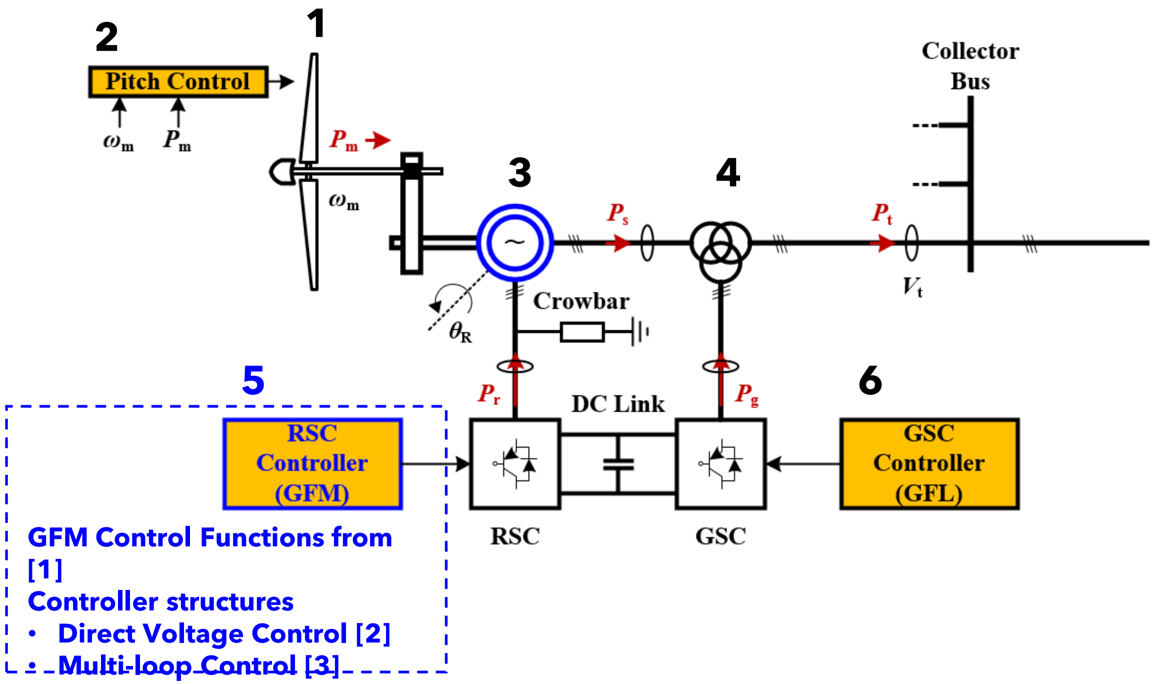


Budget Period 1

Timeline for SOPO Milestones *

Task 3: Model and HiL testbed development for hybrid plant with mixed GFM/GFL control

- Subtask 3.4 – Generic EMT model development



[1] W. Du et al., "Virtual Synchronous Machine Grid-Forming Inverter Model Specification (REGFM_B1).
[2] S. Wang, J. Hu and X. Yuan, "DFIG-based wind turbines with virtual synchronous control: Inertia support in weak grid," 2015 IEEE Power & Energy Society General Meeting, Denver, CO, USA, 2015.
[3] Dustin Howard and Einar Vaughn Larsen, "System and method for providing grid-forming control for a double-fed wind turbine generator using virtual impedance," WO 2021/145877 A1, GE, July 2021

Type-3 Wind	Status & Description
1. Turbine	**Completed**
a) Aerodynamic Torque	• Implemented as a function of wind speed and power coefficient (c_P)
b) Power Coefficient	• Implemented as a function of tip-speed ratio (λ) and pitch angle (β)
c) Shaft Dynamics	• Modeled considering shaft displacement constant (B) and shaft damping constant (D)
2. Pitch Control	**Completed** • Regulate turbine rotor speed • Consider pitch-angle ramp-up limit (deg/s). • Consider pitch motor delay
3. Induction Machine	PSCAD library model (N/A)
4. Step-up Transformer	PSCAD library model (N/A)
5. Rotor-Side Converter and Controller based on [1], [2], [3]	**Work-in-progress** • **Virtual Synchronous Machine control (Completed)** • **Voltage control (Completed)** • **Voltage reference generation (Completed)** • **I_{dq} Current priority control (Completed)** • Current limiting control (work-in-progress) • Average model will be replaced with switching model
6. Grid-Side Converter and Controller	**Work-in-progress** • **V_{dc} regulation control (Completed)** • **Current saturation (Completed)** • Average model will be replaced with switching model

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