<Public>

Grid-forming Study

WECC StS

May 20, 2024

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Grid-forming Study

- Purpose of the assessment
  - To follow up on the CSI study by focusing on spring and low inertia conditions to investigate how recent changes in technology affect the Western Interconnection.
- Top two reliability questions
  - How do grid-forming (GFM) inverters respond during a major loss of generation?
  - What percentage of total generation is needed from GFM and grid-following (GFL) inverters to keep frequency in the Western Interconnection from hitting the 59.5 Hz UFLS threshold?
    - Determine the amount of headroom that is needed to prevent the Western Interconnection from hitting the 59.5 Hz threshold (interconnection wide).

Cases Used

Scenario	Assumptions
2020 LS11_3AM (3AM)	• High Wind generation, • Light Spring Load (~72GW) • Inertia (397,840 MW*s)
24 LSP2S (1PM)	• High IBR • Medium load (~90GW) • Inertia (163,744 MW*s)

What Dynamic Models were Replaced?

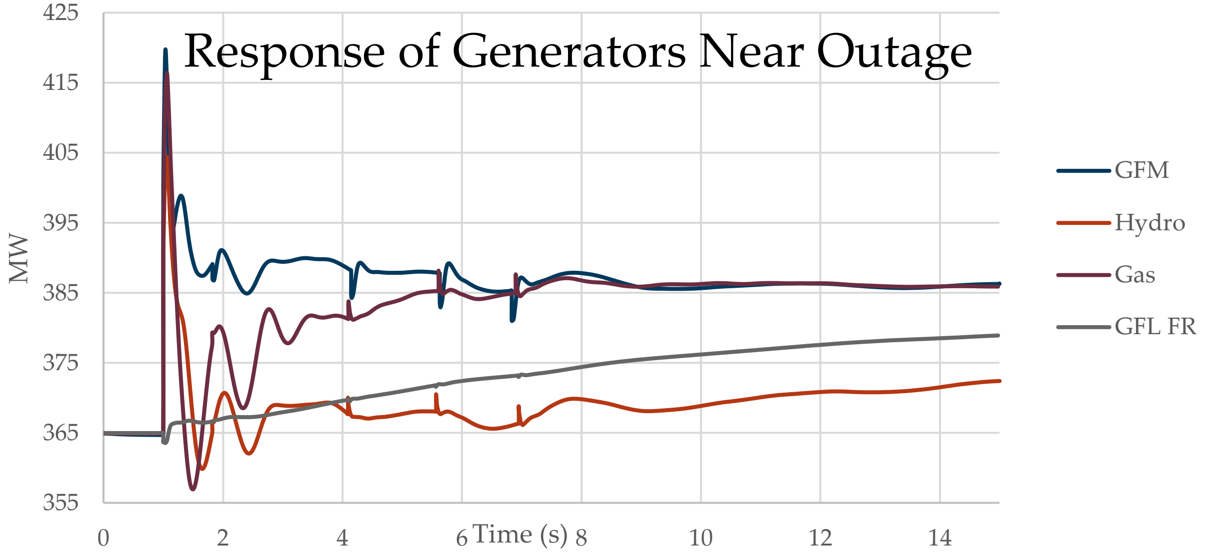
- Synchronous generators replaced with either GFL or GFM
  - 582 generating units (36,570 MW)
    - Excludes nuclear and geothermal units
- Split the 36,570 MW into four groups
  - Each group has between 9,105 and 9,164 MW
- Replaced all 36,570 MW with a nonresponsive GFL to frequency event

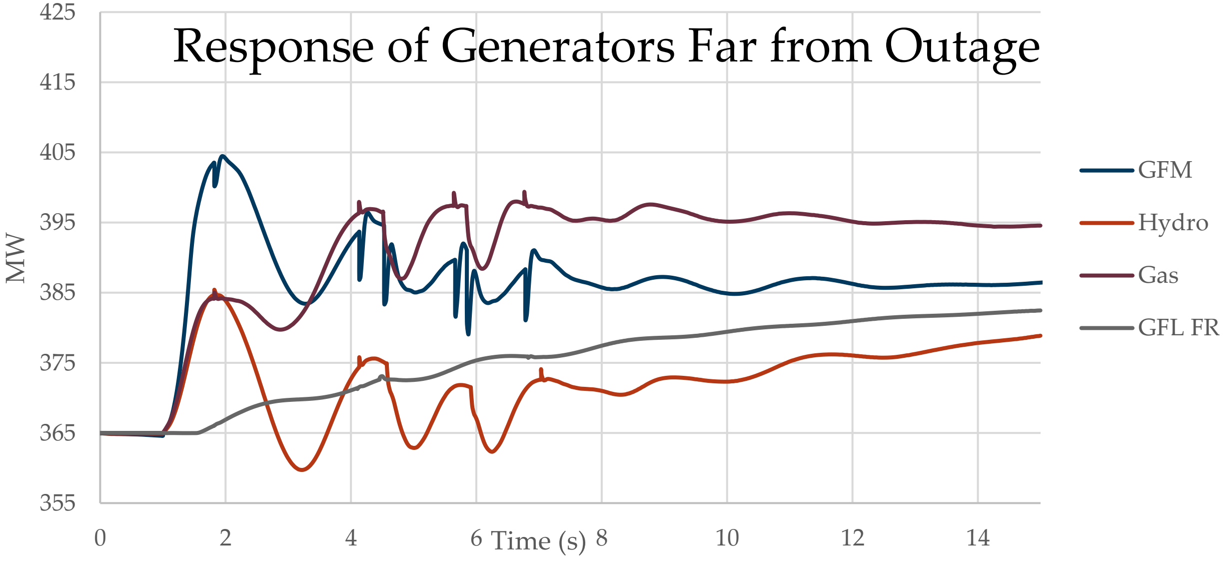
Input Data

- GFL used the generic data that GE supplies in its Positive Sequence Load Flow (PSLF) manual
  - Started with the GFL used in the CSI study
    - Modified the following parameters to disable the voltage control due to the collector system not being present in the case
      - REPC_A parameters that were changed, Kp, ki, tp, tlag, and puflag
- GFM used generic data provided by Pacific Northwest National Laboratory (PNNL)

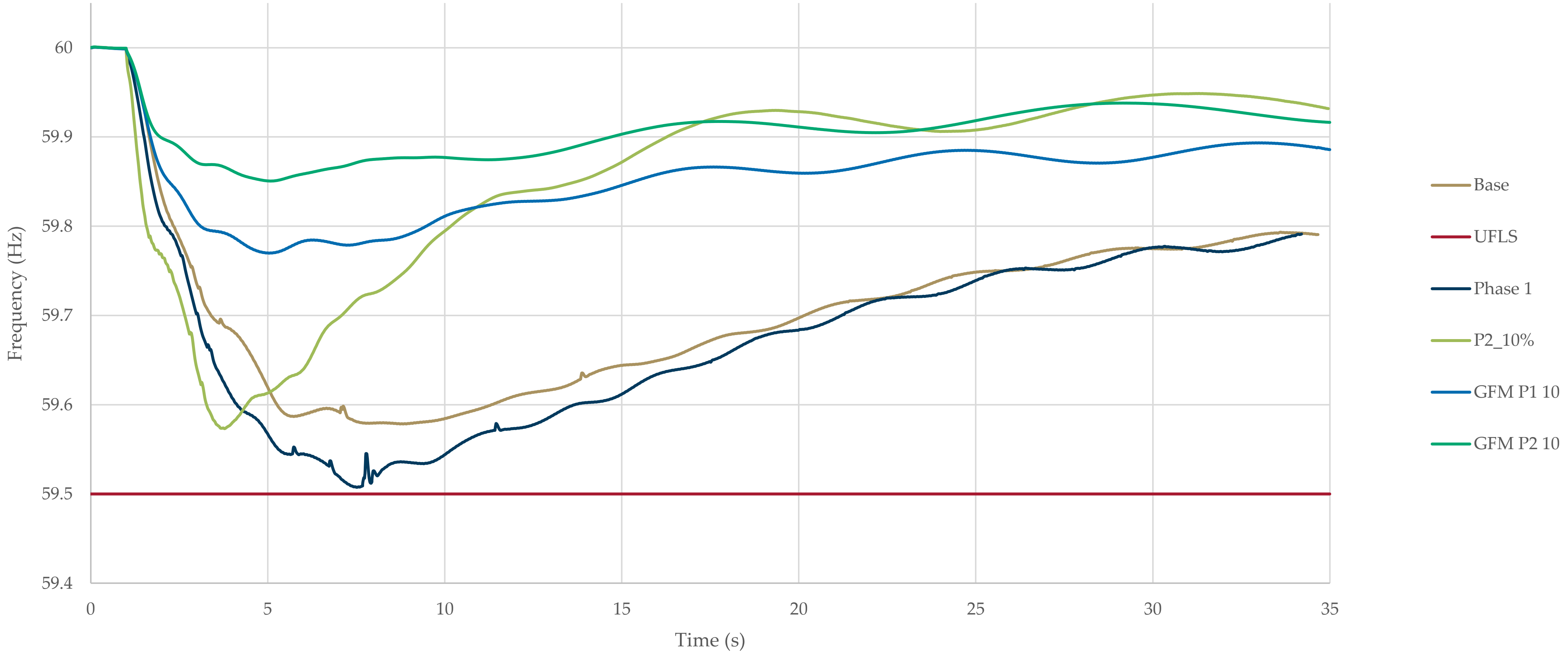
Approach

- Simulated a standard disturbance for the double Palo Verde outage
- MW response from hydro, IBR FR (frequency response activated), IBR, and gas turbine

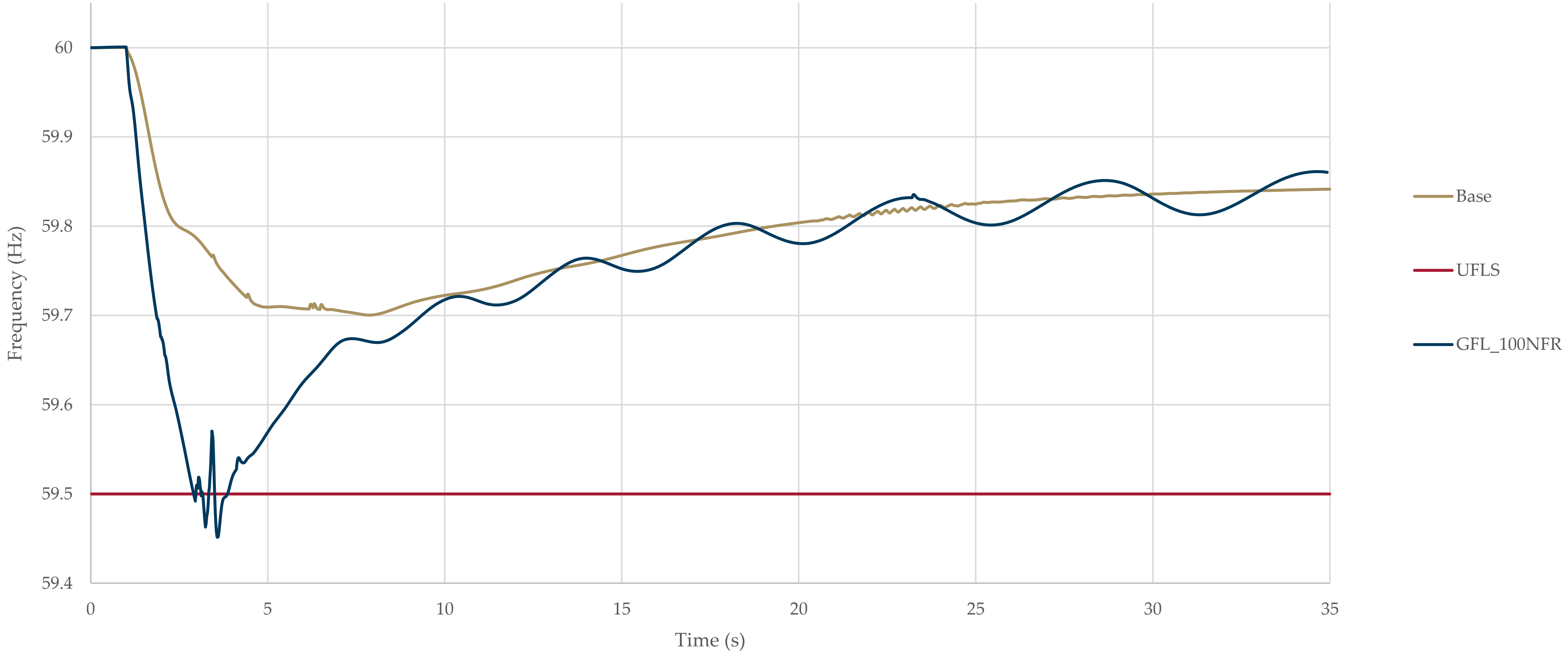




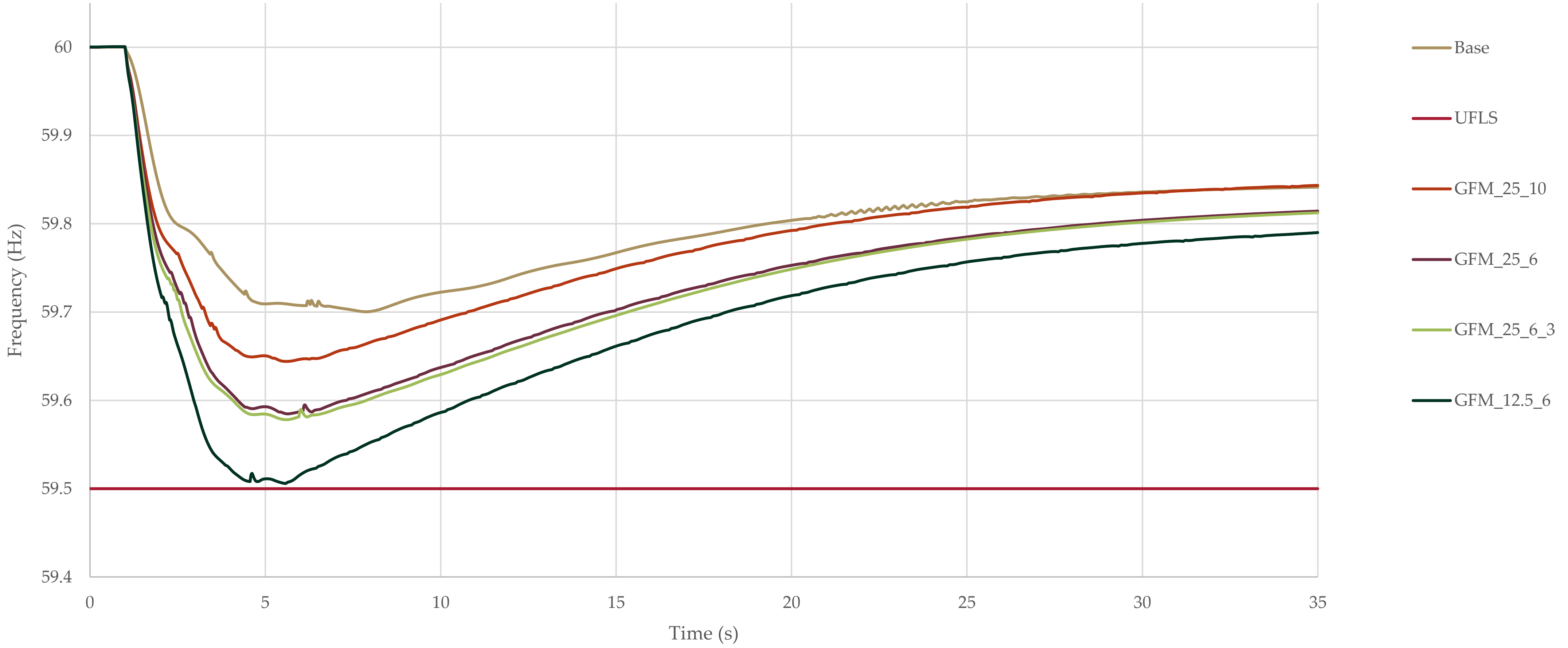
GFM vs GFL in 3AM Case for Phase 1 and 2



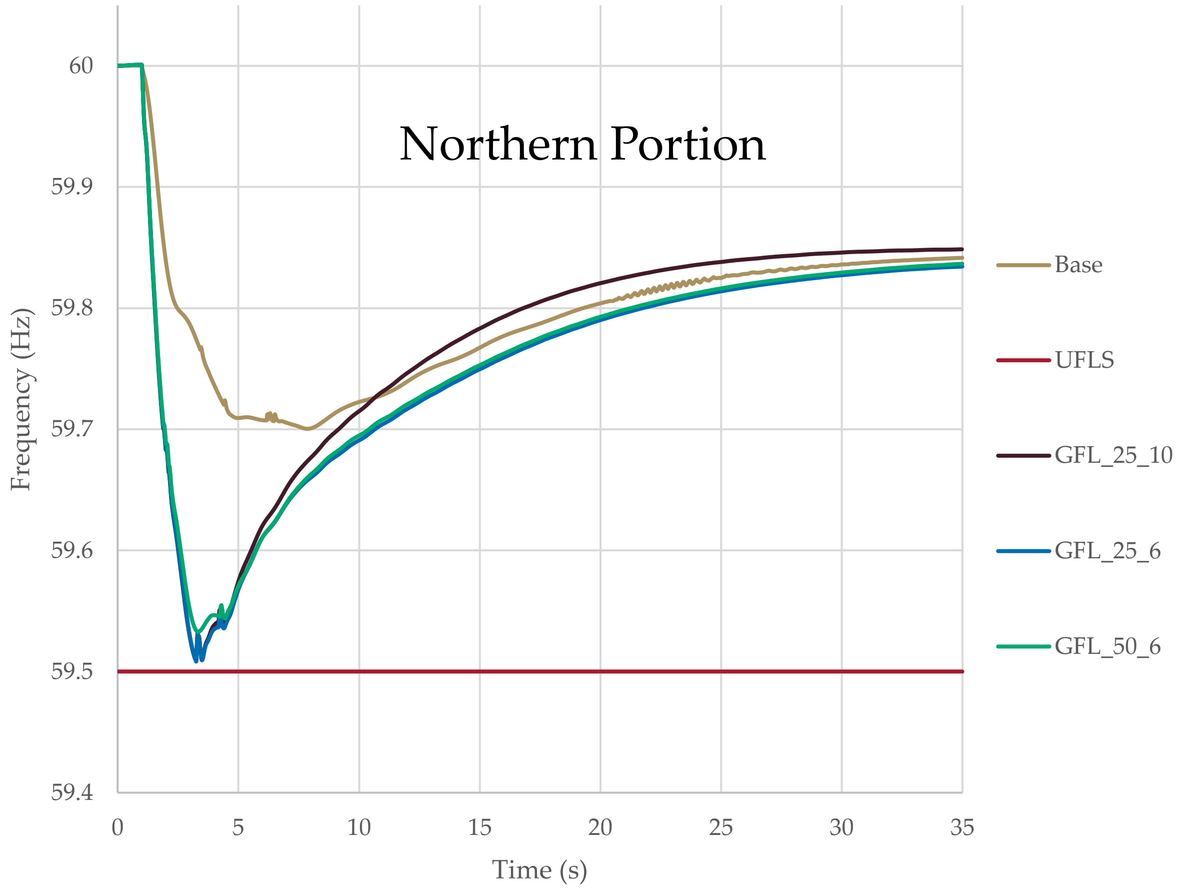
1PM Case with Nonresponsive GFL

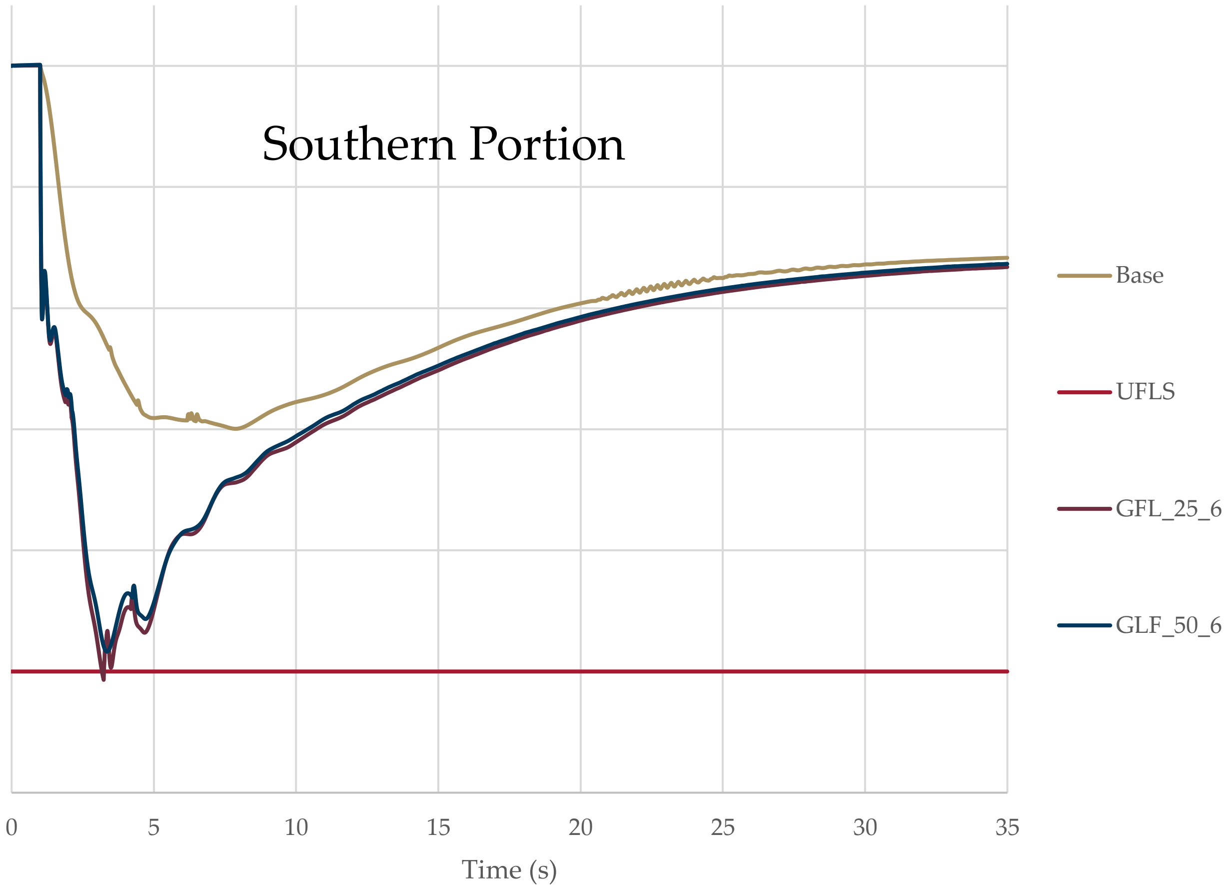


1 PM Case with GFM

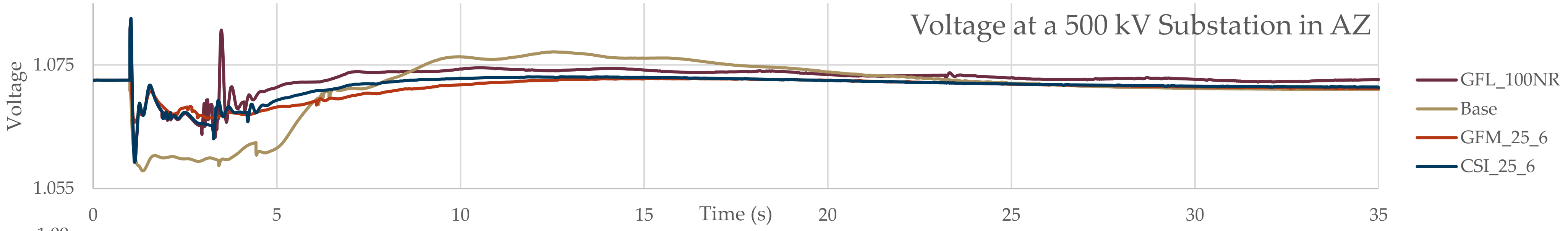


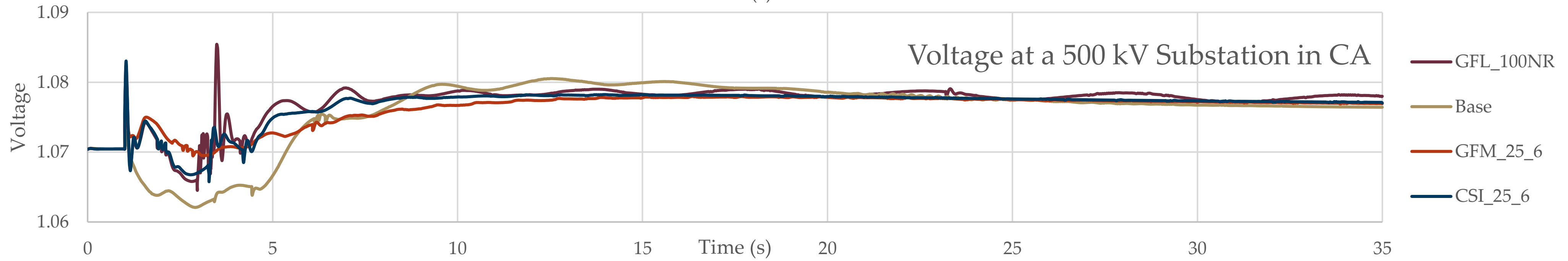
1PM Case with Frequency Response GFL

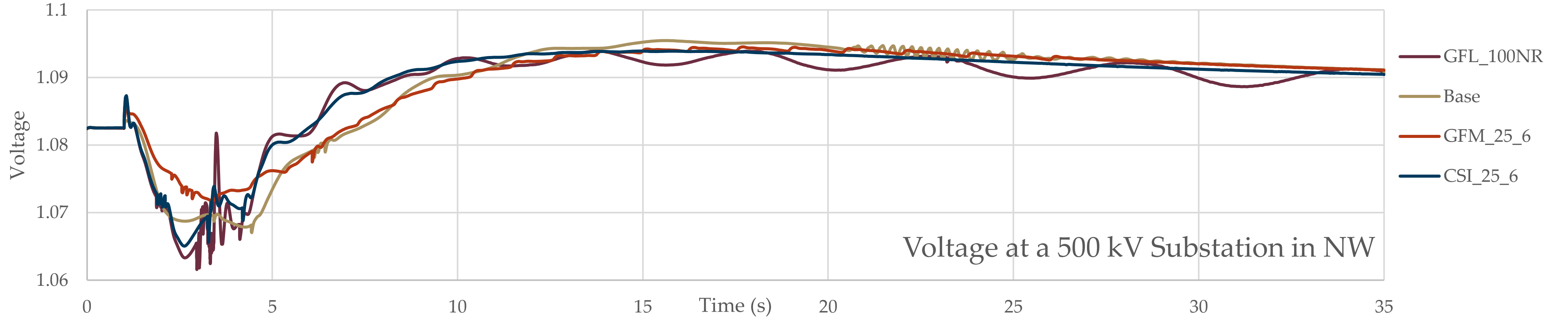




Voltages


Voltage at a 500 kV Substation in AZ
Voltage
1.075
1.055
0
5
10
15
Time (s)
20
25
30
35
GFL_100NR
Base
GFM_25_6
CSI_25_6

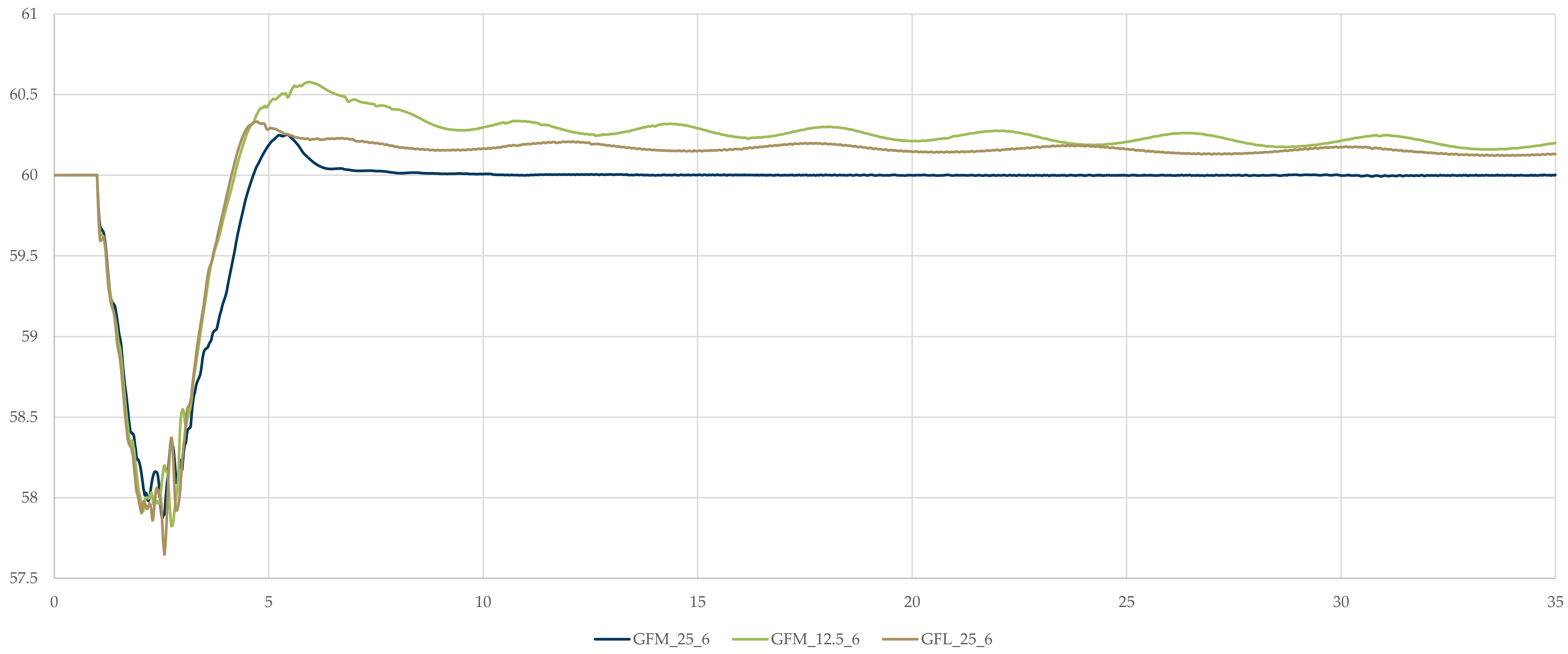

Voltage at a 500 kV Substation in CA
Voltage
1.09
1.08
1.07
1.06
0
5
10
15
Time (s)
20
25
30
35
GFL_100NR
Base
GFM_25_6
CSI_25_6


Voltage at a 500 kV Substation in NW
Voltage
1.1
1.09
1.08
1.07
1.06
0
5
10
15
Time (s)
20
25
30
35
GFL_100NR
Base
GFM_25_6
CSI_25_6

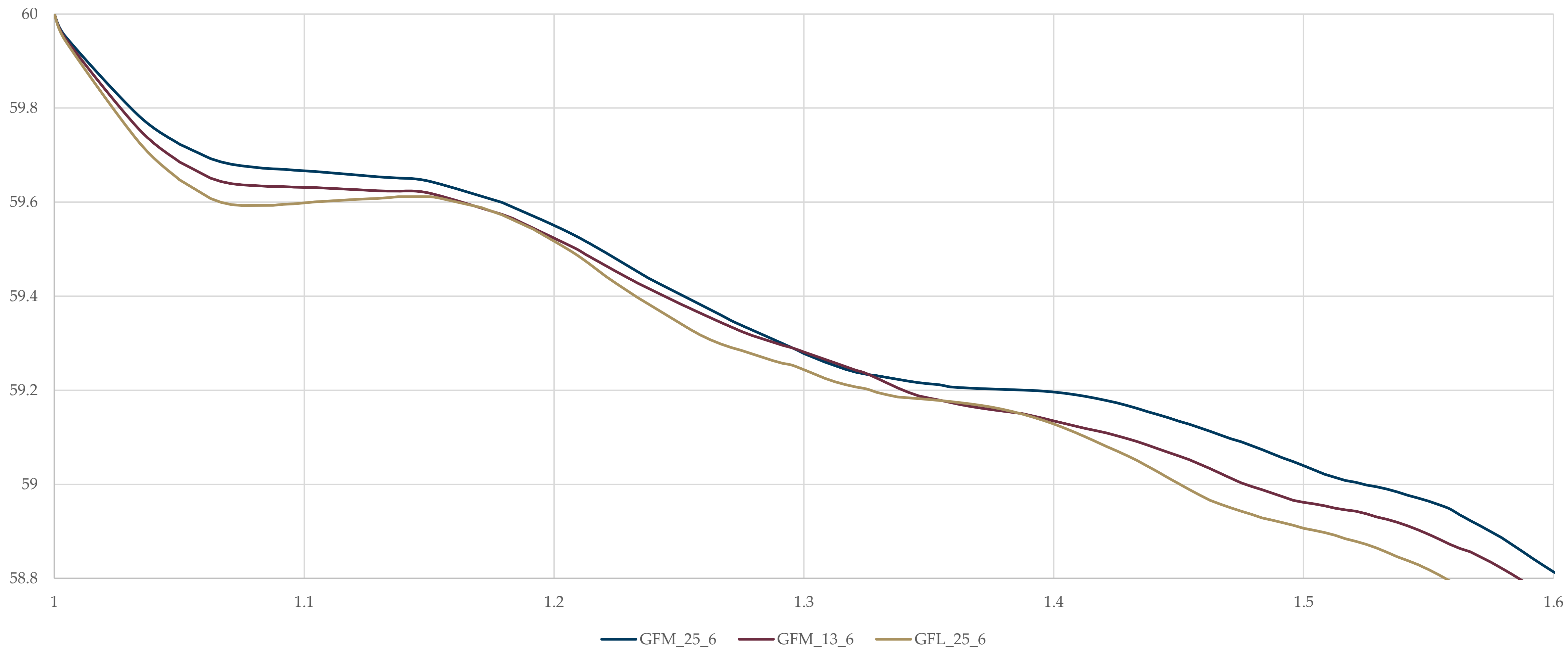
20% Imbalance Scenario

- ~20% Generation loss imbalance scenario was run on the 1PM case for the following scenarios:
  - GFM_25_6 shows the frequency in the scenario where 75% of the IBR generation is nonresponsive GFL, and 25% is GFM with 6% headroom.
  - GFM_12.5_6 shows the frequency in the scenario where 87% of the IBR generation is nonresponsive GFL, and 12.5% is GFM with 6% headroom.
  - CSI_25_6 shows the frequency in the scenario where 25% of generation is frequency responsive GFL, and 75% is nonresponsive; there is no GFM generation with 6% headroom.

Frequency Response of the Imbalance Simulations



Frequency Response of the Imbalance Simulation



20% Imbalance Results

- 20% imbalance simulated an initial loss of 222 units producing 21,733 MW of generation
  - During the simulation, an additional 7,390 to 10,069 MW were tripped due to relay settings in the dynamics file

Case name	Initial # Generating units tripped	Generation units lost	Generation loss (MW)	Load loss (MW)	ROCF (Hz/s)	Frequency Nadir (Hz)
GFM_25_6	222	456	29,638	29,123	-1.92	57.87
GFM_13_6	222	448	31,802	30,475	-2.08	57.82
GFL_25_6	224	439	30,855	30,023	-2.19	57.64

Observations and Recommendations

- **Observation 1:** GFM IBR technology shows advantages over GLF technology in maintaining system frequency. With the expected increase in the IBR fleet, ensuring that the Western Interconnection has adequate frequency response from IBRs is critical.
- **Recommendation 1**: Planning Coordinators should strongly consider using GFM technology when replacing synchronous generators with IBRs. With increasing penetration of IBRs, WECC anticipates that the Western Interconnection will need increased and more robust frequency response from IBRs. If the IBR is a battery energy storage system (BESS), it should be designed to provide reliable and robust performance that supports high IBR penetration in the Western Interconnection.
- **Observation 2**: Imbalance simulations show that up to 10% of additional generation is tripped offline due to protection settings, or lost synchronization with the grid. This increase resulted in more load shedding than planned in the simulations with just the 20% imbalance.
- **Recommendation 2**: The Under Frequency Load Shedding Work Group (UFLSWG) should look at the UFLS methodology considering the results of the imbalance simulations in this study and determine how to evaluate the additional generation tripped by the protection relays in the imbalance simulations.

Observations and Recommendations

- **Observation 3**: Rate of Change of Frequency (ROCOF) is one measure of the health of a power system and is very sensitive to the amount of inertia. With the increasing number of IBRs replacing traditional synchronous generators, the subsequent reduction in system inertia is likely to increase ROCOF. The faster that frequency declines after the loss of generation, the more load is at risk of being shed due to underfrequency conditions. It was also observed that when the amount of generation lost far exceeds the frequency responsive generation, ROCOF remains relatively unchanged. However, the initial frequency response within 0.1 seconds of disturbance does improve when there is significant penetration of frequency-responsive GFM inverter technology in the system.

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