# Grid forming Inverters

## Case studies to evaluate value proposition

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unifi consortium
universal interoperability for grid-forming inverters

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Please contact presenter for the many references that go into more details of the work

# Points that came up when OEMs were asked “What is GFM?”

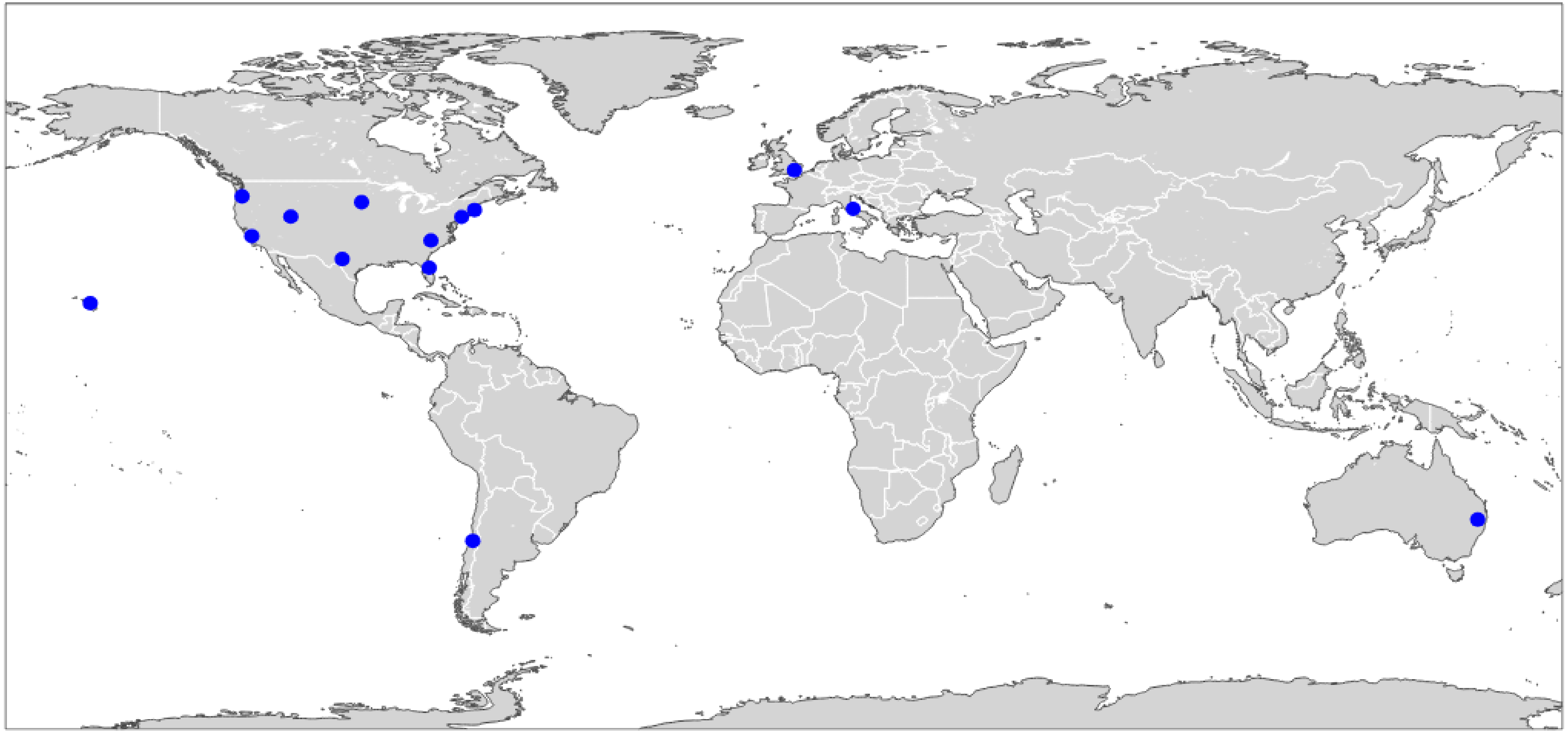
- Surviving islanding is important for microgrid.
- For macrogrid, customers are more interested in stabilization, degrees of freedom (virtual impedance), fast energy injection
  - Very few customers care about loss of last synchronous machine
- Few OEMs have different flavors of GFM for islanded operation, large grid operation, strong grid operation, weak grid operation
- Distinct difference and big jump to go from non-blackstart capable GFM to blackstart capable GFM
- Multiple categories could fit in between definitions of GFL and GFM
- GFM appear as low-impedance voltage source (sub-cycle response)

# Case Studies

# Objectives of case studies

- Is GFM needed?
- If yes, does GFM provide value?
- What capacity and current limits are required?
- At which location should GFM be deployed?
- How does need for GFM compare with utilization of capability of existing resources?

# GFM case studies by EPRI with worldwide electric power utilities



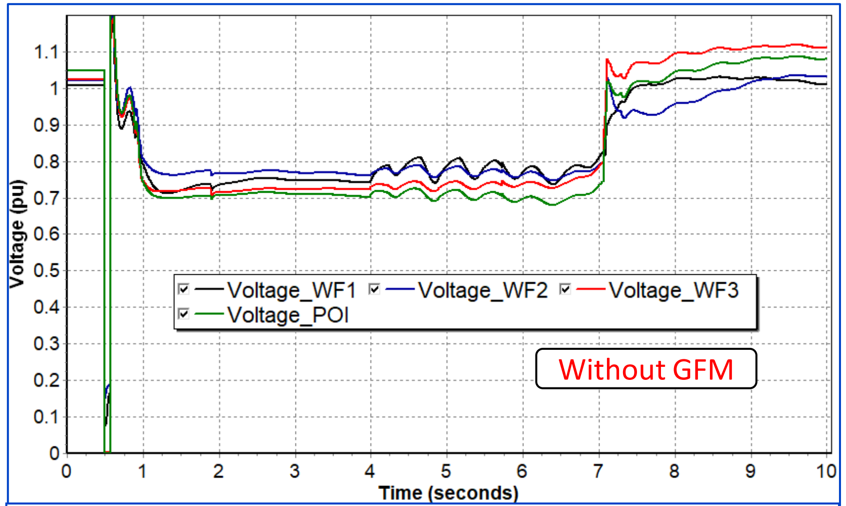
Represents a combination of both ongoing and completed case studies

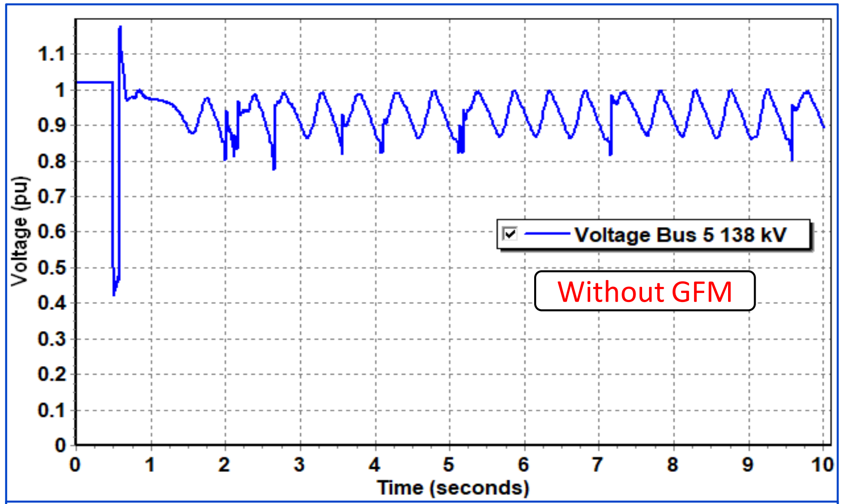
# Southwest region of North America

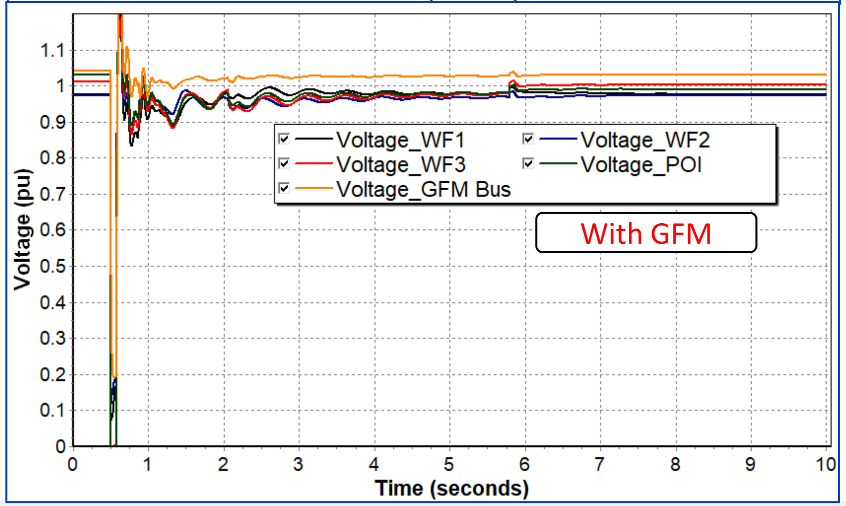
Objective: Evaluate ability of GFM to stabilize local areas with high IBR generation under N-*x* contingency

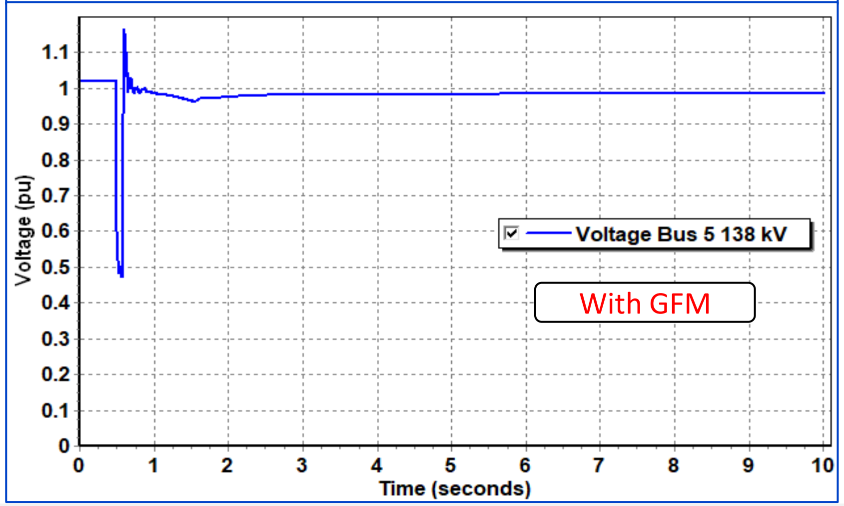
Local area 1

Local area 2




- Adding GFM to the local areas has capability to improve stability and increase transfer from IBR.
- Sizing and siting of GFM resource is important

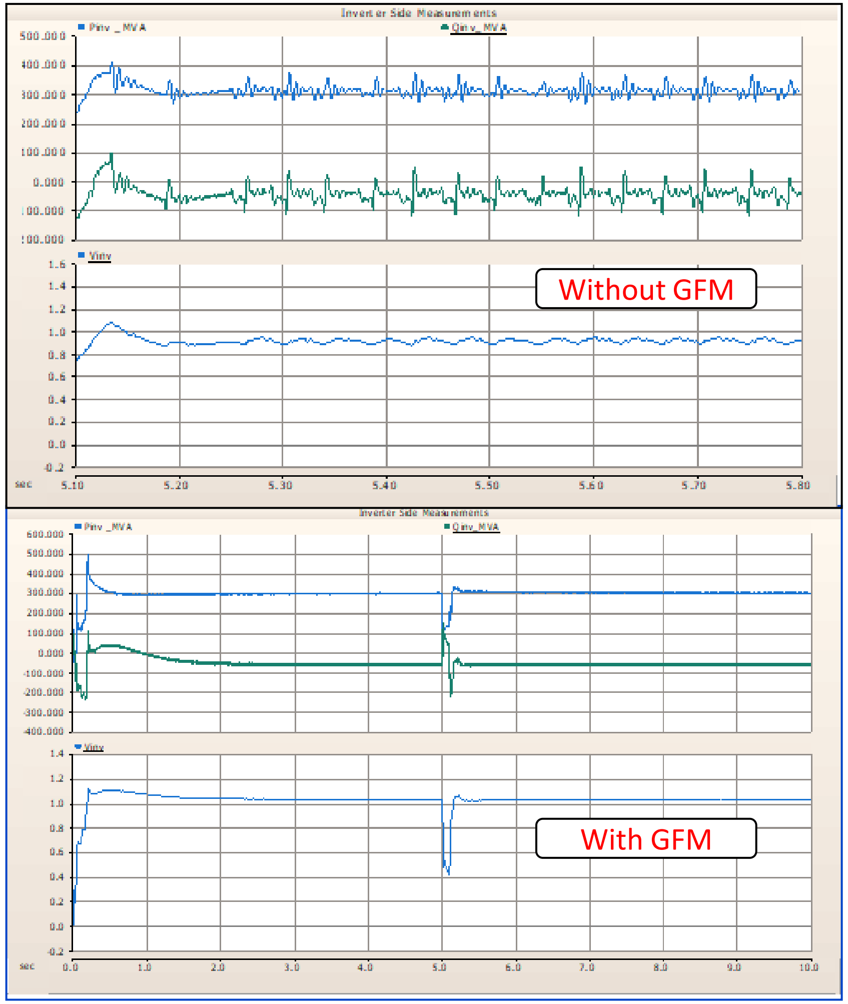
GFM can be a solution (out of many) to help stability and increase power transfer from IBRs

# Southeast region of North America

Objective: Evaluate ability of GFM to stabilize local areas with high IBR generation under N-*x* contingency

Local area 1


Local area 2

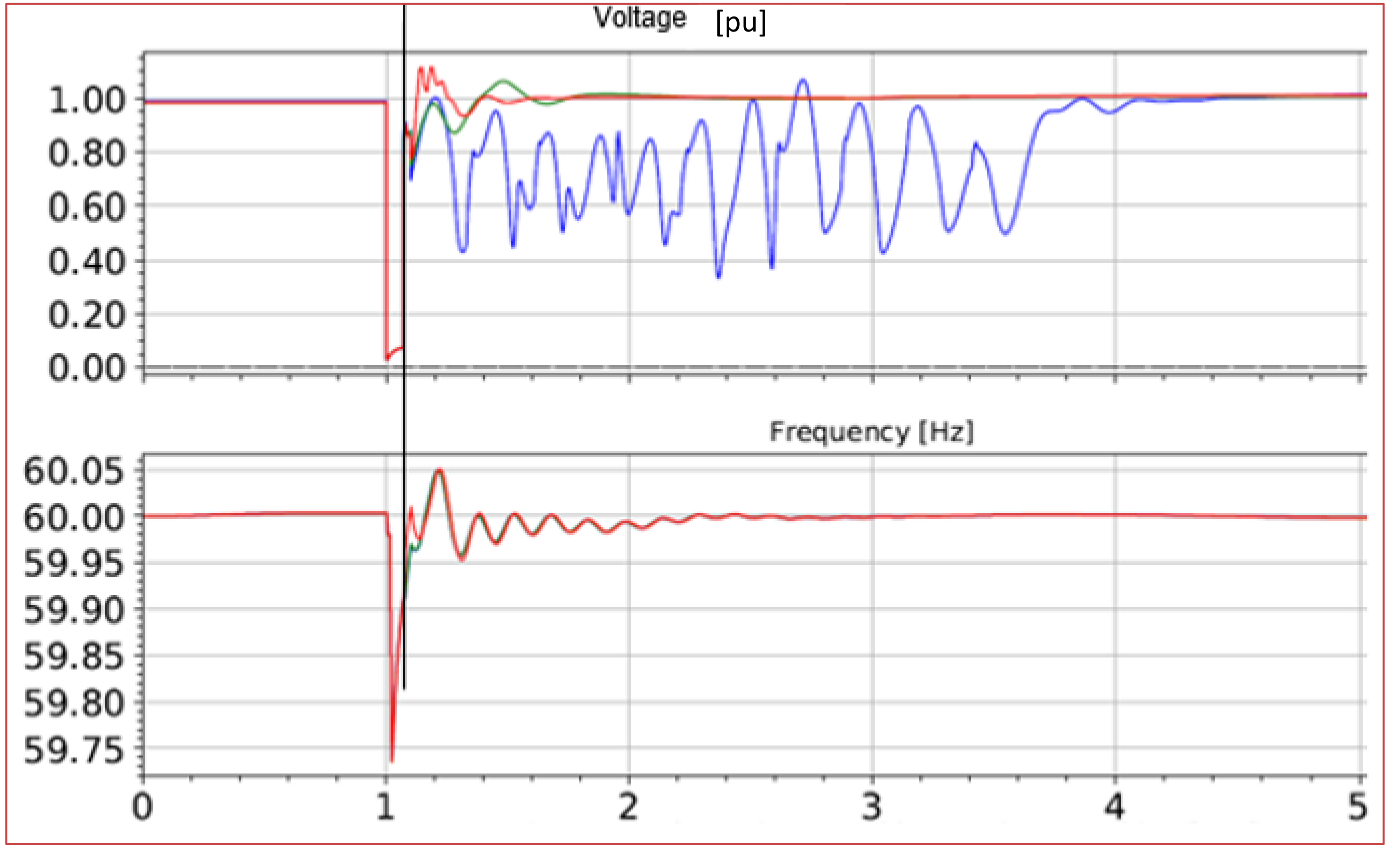



- Adding GFM to the local areas has capability to improve stability and increase transfer from IBR.
- Sizing and siting of GFM resource is important

GFM can be a solution (out of many) to help stability and increase power transfer from IBRs

# Midwest region of North America

Objective: Evaluate ability of GFM to alleviate transmission stability constraint




No-GFM, GFM, Sync con

- Maintenance outage followed by N – 2 event
- Without GFM, wind generation is to be curtailed in region to maintain stability
- Both GFM and Sync con can stabilize the region without wind curtailment

In a large interconnected system, GFM could help in local regions to improve stability



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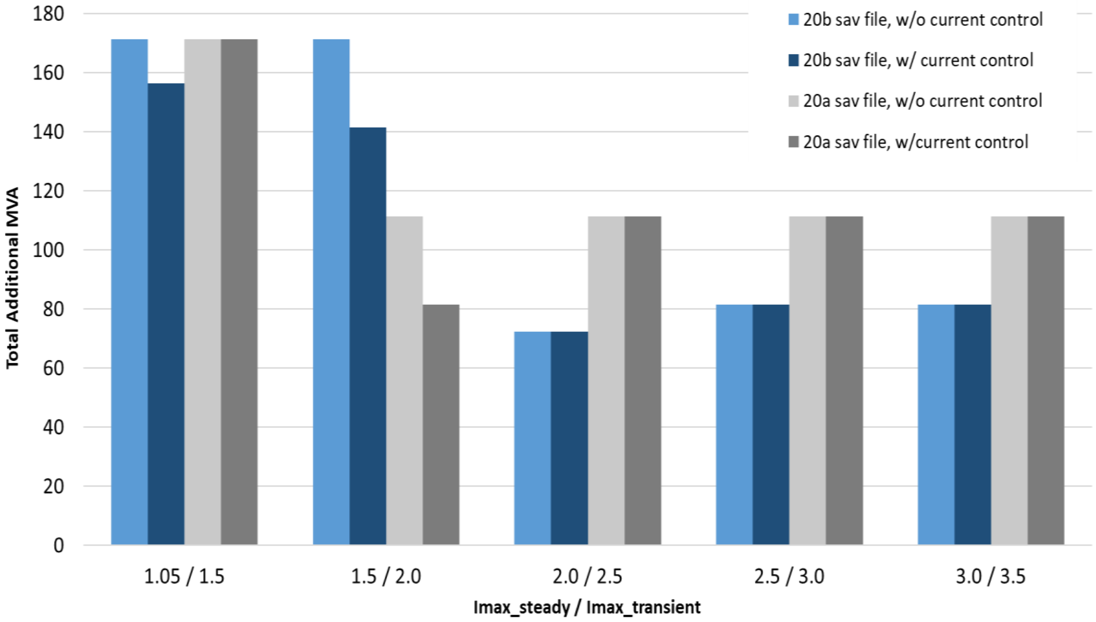
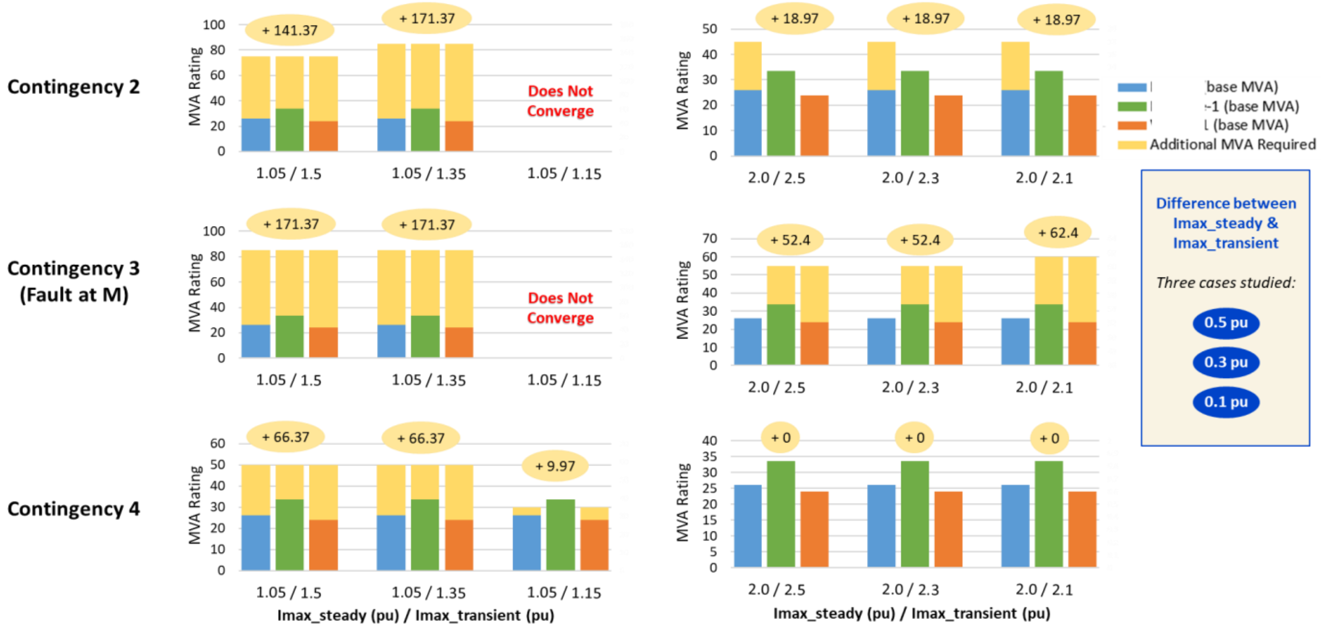
# Island Network

Objective: Determine MVA of GFM along with required amount of max-current




- MVA of GFM needed is a function of various factors
- Depending on value of maximum current (both transient and steady state), the required MVA can change

| | 20a sav (online) | 20b sav (online) | Total (offline + online) |
|---|---|---|---|
| GFM IBR (MVA) | 83.63 | 117.23 | 144.23 |
| non-GFM IBR (MVA) | 211.21 | 244.81 | 636.93 |
| DER** (MVA) | 164.04 | 164.04 | 230.95 |

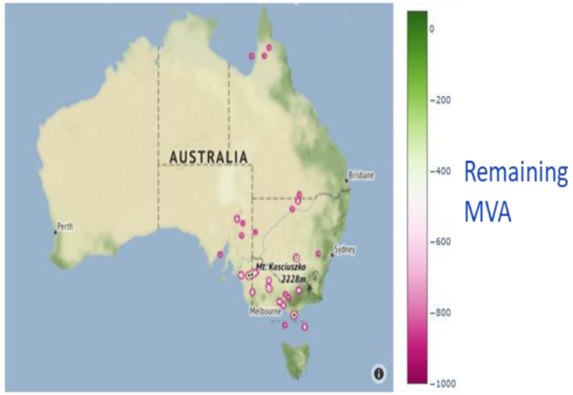
** systems < 10 MVA

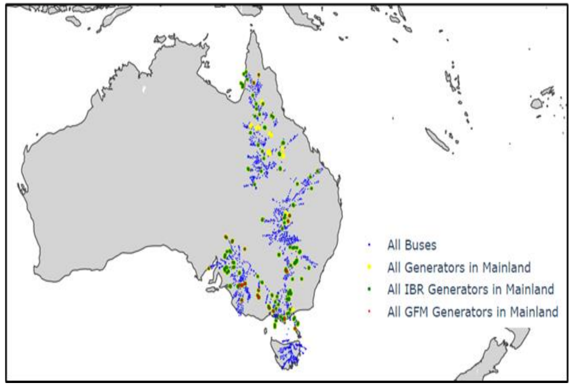
Base case values

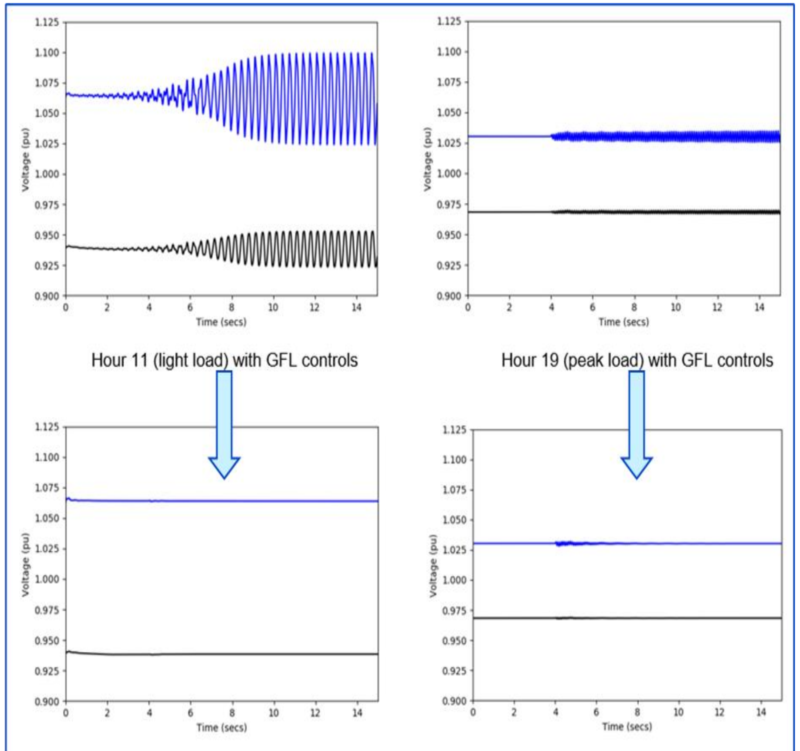
Important to decouple notion of grid forming from fault current injection and recovery from fault

# Long interconnected power system

Objective: Determine size, location, and impact of GFM on small signal stability across 24 hours with high IBR percentage



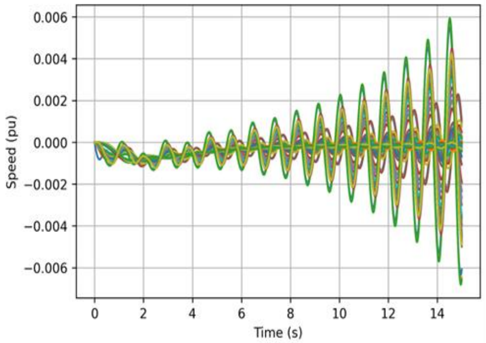




Hour 11 (light load) with GFL controls

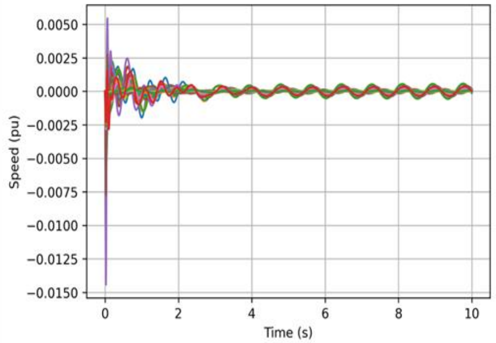
Hour 19 (peak load) with GFL controls

Hour 11 (light load) with GFM controls

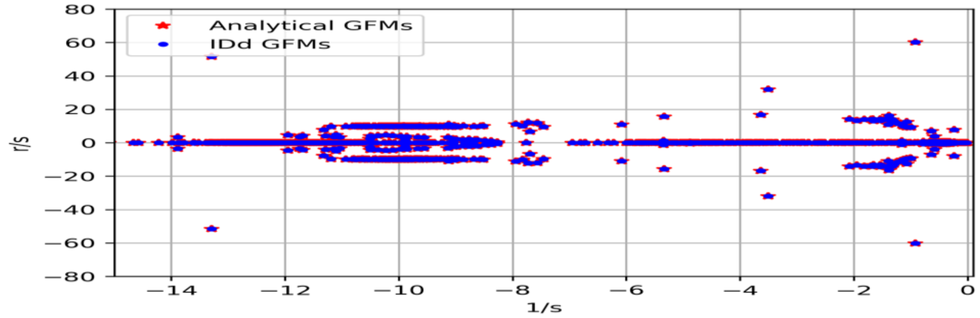
Hour 19 (peak load) with GFM controls




NEM Impulse Response for High GFL IBR Penetration – Constant Impedance Loads




NEM Impulse Response for High GFL IBR Penetration and GFM IBRS – Constant Impedance Loads



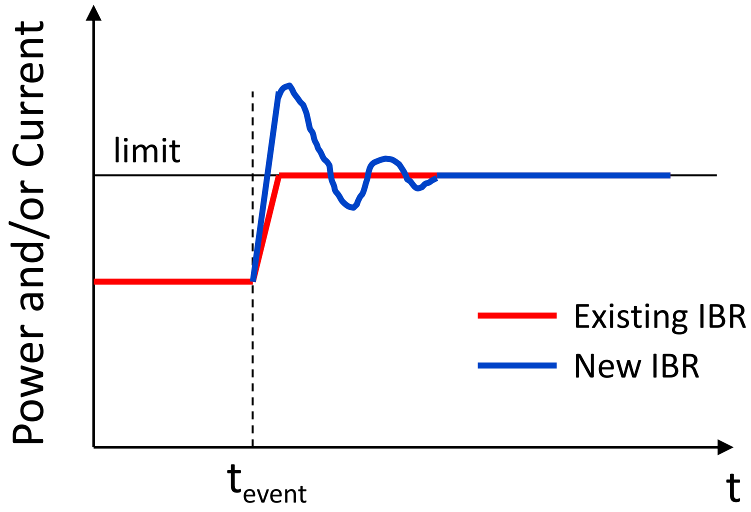

Use of GFM devices at identified locations can help mitigate small signal instability across a 24-hour period

| Area | Area Nam | SyncGen | nonGFM | GFM |
|---|---|---|---|---|
| 1 | NSW | 3.4 | 13.3 | 0.2 |
| 2 | VCT | 1.3 | 9.2 | 0.8 |
| 3 | QNL | 8.7 | 5.2 | 0.073 |
| 4 | SAU | 0 | 4.3 | 4.2 |

Values in GVA

Since case study results may be classified as CEII, a synthetic Australia network used to show visualization of results

# A deeper dive into operation at limits

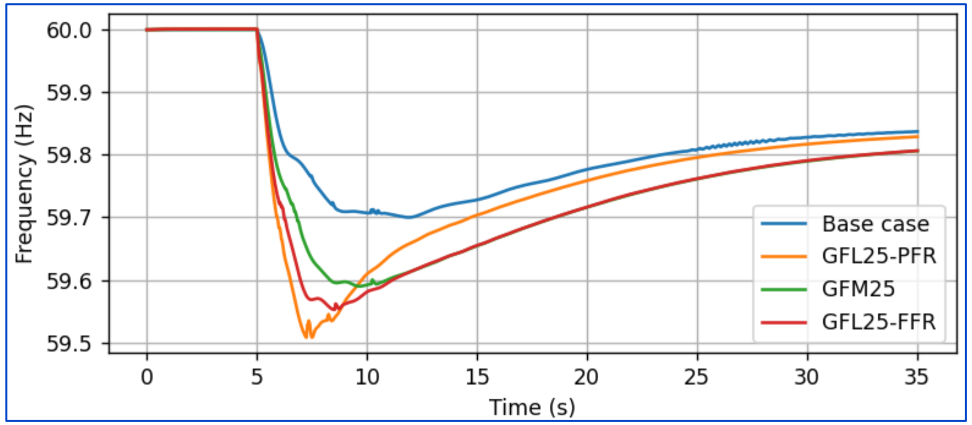



- Existing IBR technology
  - Limits on power and current enforced quickly and immediately
  - Results in reduced flexibility in dynamic behavior
- New IBR technology
  - Limits on power and current enforced in a slightly relaxed manner
    - Potentially due to improvements in hardware capabilities
  - Allows for increased flexibility in dynamic behavior

**Not everything about GFM is due to changes in control**

# Large interconnected power system in North America

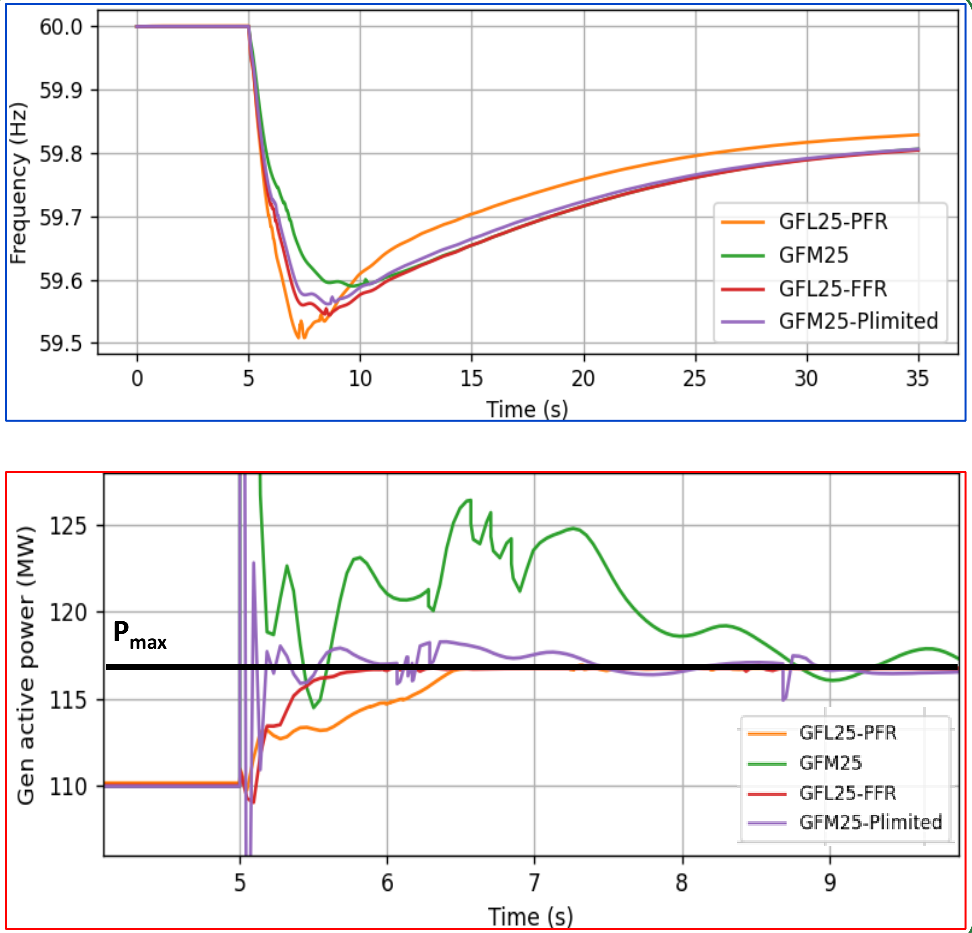
Objective: Determine impact of GFM on frequency response of large interconnections




25 indicates percent of devices responding to frequency deviation

- Fast frequency response (FFR) is improved compared to only Primary frequency response (PFR)
- Response from GFM appears to be further improved

Looking further into the details

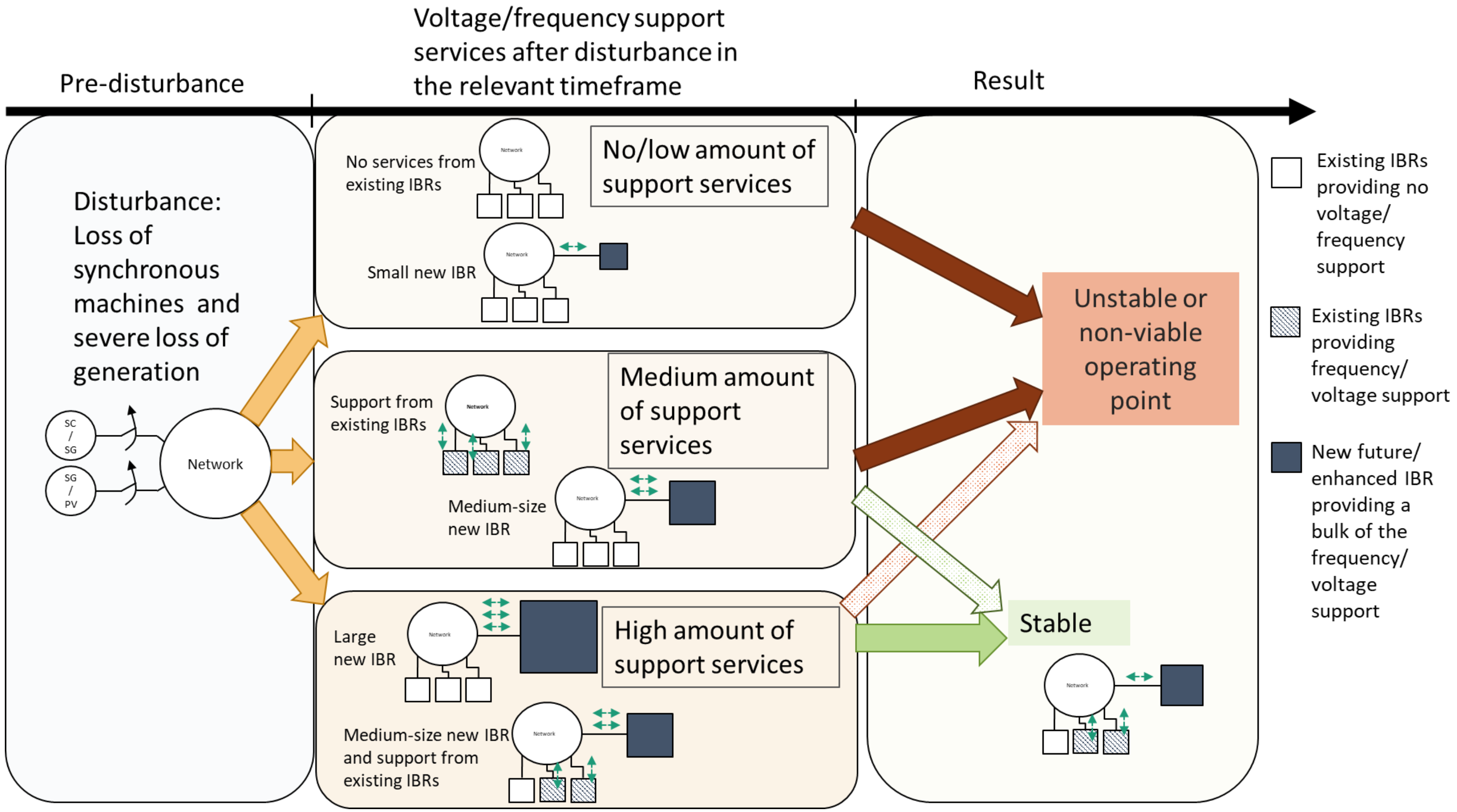



Enforcement of active power limit has a noticeable impact

Important to understand the nuances in response from IBR devices as they can impact various recommendations. Especially important are aspects related to limits

# Key lessons from various case studies

- Grid services needed from IBRs, especially in IBR-dominated grids
- These can be provided by a few new IBRs or by utilizing the capabilities present in the existing IBRs to share the burden on new IBRs
- Focus on the actual performance/services required from IBRs rather than saying that a ‘catch-all’ future IBR is needed
- Multiple services may be required for a disturbance
- The timeframe during which these services are required may change per system and disturbance




**A lot about GFM functionality and how we want to make us of it, test it, validate it, is yet to be understood and characterized**



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