Frequency Response in High IBR Scenario

Illustration Studies

WECC Modeling and Validation Subcommittee

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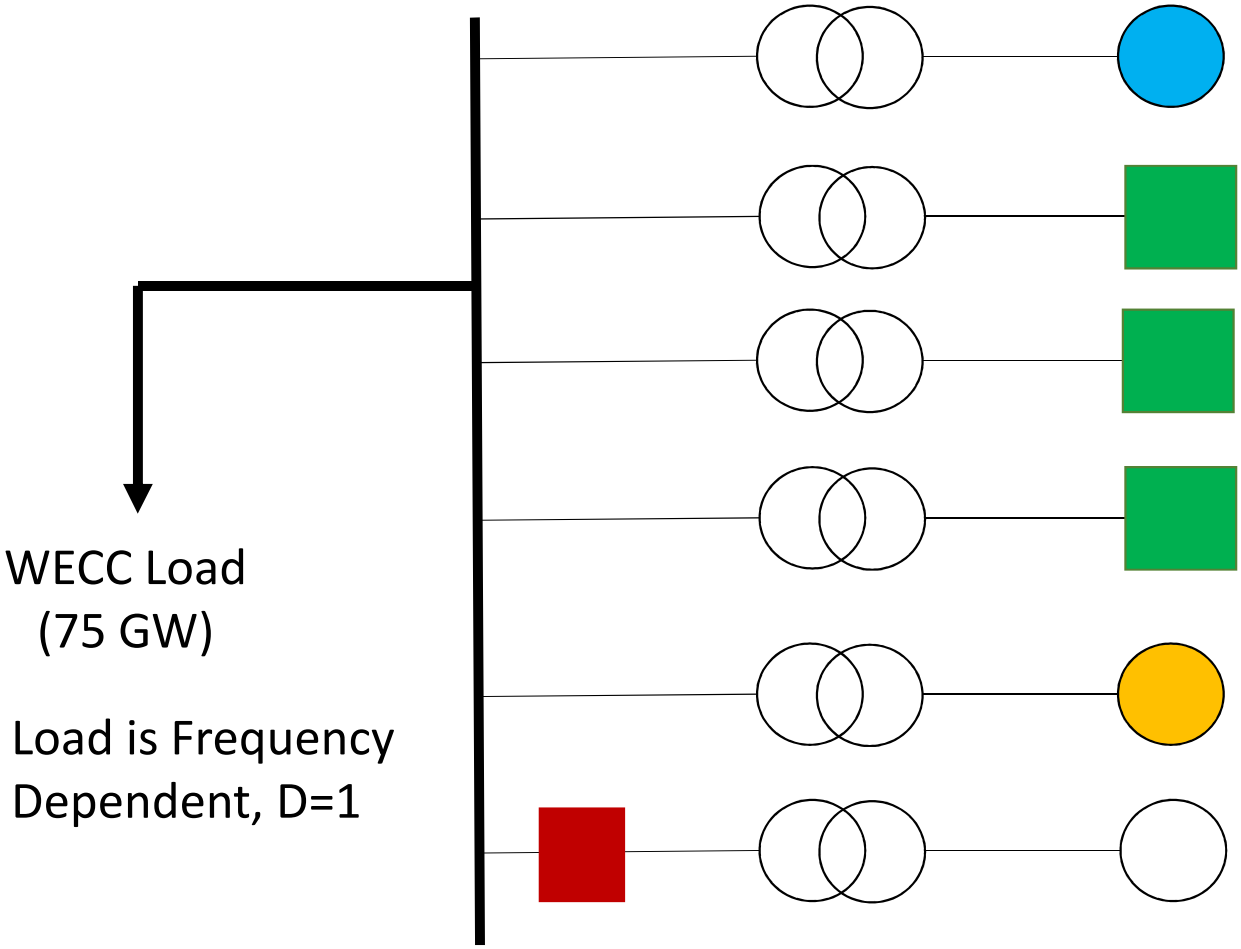
BPA Transmission Planning

microWECC model



Hydro – Responsive, 15% headroom

IBR1 – Non-Responsive

IBR2 – Responsive, Grid-Following

IBR3 – Responsive, Grid-Forming

Steam (non-responsive)

Resource Contingency

WECC Load
(75 GW)

Load is Frequency Dependent, D=1

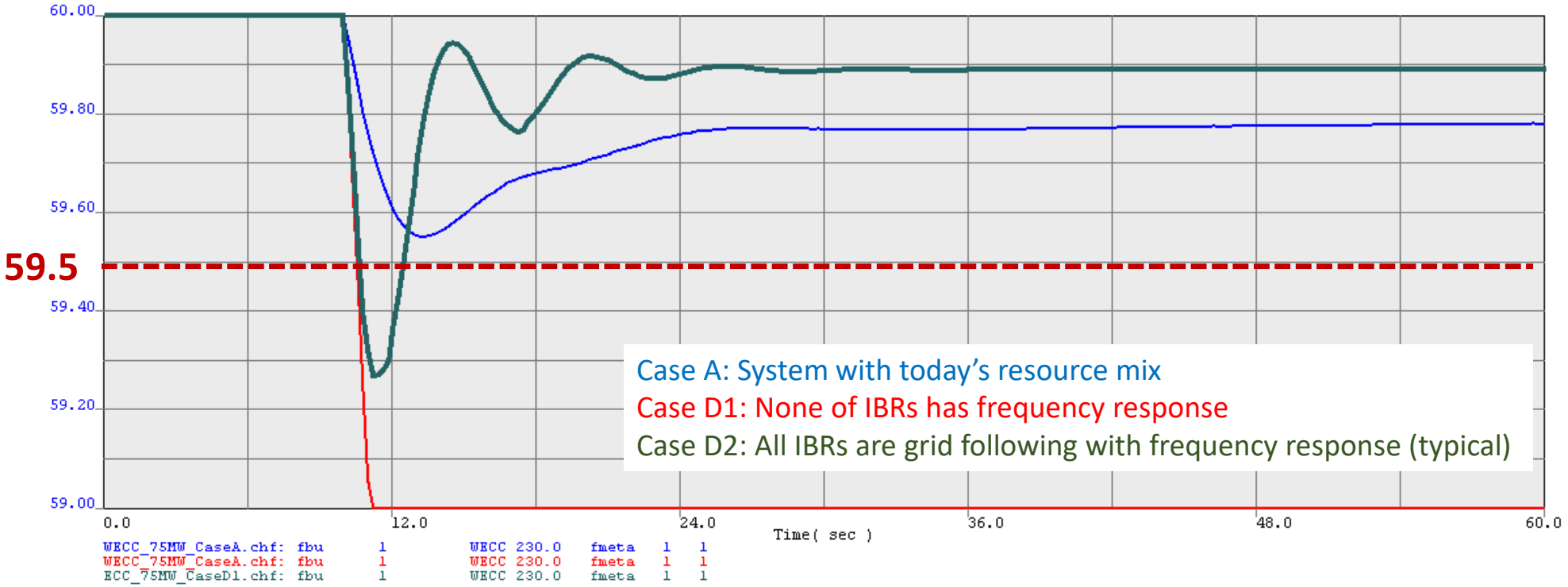
Resources

- Hydro:
  - governor droop (5%) control, response time is 30-45 seconds, 15% power headroom
- Inverter-Based Resources 1
  - Constant power control, maximum power output, no frequency controls
- Inverter-Based Resources 2 – **Grid Following**
  - Inverters operate in current injection mode
  - Inverters follow power order, operate with 10% power headroom
  - **Droop (5%) frequency control is implemented in plant-level controls**
  - Simulations were performed with typical and fast plant-level control settings
- Inverter-Based Resources 3 – **Grid Forming**
  - Inverters control internal Thevenin voltage
  - Inverters operate with 10% power headroom
  - **Droop (5%) frequency control is implemented in inverter-level controls**
- Resource Contingency for Western Interconnection is 2,800 MW

Scenarios

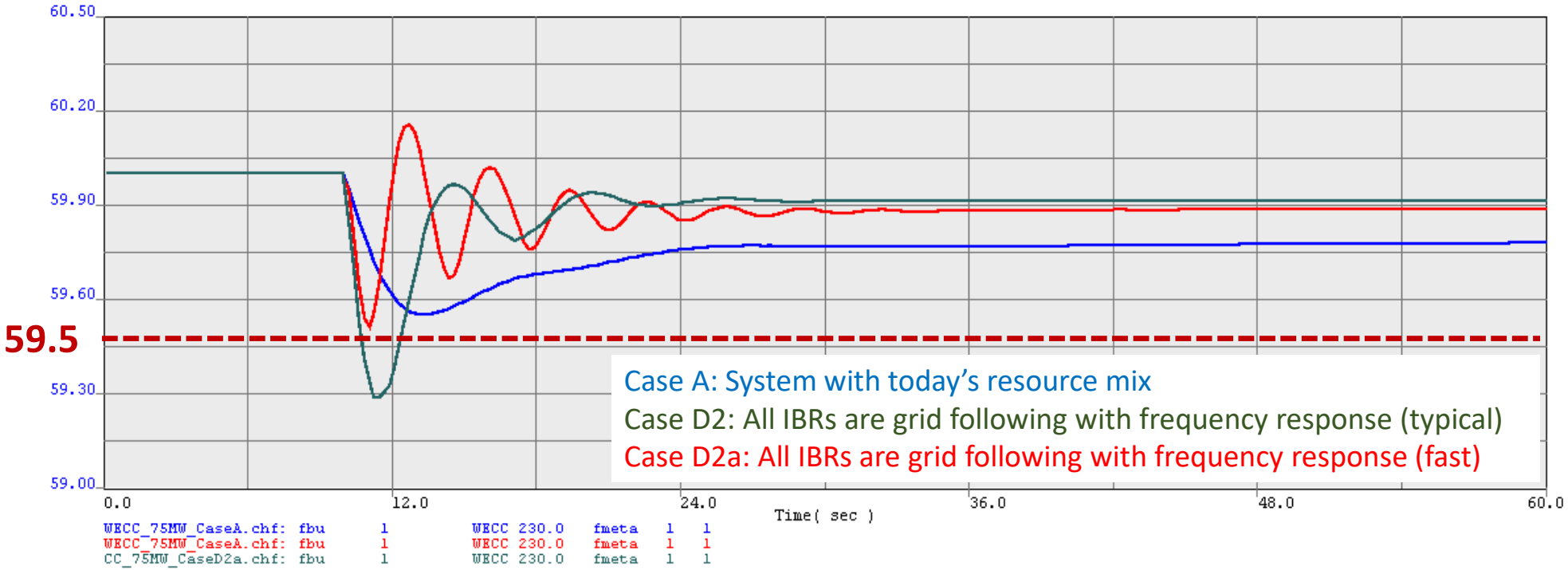
	Case A		Case D1		Case D2		Case D3		Case D123A	
Hydro Generation	20,800	28%	15,800	21%	15,800	21%	15,800	21%	15,800	21%
IBR - No Frequency Response	15,000	20%	55,000	73%	0	0%	0	0%	25,000	33%
IBR - Grid Following	0	0%	0	0%	55,000	73%	0	0%	15,000	20%
IBD - Grid Forming	0	0%	0	0%	0	0%	55,000	73%	15,000	20%
Palo Verde 1	1,400	2%	1,400	2%	1,400	2%	1,400	2%	1,400	2%
Palo Verde 2	1,400	2%	1,400	2%	1,400	2%	1,400	2%	1,400	2%
Palo Verde 3	1,400	2%	1,400	2%	1,400	2%	1,400	2%	1,400	2%
Thermal Synchronous	35,000	47%	0	0%	0	0%	0	0%	0	0%
TOTAL	75,000		75,000		75,000		75,000		75,000	
INERTIA (GW*SEC)	266		80		80		80		80	

Simulations – GFL models



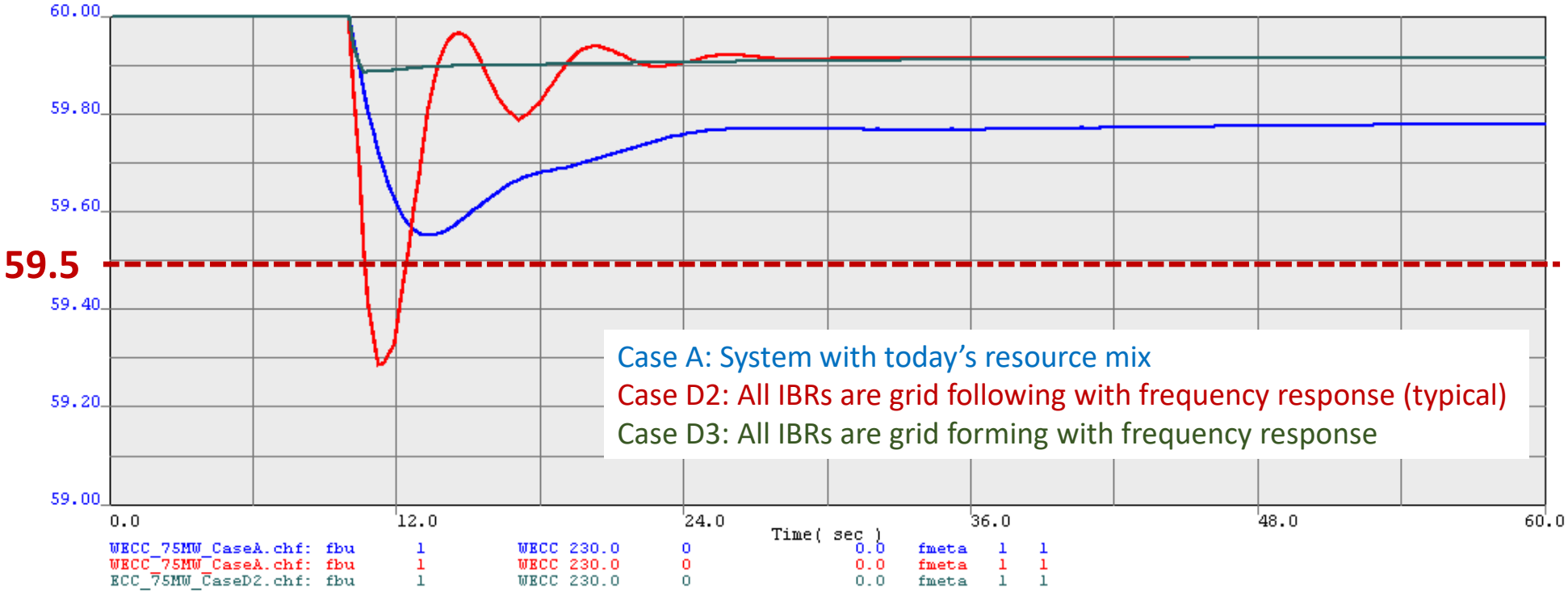
System is unstable with no IBR frequency response
Plant-level IBR frequency response alone is insufficient

Simulations – GFL models



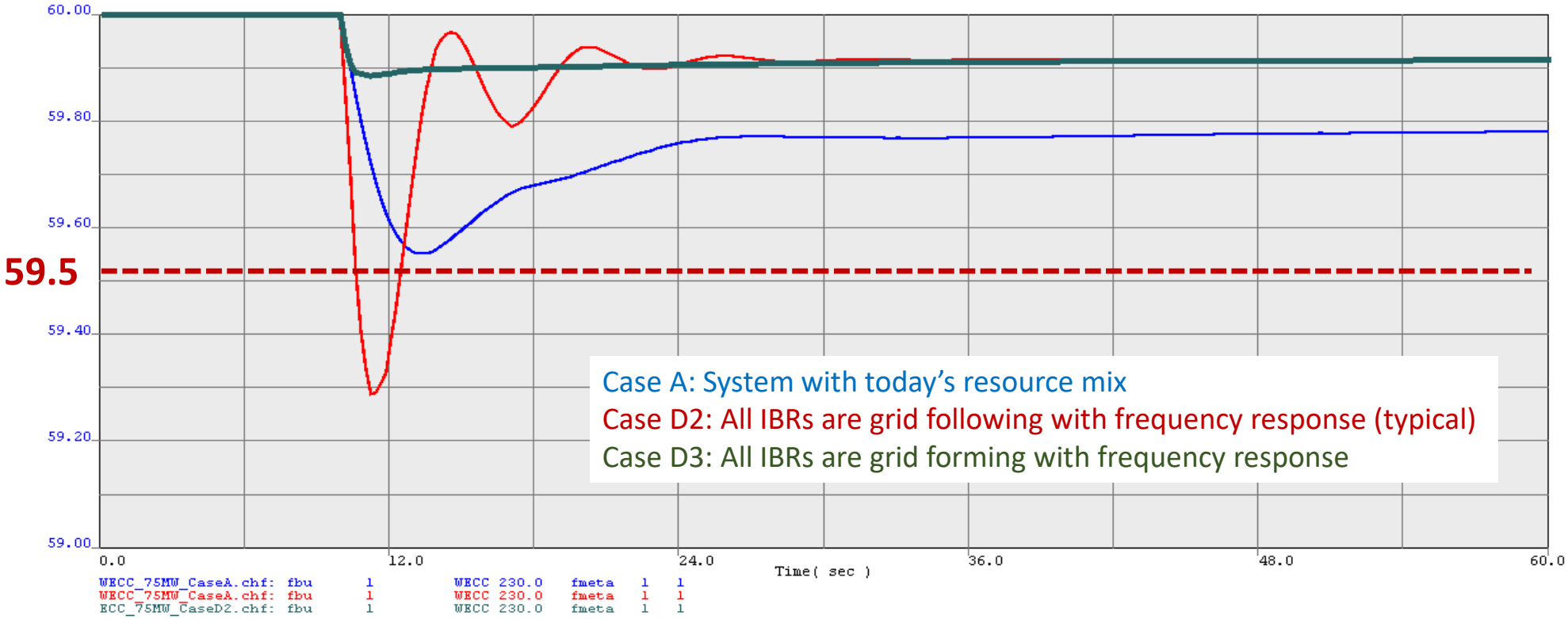
Accelerating response of plant level controls of grid-following resources results in better frequency performance, but introduces oscillatory system frequency response

Simulations – PNNL GFM Model



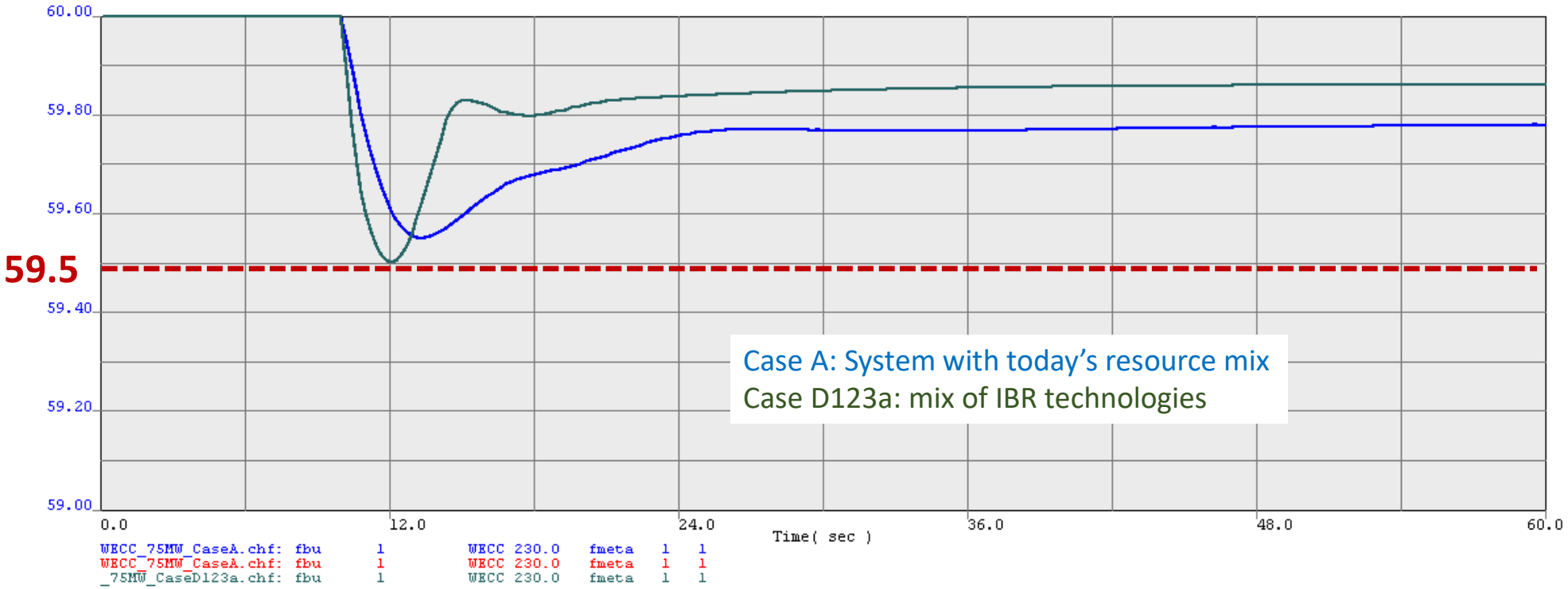
IBR Fast frequency response from grid-forming inverters can be effective in maintaining system frequency (inverter-level, droop control, headroom)

Simulations – EPRI GFM Model



IBR Fast frequency response from grid-forming inverters can be effective in maintaining system frequency (inverter-level, droop control, headroom)

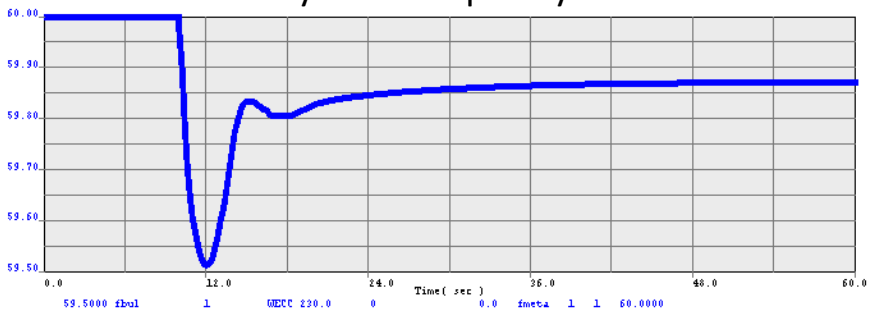
Simulations



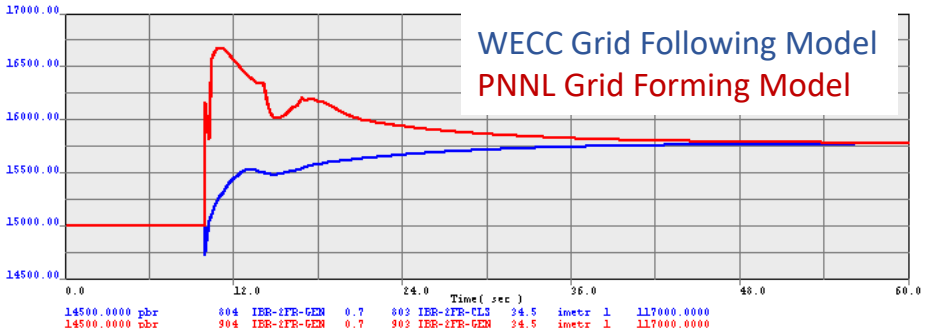
An appropriate mix of IBRs with fast and plant-level frequency response can achieve adequate frequency response in a system with high IBR percentage

Simulation Details for Case D123

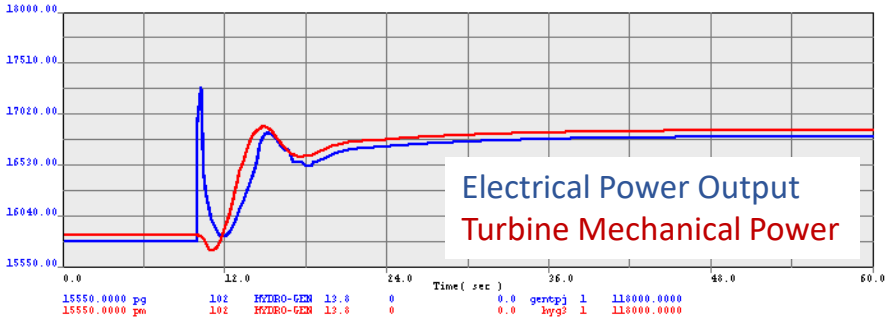
System Frequency



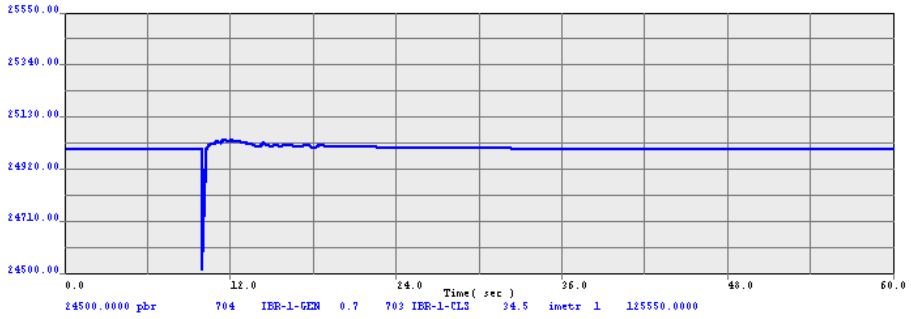
IBRs on Frequency Response



Hydro Generator



IBR with no Frequency Response



Conclusions

Significant amount of IBRs will be required to provide Frequency Response to maintain grid reliability to enable high percentage of IBR integration in the Western Interconnection

Significant percentage of IBRs must have Grid Forming capabilities and provide Fast Frequency response

Acknowledgements

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Technology Assessment Discussion

Wind power plants

Solar power plants

Energy storage (AC and DC coupled)