Modeling and Model Validation of Inverter Based Resources

ESIG/NAGF/NERC/EPRI Generation Interconnection Workshop

August 10, 2022

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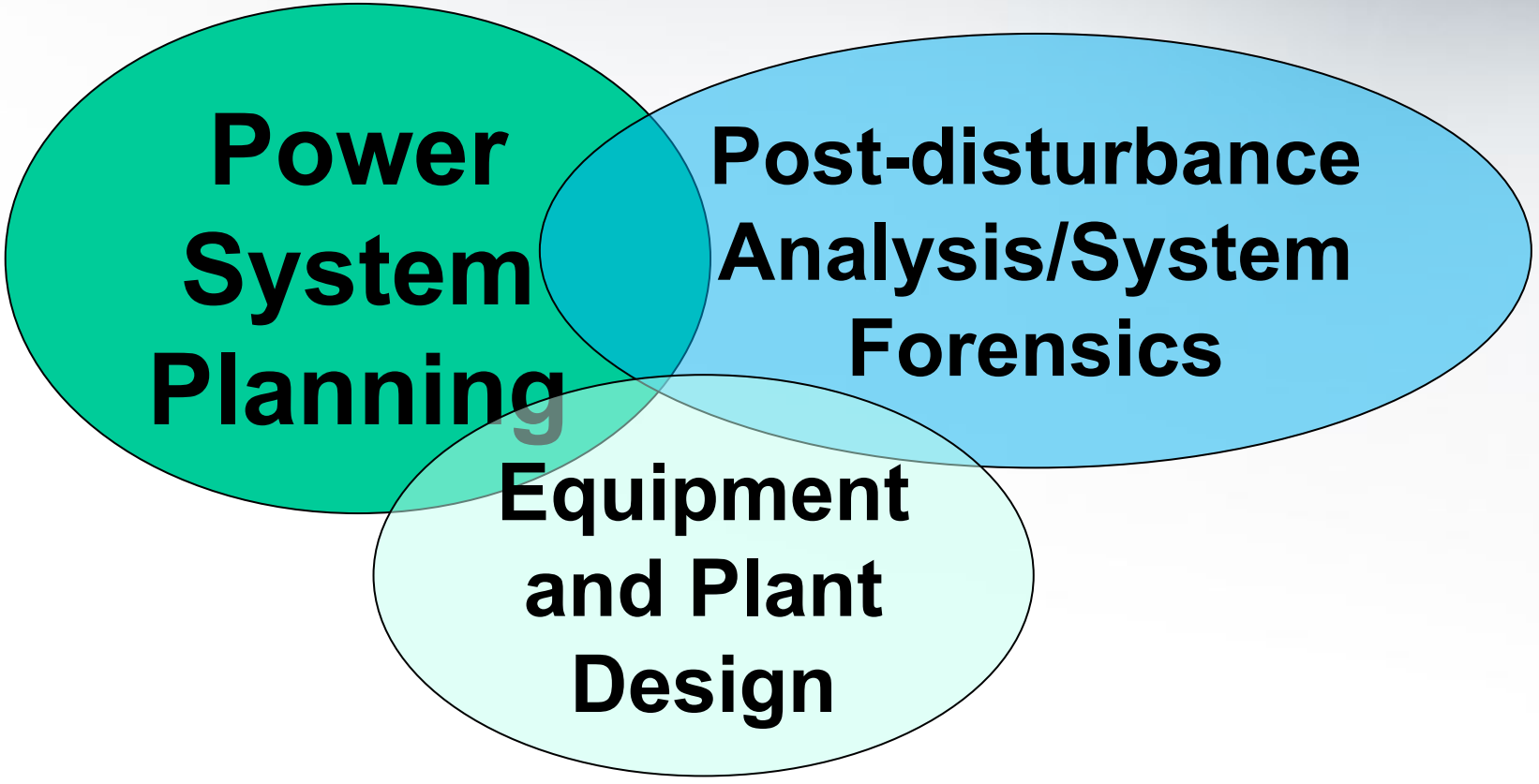
Various Uses of Models



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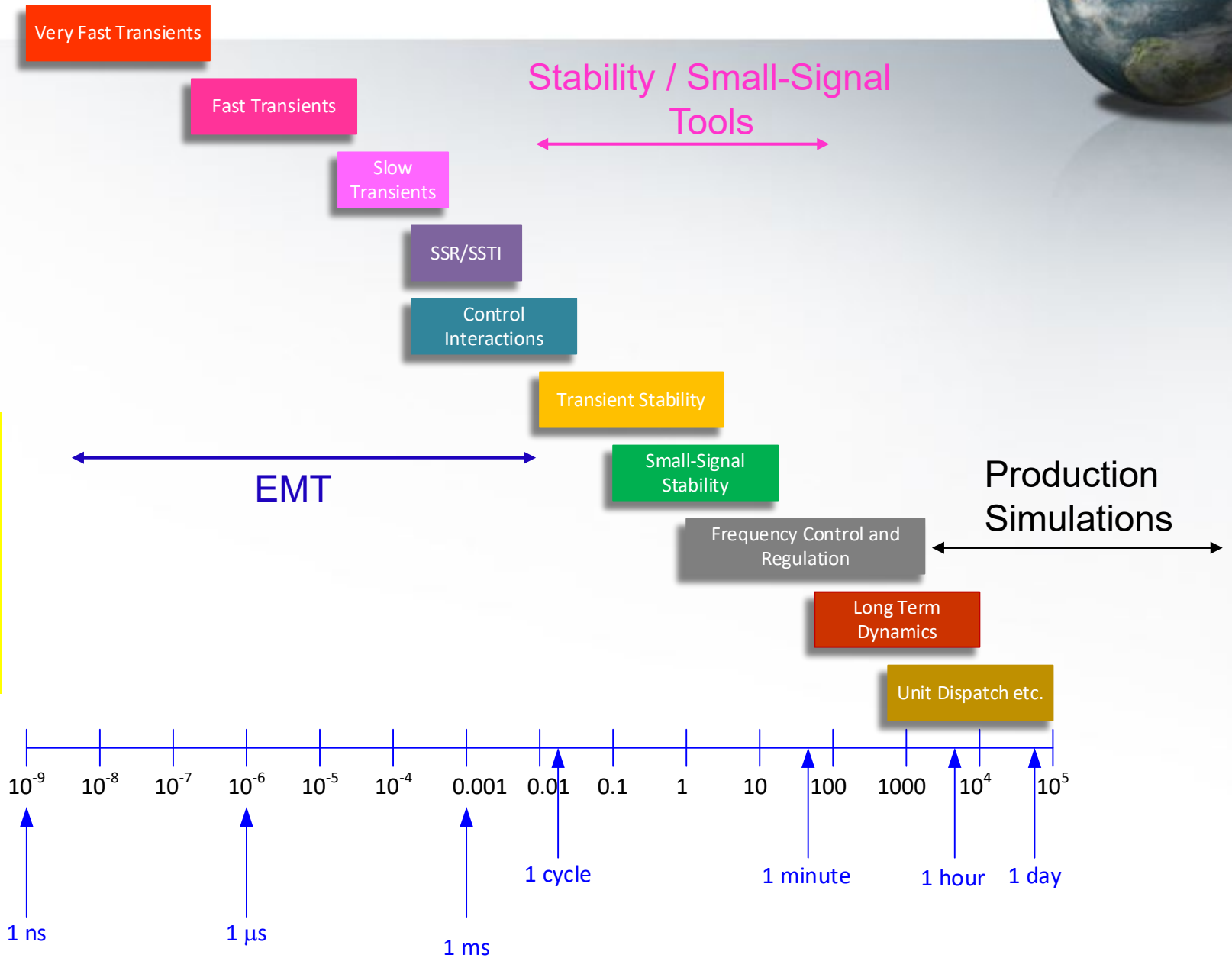
Power System Dynamics



Illustrative of the concepts; not an all encompassing diagram

Modeling Types

- Hardware in the Loop (HIL)
- EMT Models
- User-written “real-code” based
- User-written developed in native software tool’s language
- Standard-library (“generic”) parameterized

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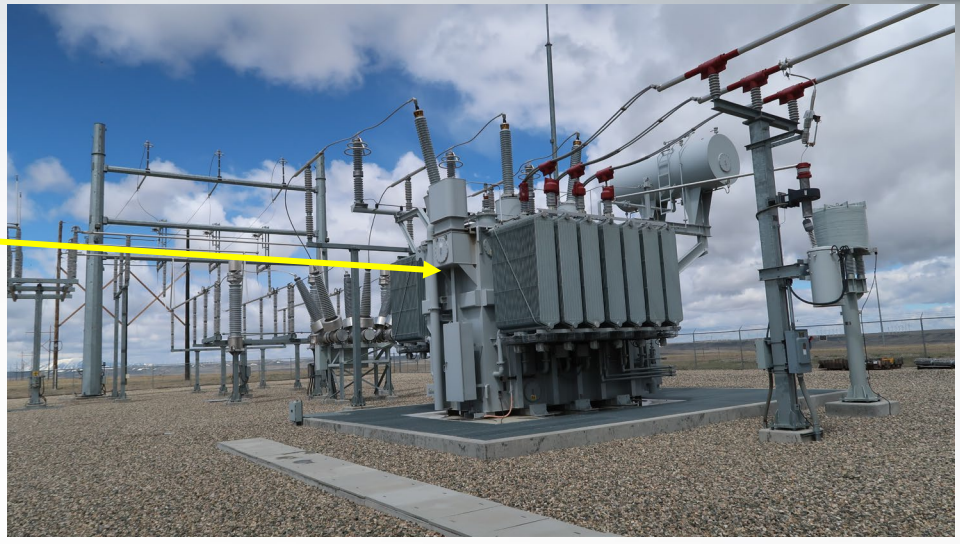
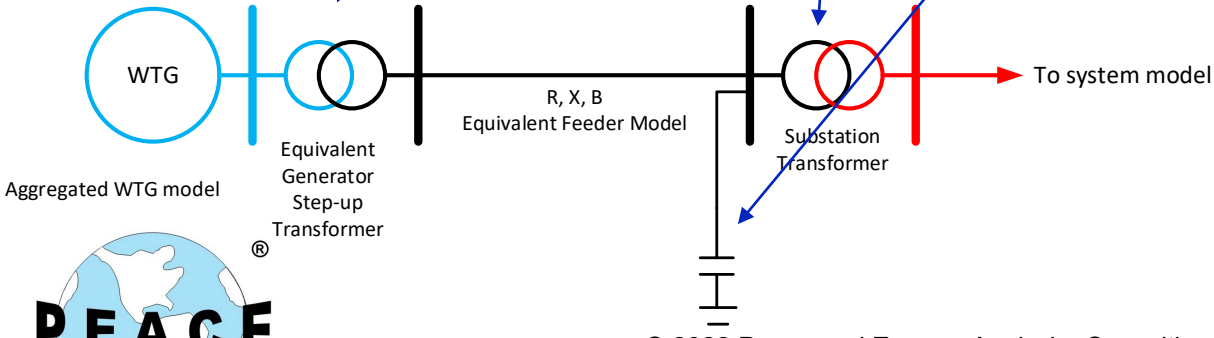
Aggregated Model Typically Used For System Studies

Pad Mount GSU

Substation Transformer



Shunt Capacitor Bank at POI



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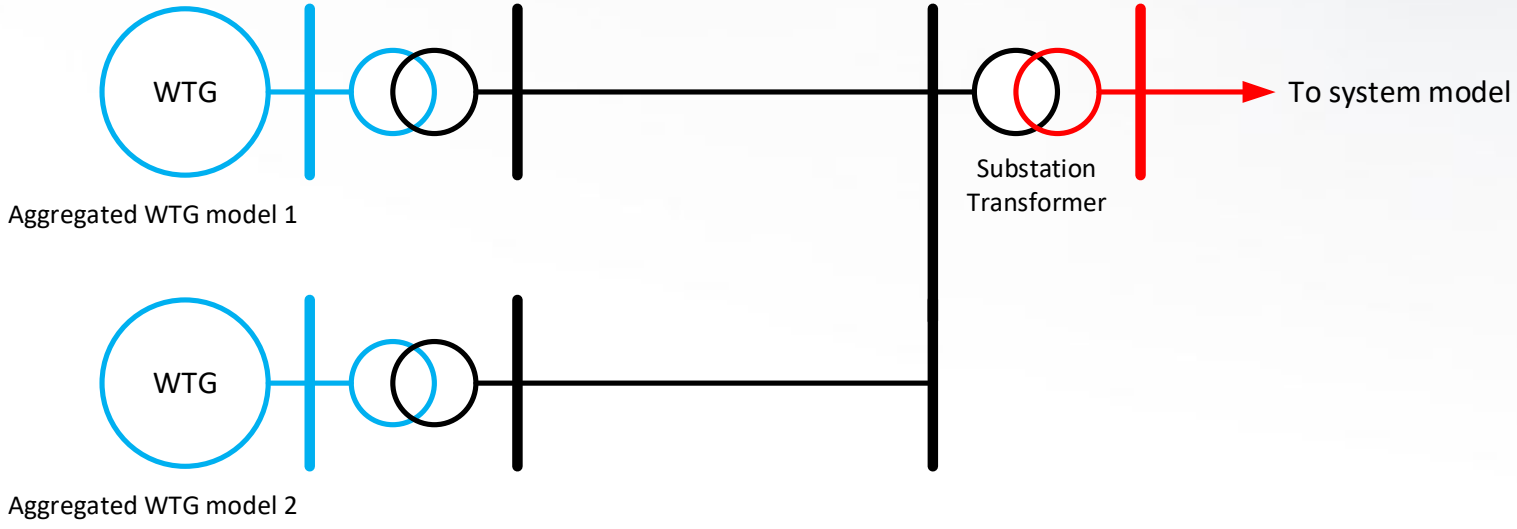
May Need More than One Aggregate

If multiple types of WTGs (or PV, etc.), then need more complex model, e.g.



Some Limitations

- Single-machine equivalent not adequate for detailed collector system design
- Actual voltage profile in the collector system (due to variations in output across individual turbines) will mean that reactive power output at point-of-interconnection (POI) will not be 100% accurate
- However, response at POI is very good and acceptable for power system studies in power flow, positive-sequence stability and EMT (Reference see: *J. Brochu, C. Larose, and R. Gagnon, "Validation of Single- and Multiple-Machine Equivalents for Modeling Wind Power Plants", IEEE Trans. On Energy Conversion, June, 2011. http://ieeexplore.ieee.org/document/5668524/*)

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Real Life Example for Power Flow

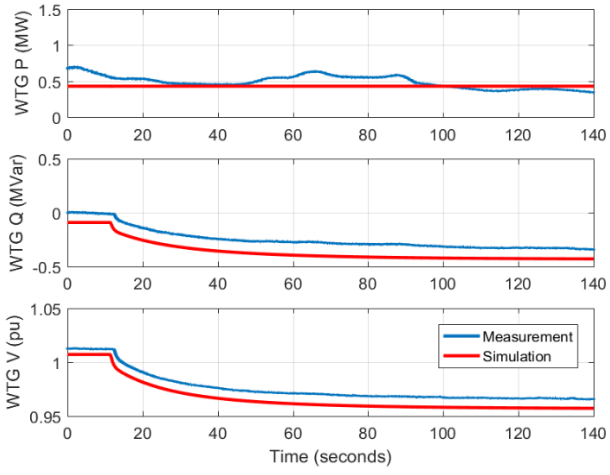
- Actual measurements at three large WPPs
- Simulations in interconnection wide model, using single machine aggregate model (2 significant figures after decimal point)

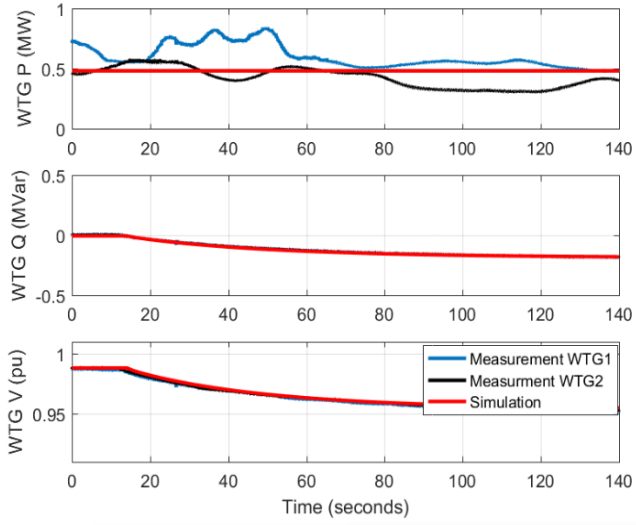
	Measured			Simulated		
	P (pu)	Q (pu)	V (pu)	P (pu)	Q (pu)	V (pu)
WPP1	0.15	-0.28	1.021	0.15	-0.28	1.025
WPP1	0.15	0.098	1.046	0.15	0.098	1.047
WPP2	0.25	-0.33	1.021	0.25	-0.33	1.021
WPP2	0.35	0.25	1.041	0.35	0.27	1.049
WPP3	0.66	-0.45	1.036	0.66	-0.45	1.036
WPP3	0.69	0.29	1.06	0.69	0.29	1.06

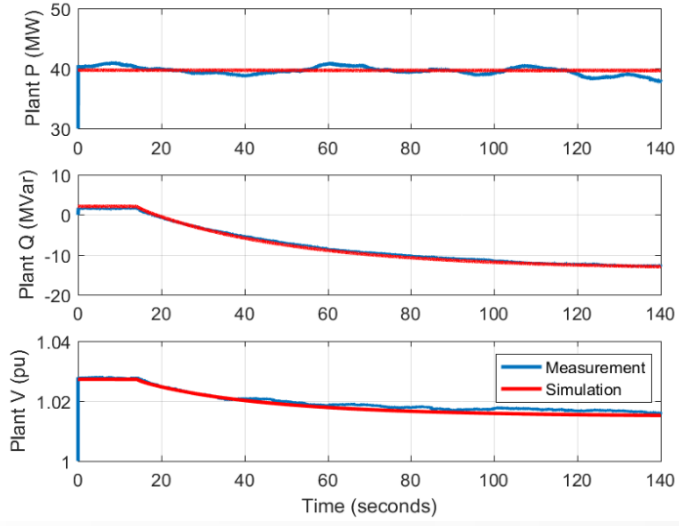
Real Life Example for Dynamics

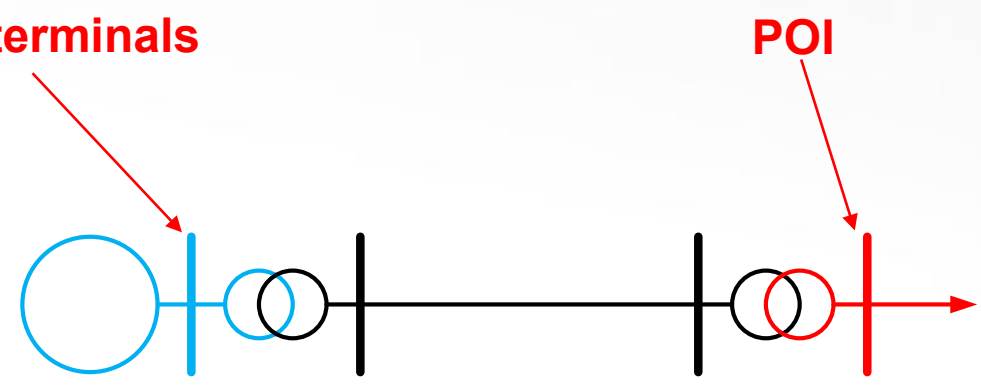
Individual IBR monitoring not needed for validation; done here for interest sake

Of course not always perfect, since aggregate cannot emulate V/Q correctly at every node in collector system









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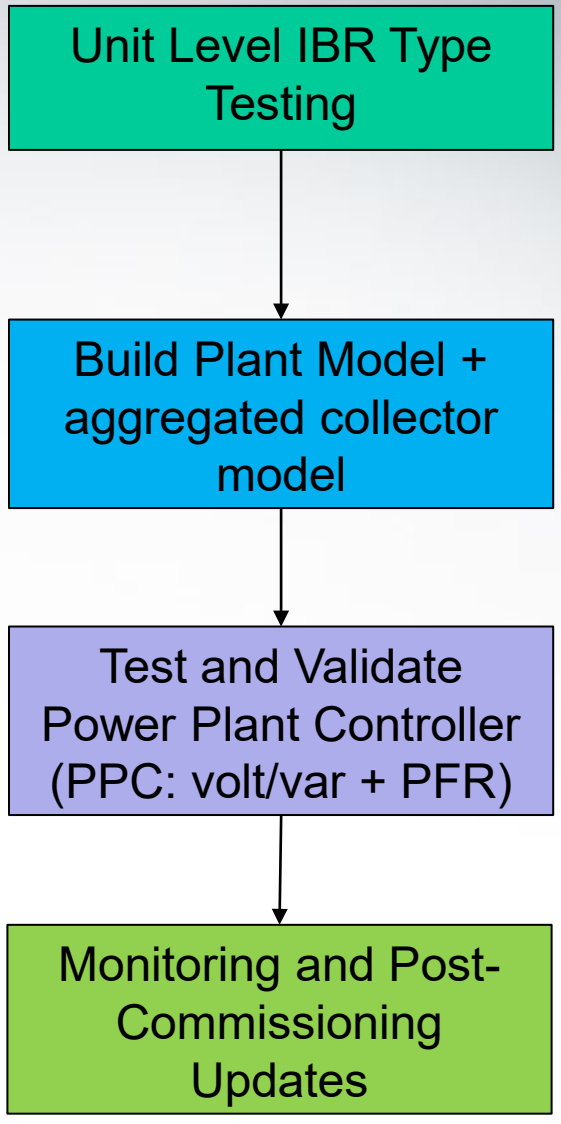
Approach to Model Validation

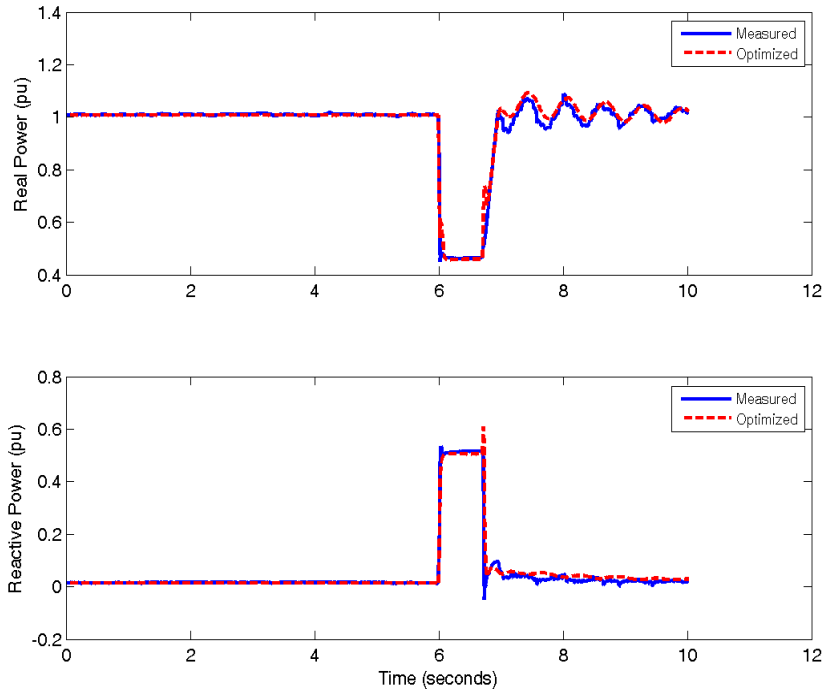
IEEE P2800.2 WG is presently working hard to defined all this through an industry wide effort – this guide will be needed once complete to offer guidance on the details of the approach

Here we give a high-level simple depiction of the concept, based on past work/experience

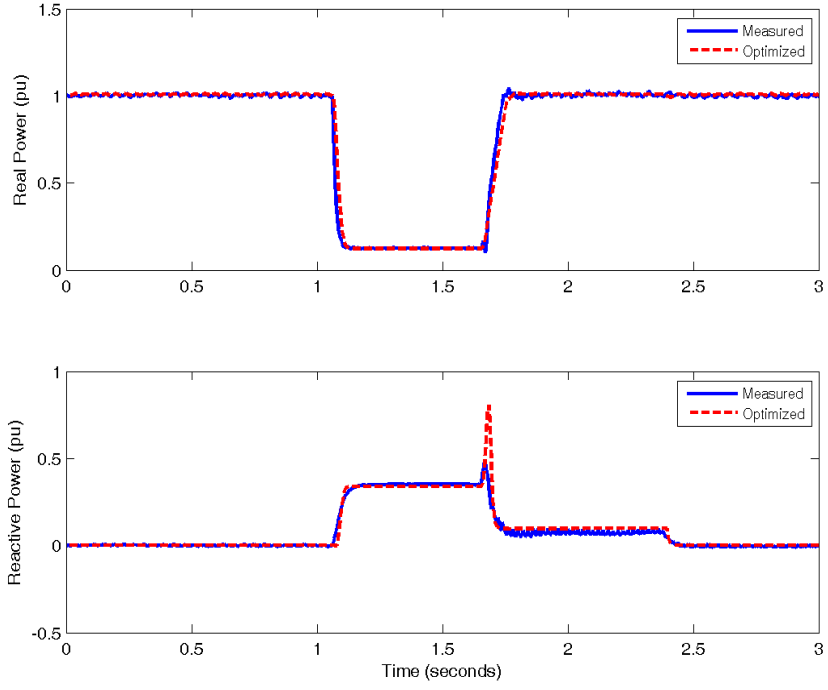


Single IBR Unit Validations

Type 4a (Vendor 1)

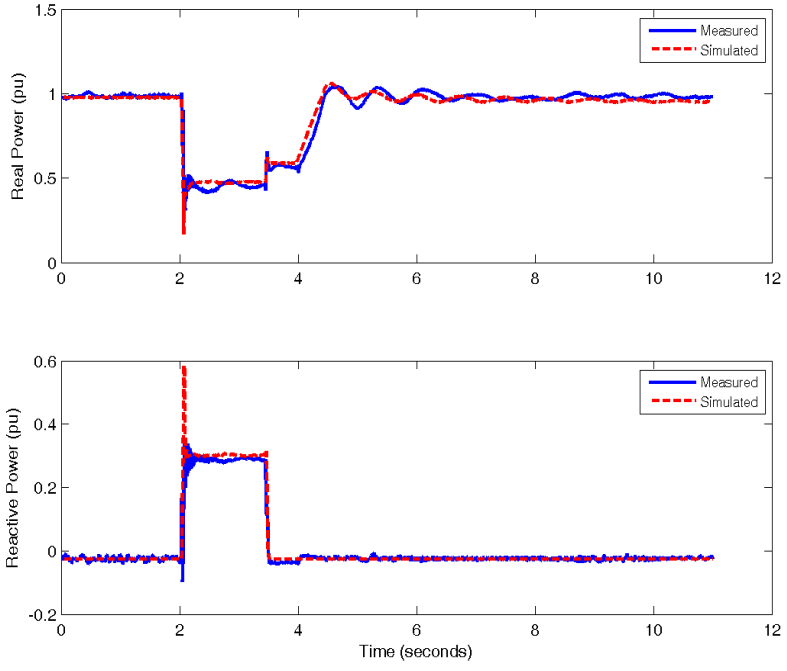


Type 4b (Vendor2)

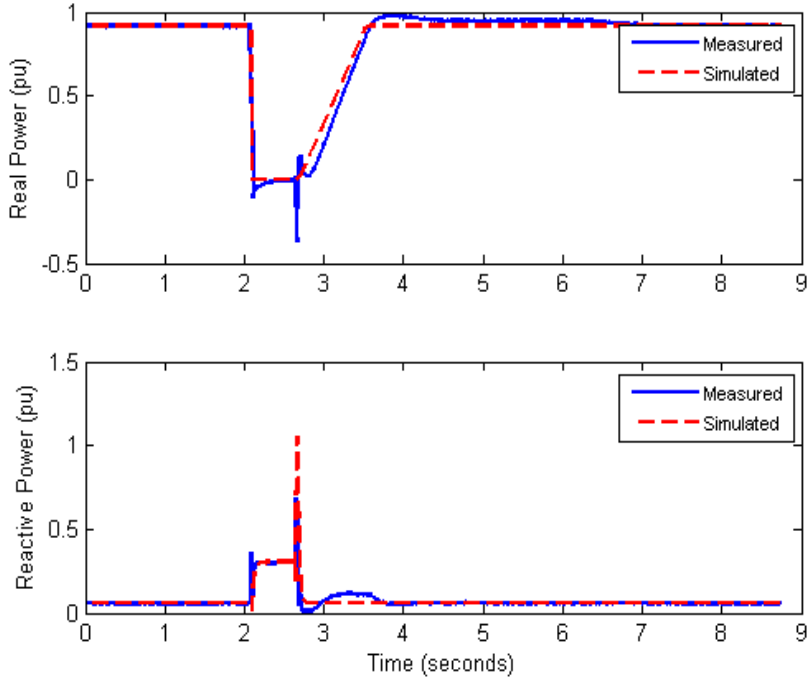


Single WTG/PV Validations

Type 3 (Vendor 2)



PV Inverter (Vendor4)



Field Testing a IBR Plant PPC

Volt/Var Testing:

- Switch a large transmission MSC (if possible, coordinate with TO)
- Switch MSC in collector system (where possible)
- Voltage reference step tests on the plant-level controller
  - Small steps (e.g. 1 to 3 %)

Primary Frequency Response Testing:

- Disturbance recording
- Frequency reference step tests

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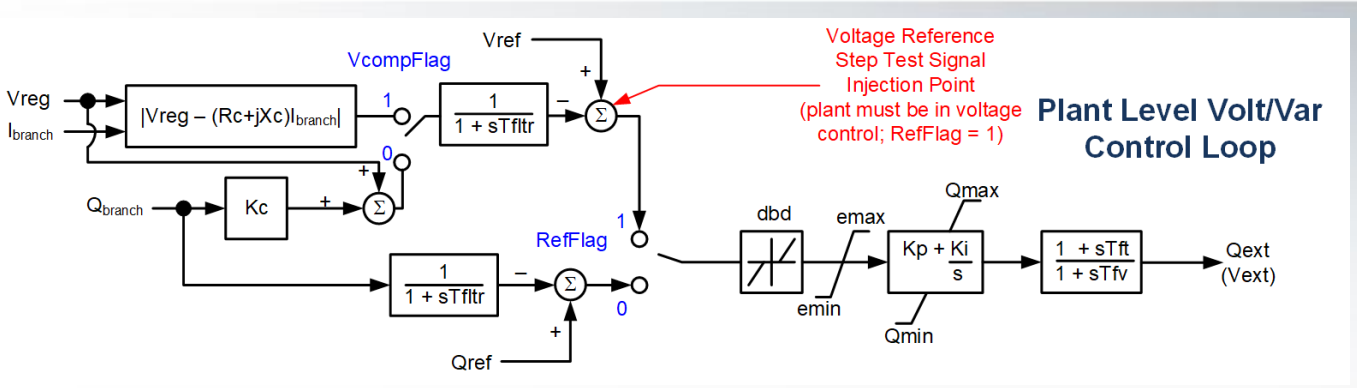
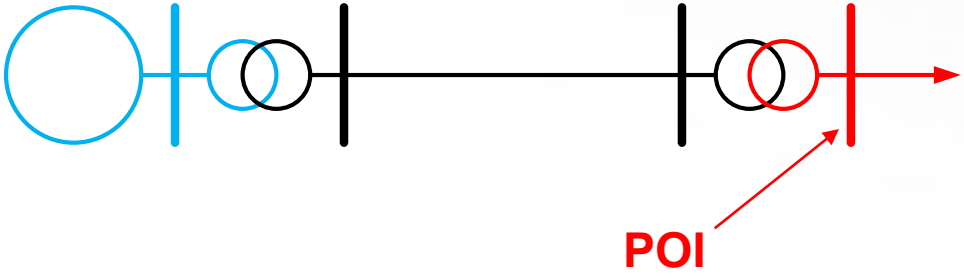
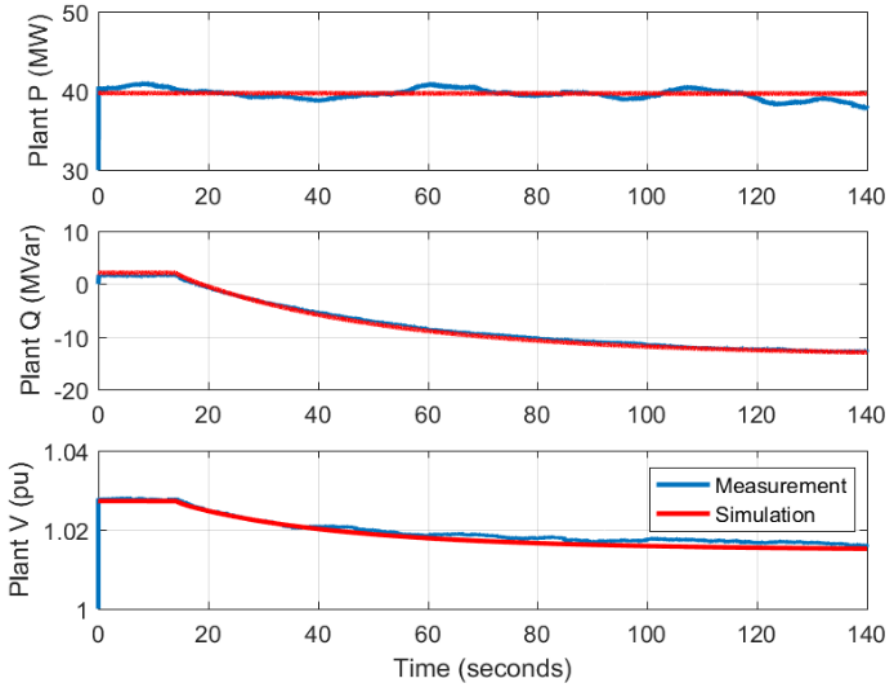
Examples of Real Tests







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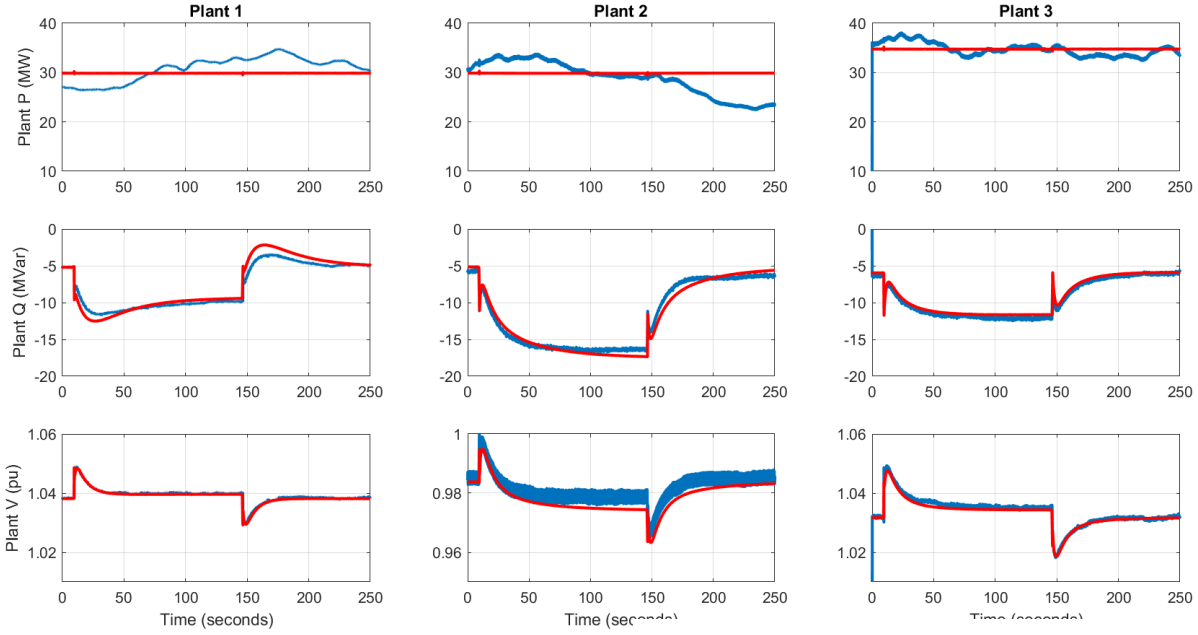
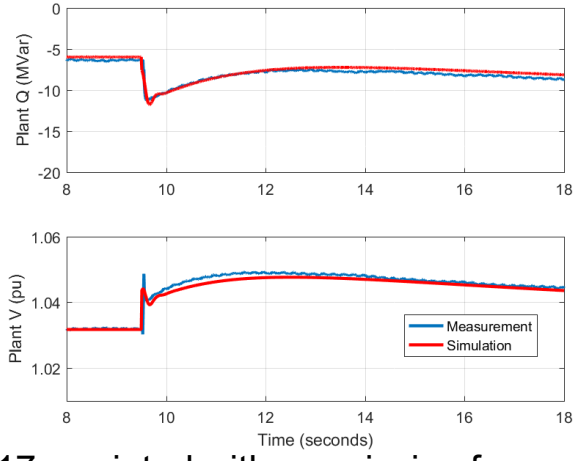
MSC Switching [1]





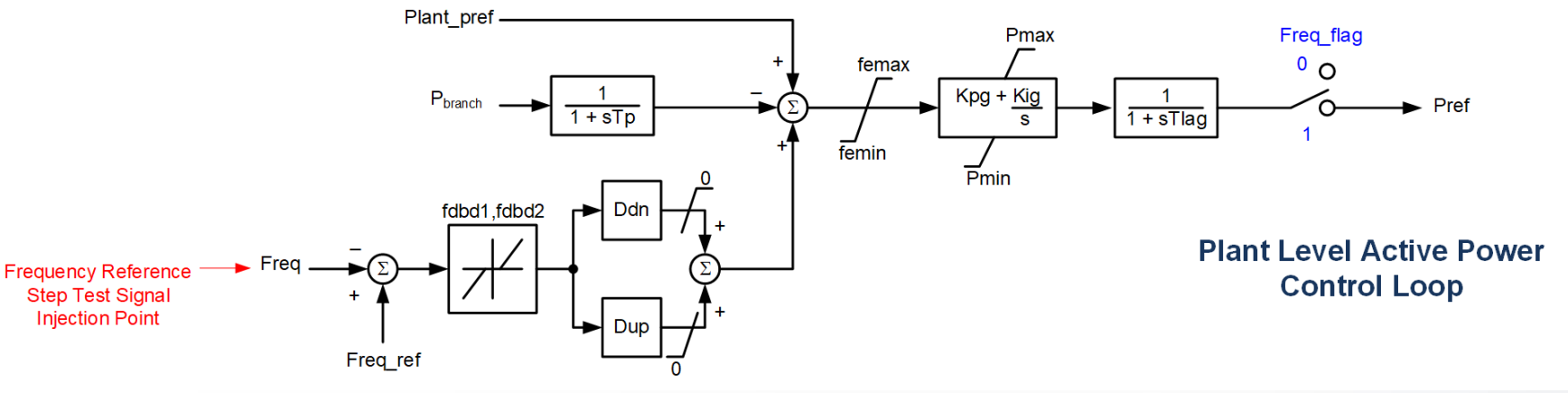
Transmission MSC Switching

Recording/Simulation on all three (3) WPPs in the vicinity of the MSC

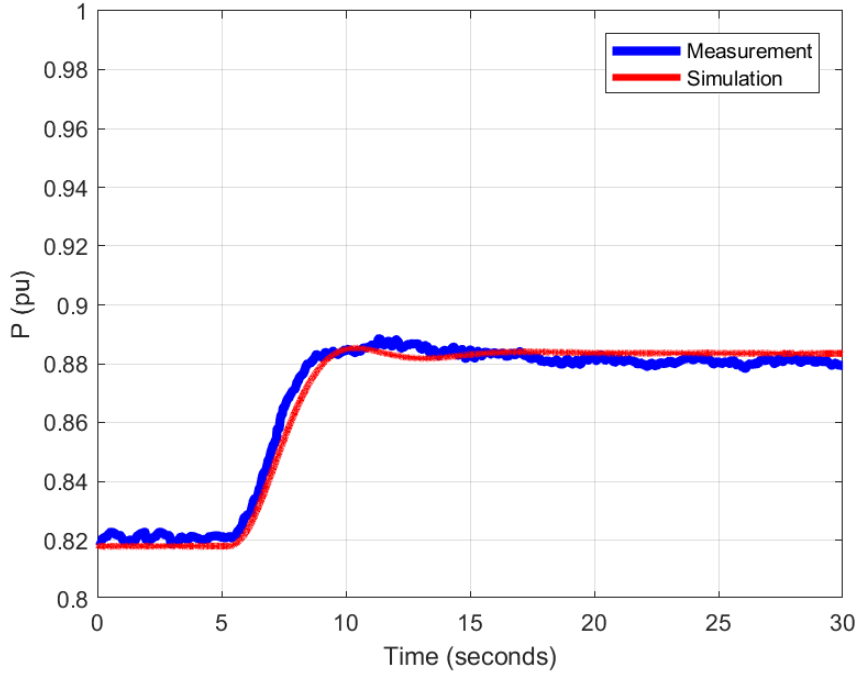
(Model first tuned based on Vref Step, then retested with MSC switching)

Confirms turbine-level local V-control

Frequency Response Step Test

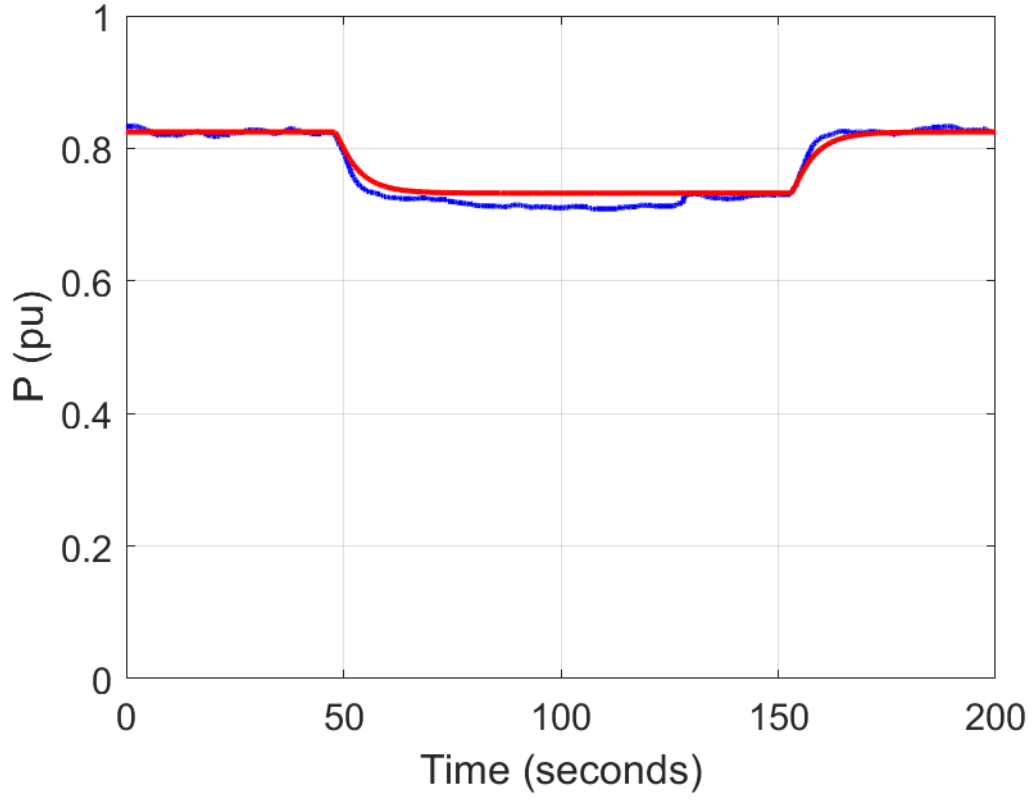


- WTG (type 3 in this case) with actual primary frequency response controls enabled
- Validation with Freq. Ref. Step test using 2nd generation generic models



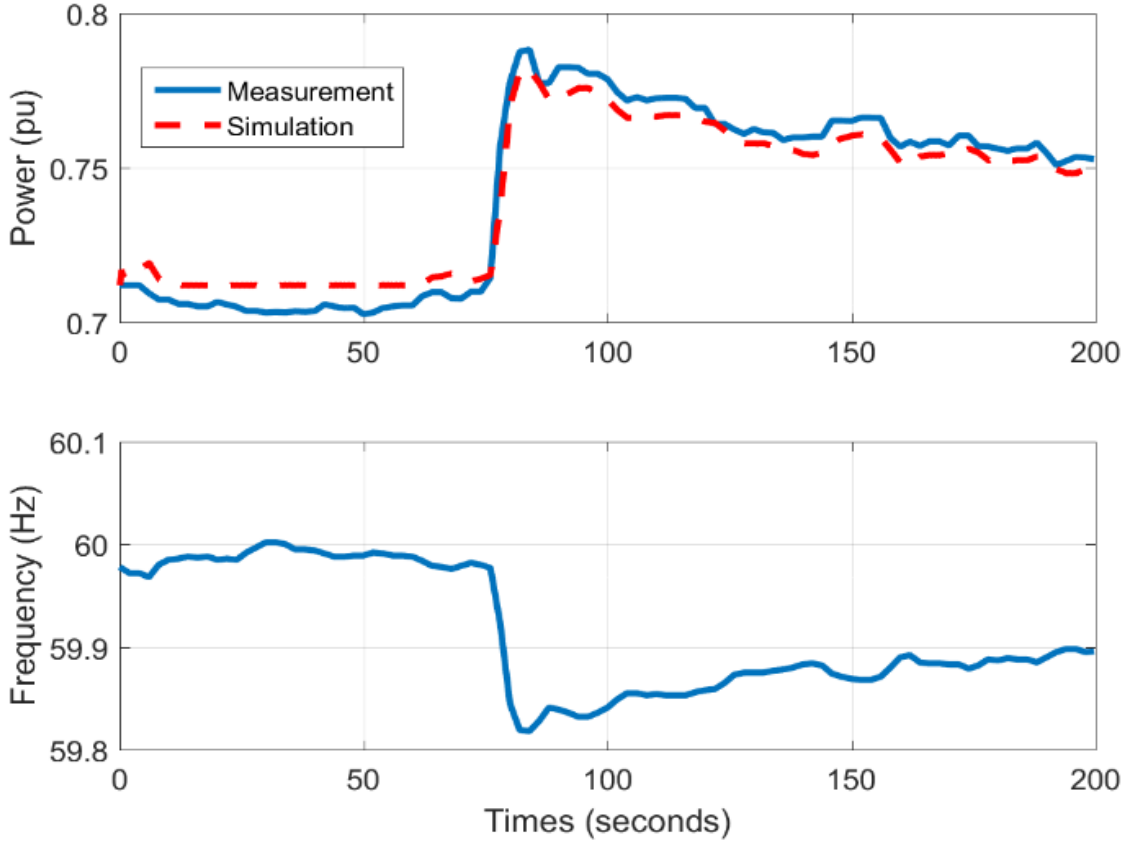
Frequency Response Step Test

Large IBR plant, using detailed vendor specific user-written models for IBR units and PPC



Disturbance Monitoring

Actual response of a type 4 WTG in a real system to a frequency event



Post-Commissioning Updates

- Disturbance monitoring is the best way to capture events and routinely check the models
- If discrepancies found, revalidation may be necessary
- Material changes to the plant may also warrant revalidation

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Conclusions

- Modeling is important with good and useful models
- Proper validation of models is important
- Knowing which models to use and where is extremely important
- <u>Moderation is the Key:</u>
  - Do not get stuck in the details so as to loose sight of the purpose of modeling
  - Do not brush over simple yet important details

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REFERENCES

[1] P. Pourbeik, N. Etzel and S. Wang, “Model Validation of Large Wind Power Plants Through Field Testing”, *IEEE Transactions on Sustainable Energy*, Available on-line since November, 2017 (http://ieeexplore.ieee.org/document/8118170/)

[2] P. Pourbeik, J. Sanchez-Gasca, J. Senthil, J. Weber, P. Zadehkhost, Y. Kazachkov, S. Tacke, J. Wen and A. Ellis, “Generic Dynamic Models for Modeling Wind Power Plants and other Renewable Technologies in Large Scale Power System Studies”, IEEE Trans. on Energy Conversion, pp. 1108 – 116, September, 2017 http://ieeexplore.ieee.org/document/7782402/

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