

Modeling and Model Validation of Inverter Based Resources

***ESIG/NAGF/NERC/EPRI Generation
Interconnection Workshop***

August 10, 2022

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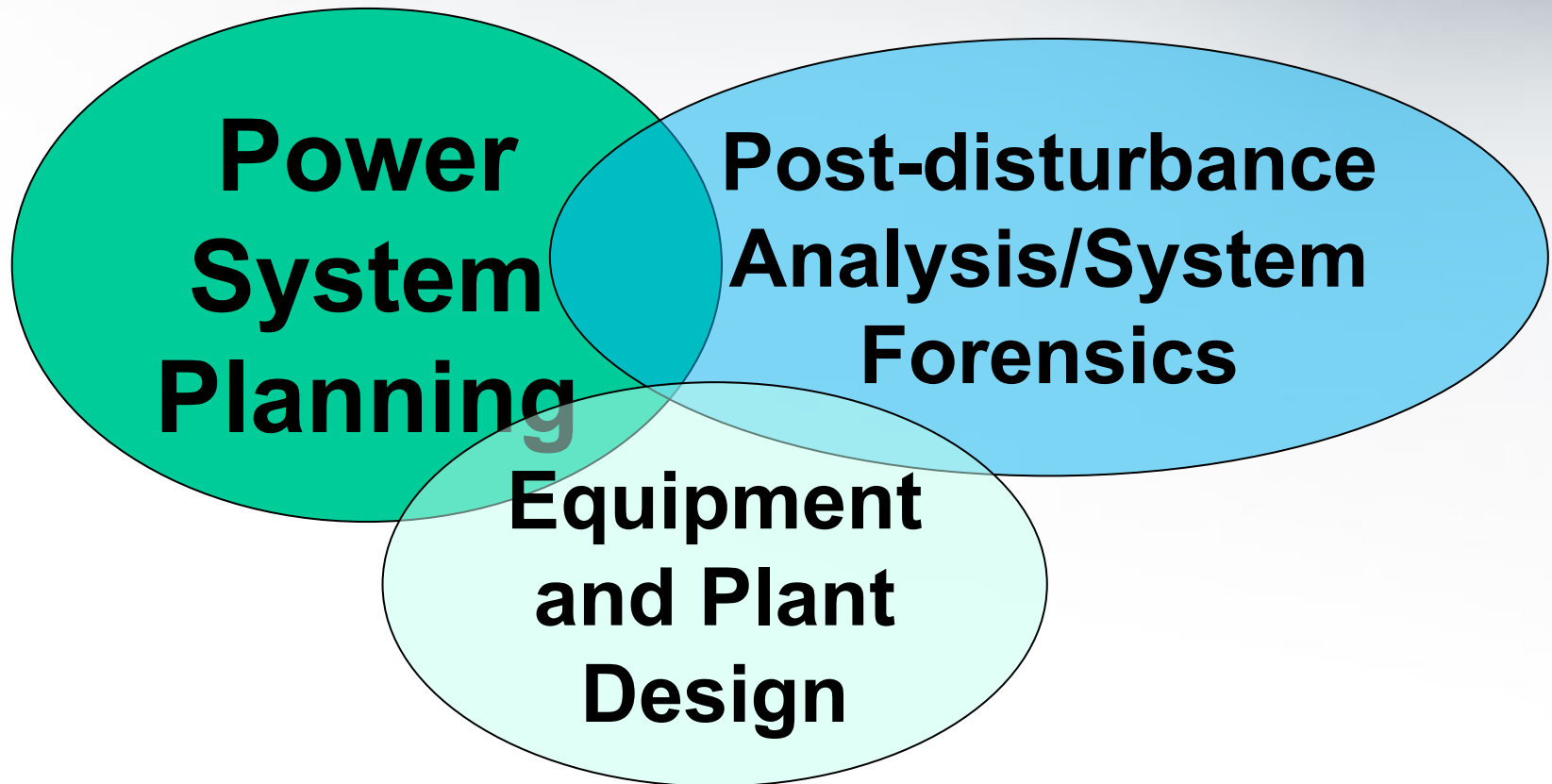


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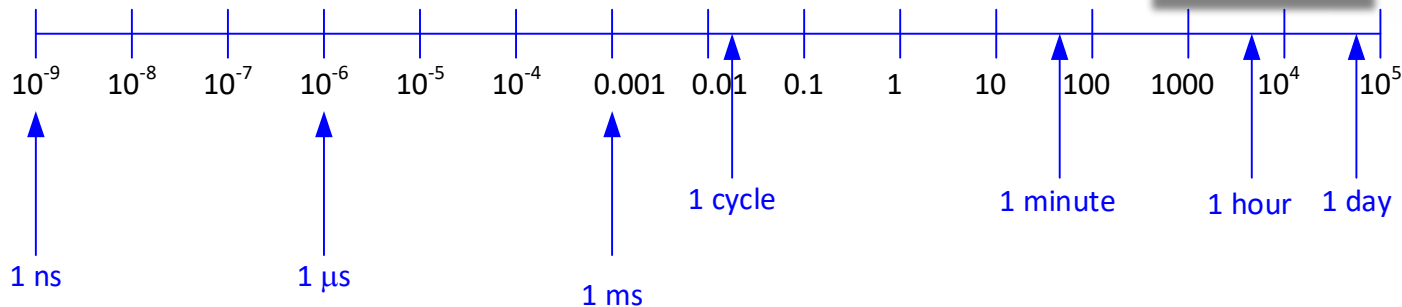
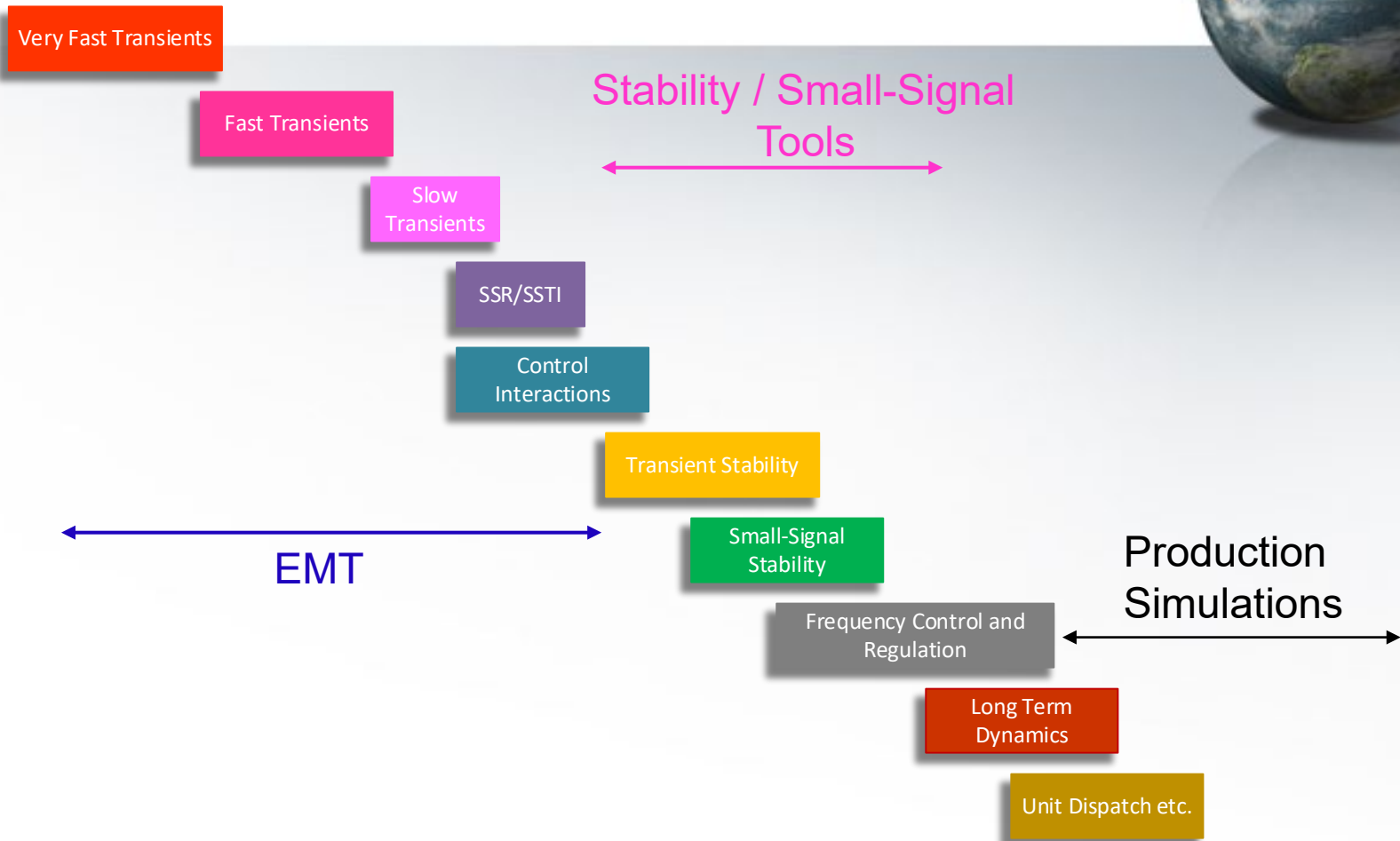
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Various Uses of Models



Power System Dynamics



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



Aggregated Model Typically Used For System Studies



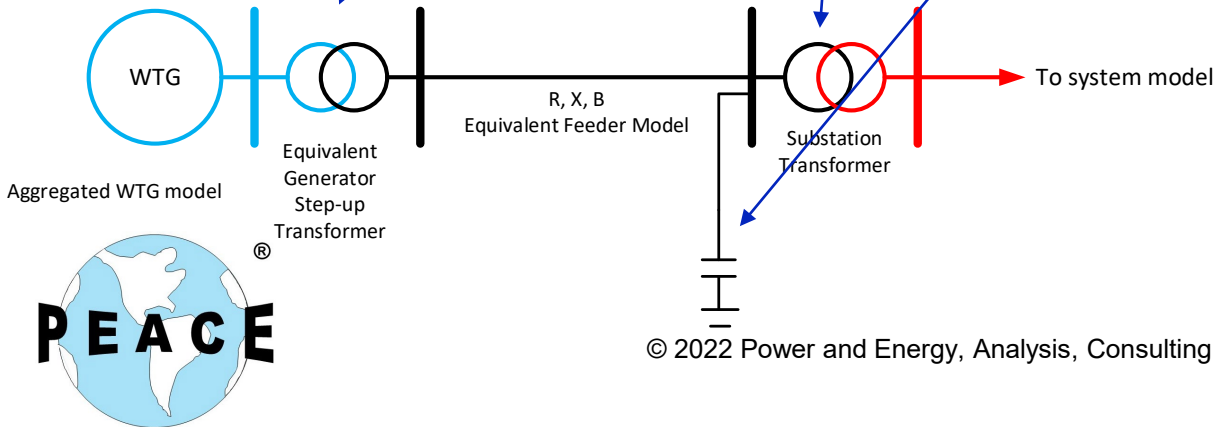
Pad Mount GSU



Substation Transformer



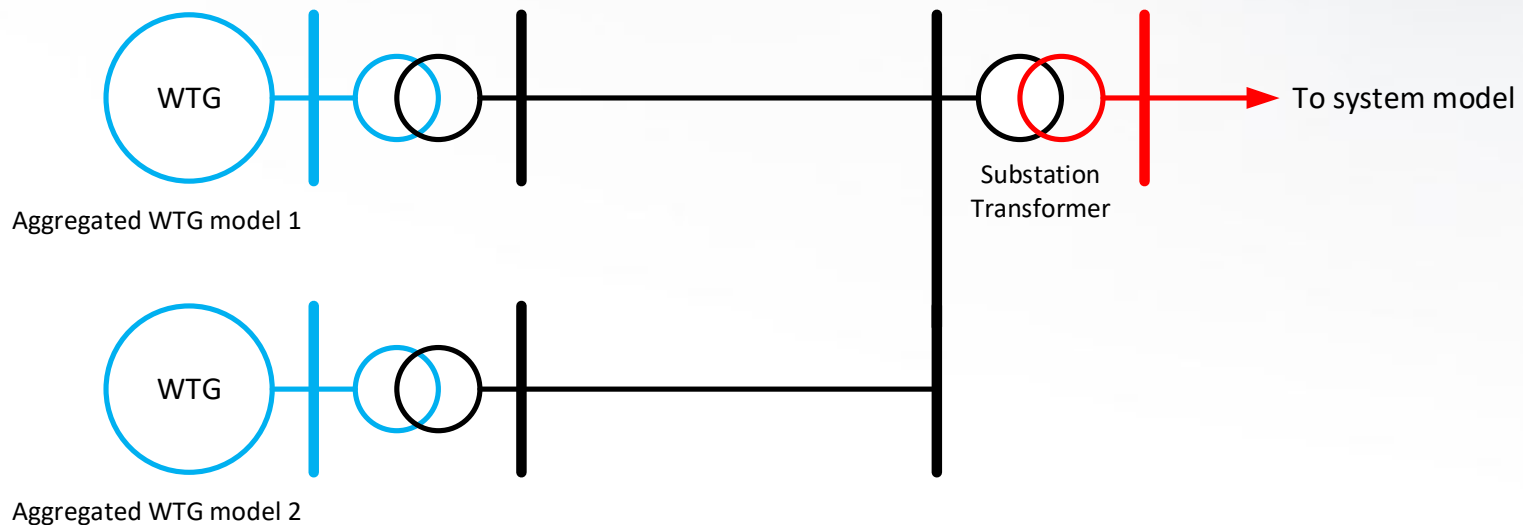
Shunt Capacitor Bank at POI



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/>)



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

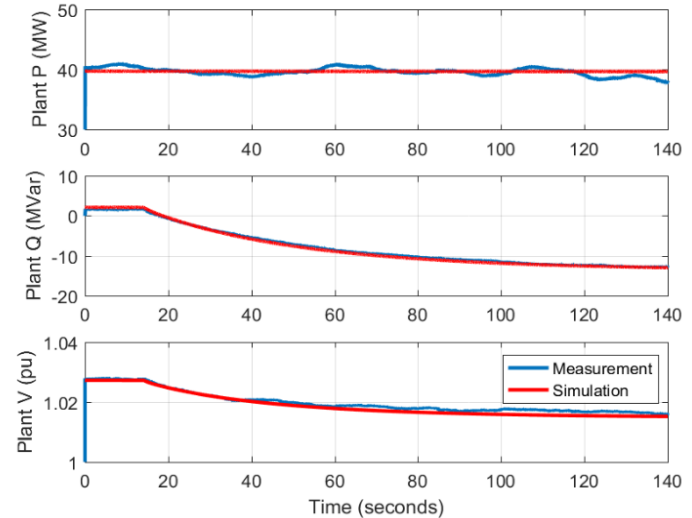
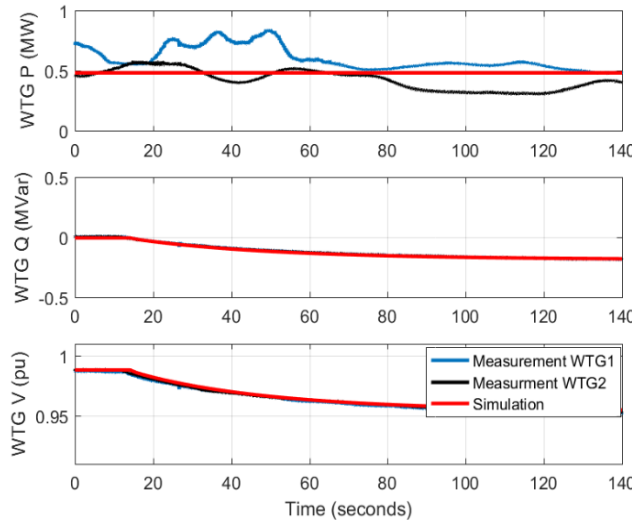
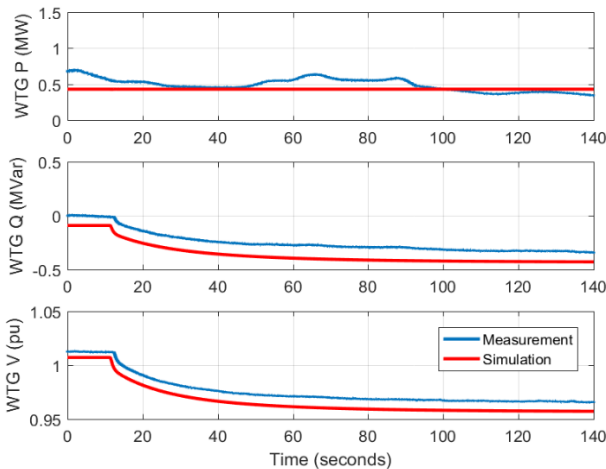


Real Life Example for Dynamics



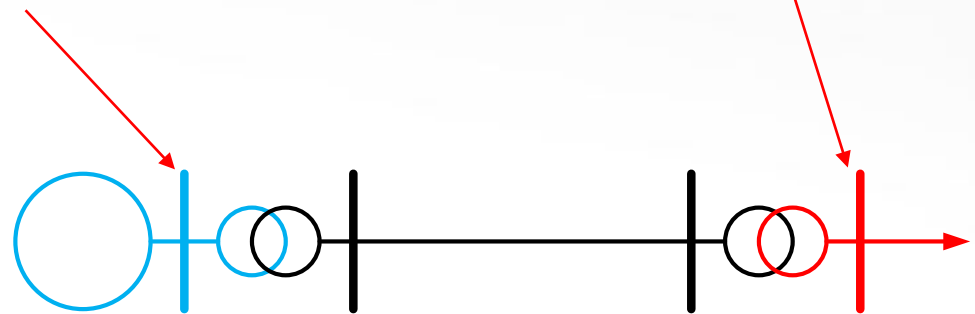
Individual IBR monitoring not needed for validation; done here for interest sake

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



WTG terminals

POI



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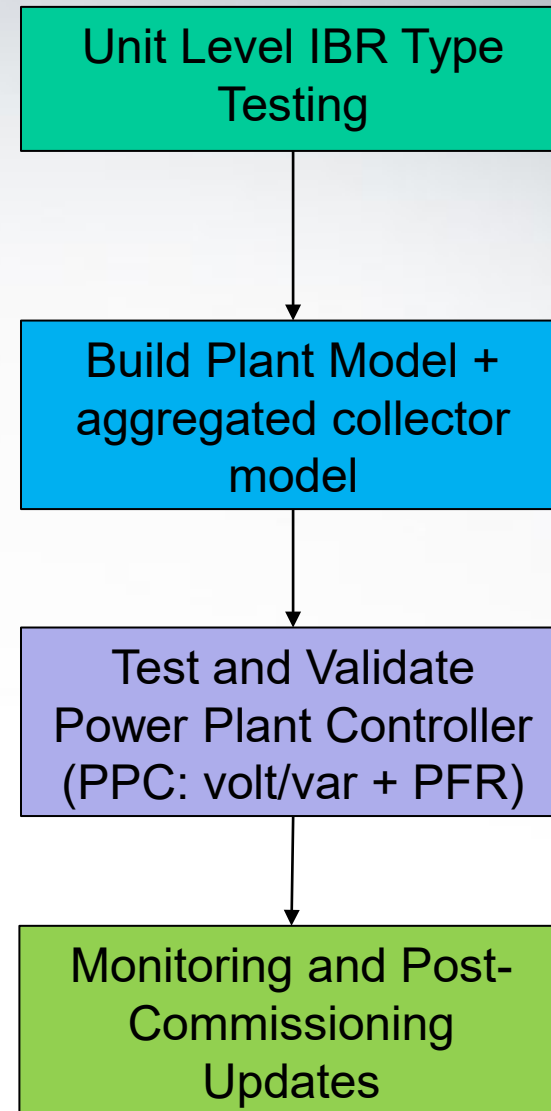


Approach to Model Validation



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

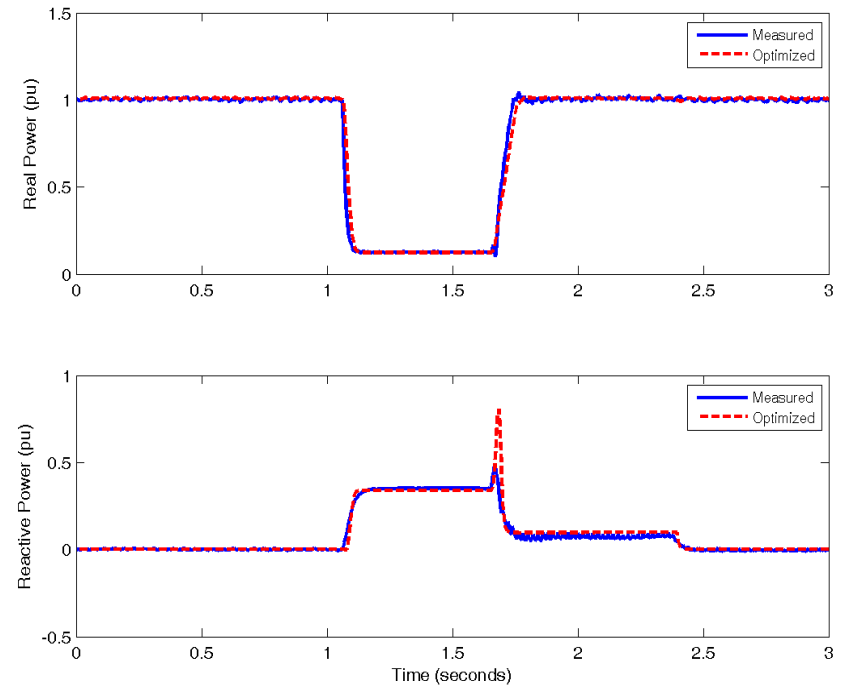
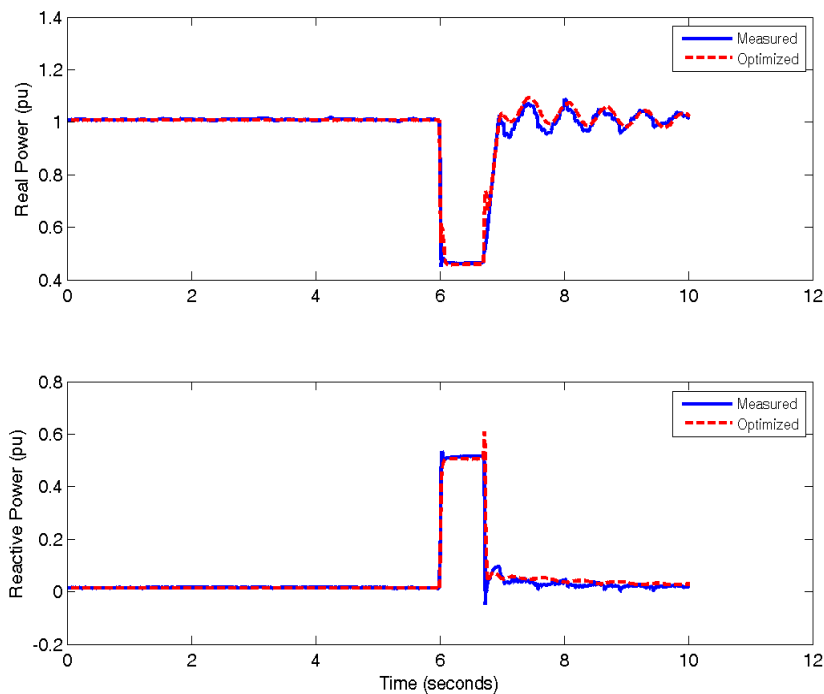


Single IBR Unit Validations



Type 4a (Vendor 1)

Type 4b (Vendor2)



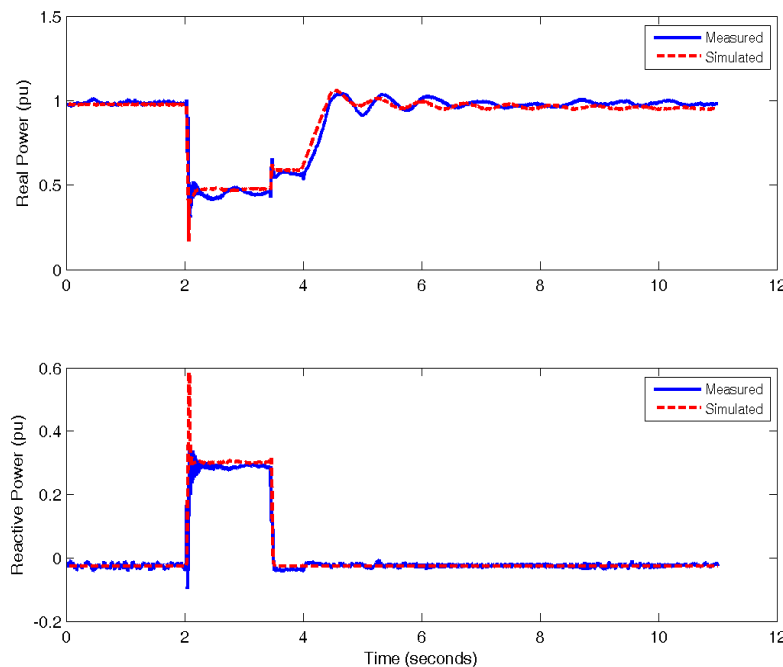
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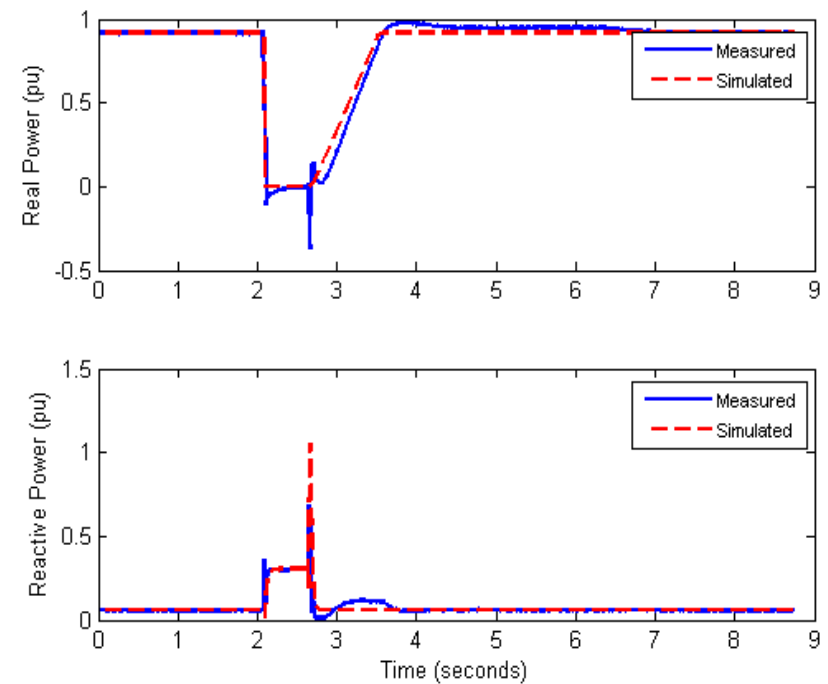
Single WTG/PV Validations



Type 3 (Vendor 2)



PV Inverter (Vendor4)



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Field Testing a IBR Plant PPC



Volt/Var Testing:

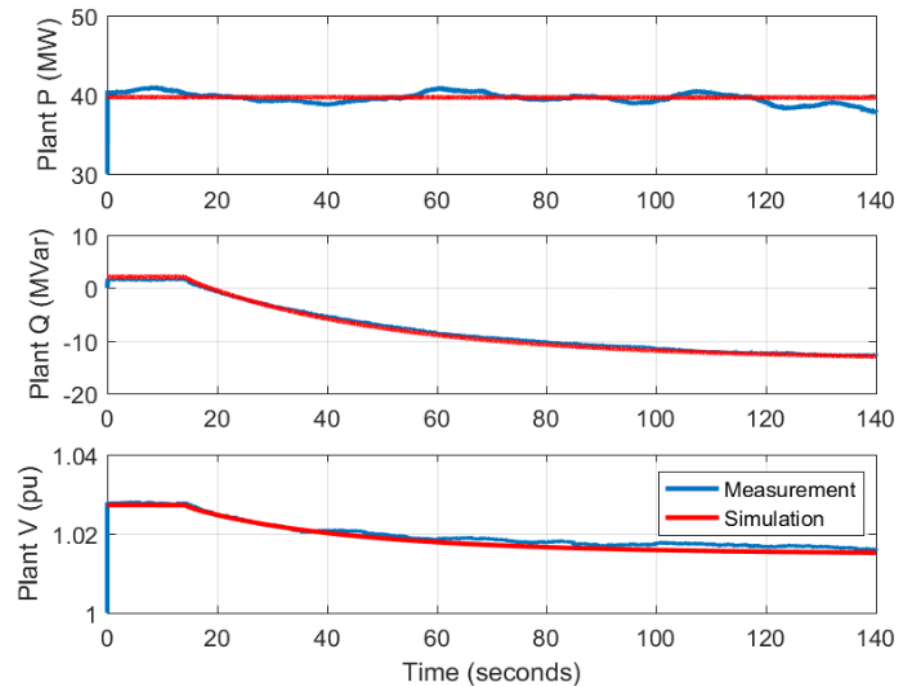
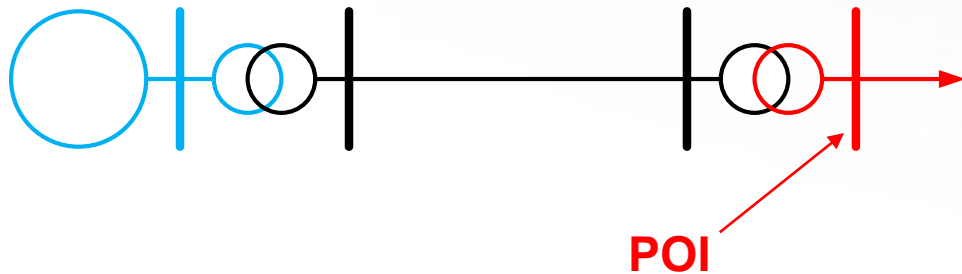
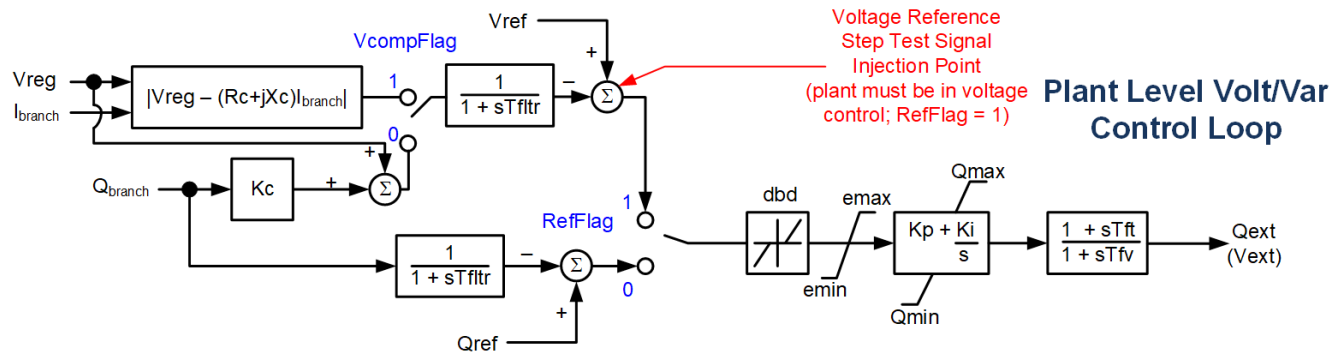
- Switch a large transmission MSC (if possible, coordinate with TO)
- Switch MSC in collector system (where possible)
- Voltage reference step tests on the plant-level controller
 - Small steps (e.g. 1 to 3 %)

Primary Frequency Response Testing:

- Disturbance recording
- Frequency reference step tests



Examples of Real Tests



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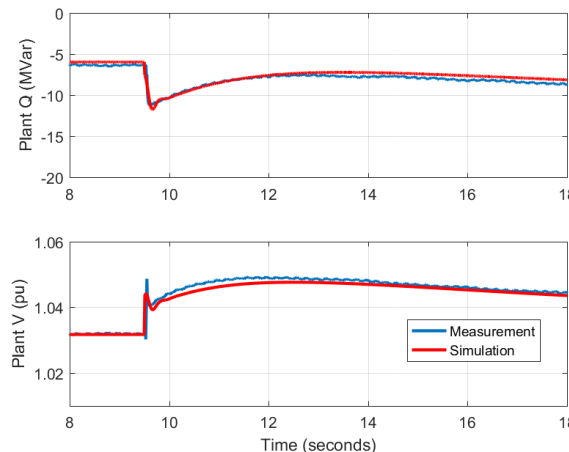
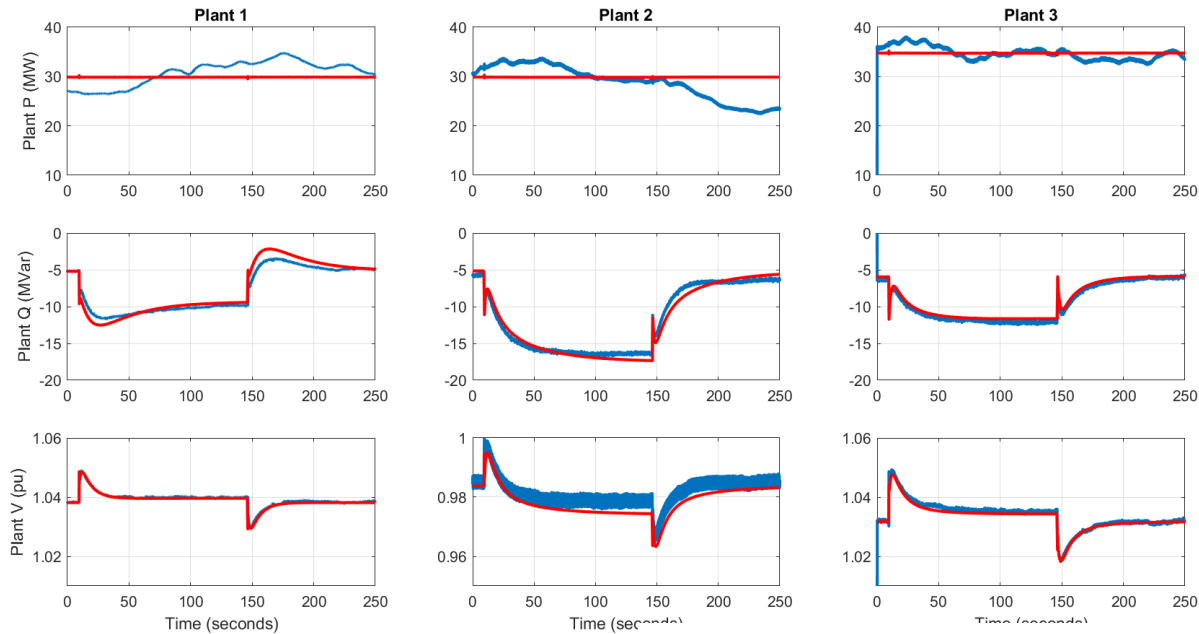
MSC Switching [1]



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)



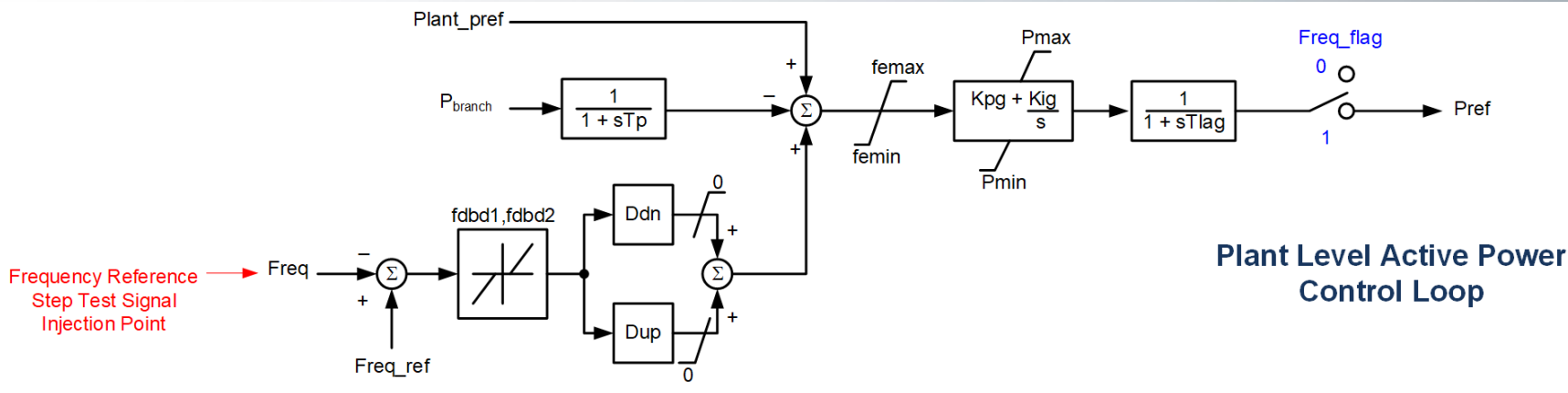
Confirms turbine-level local V-control



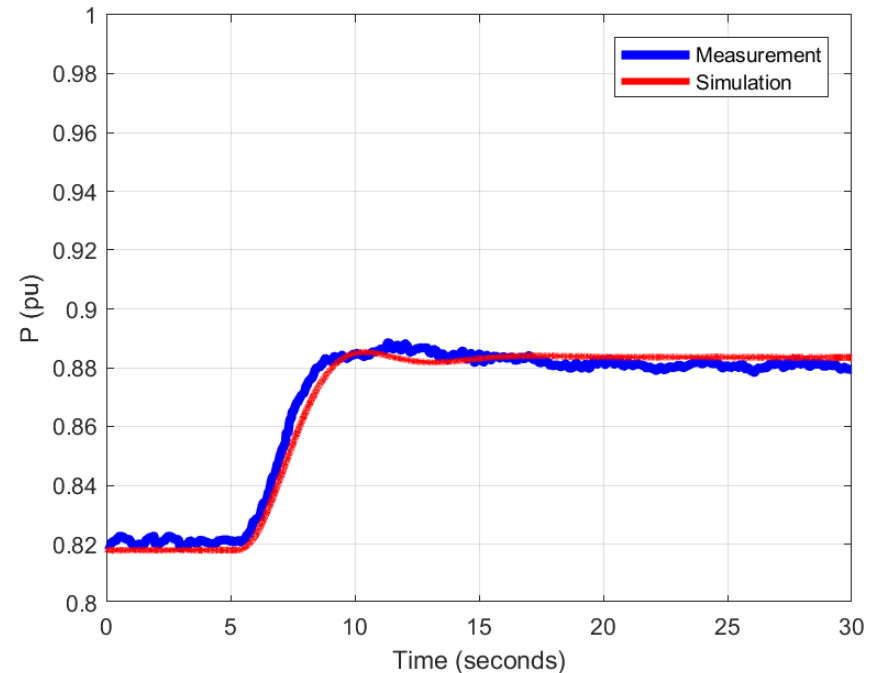
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Frequency Response Step Test



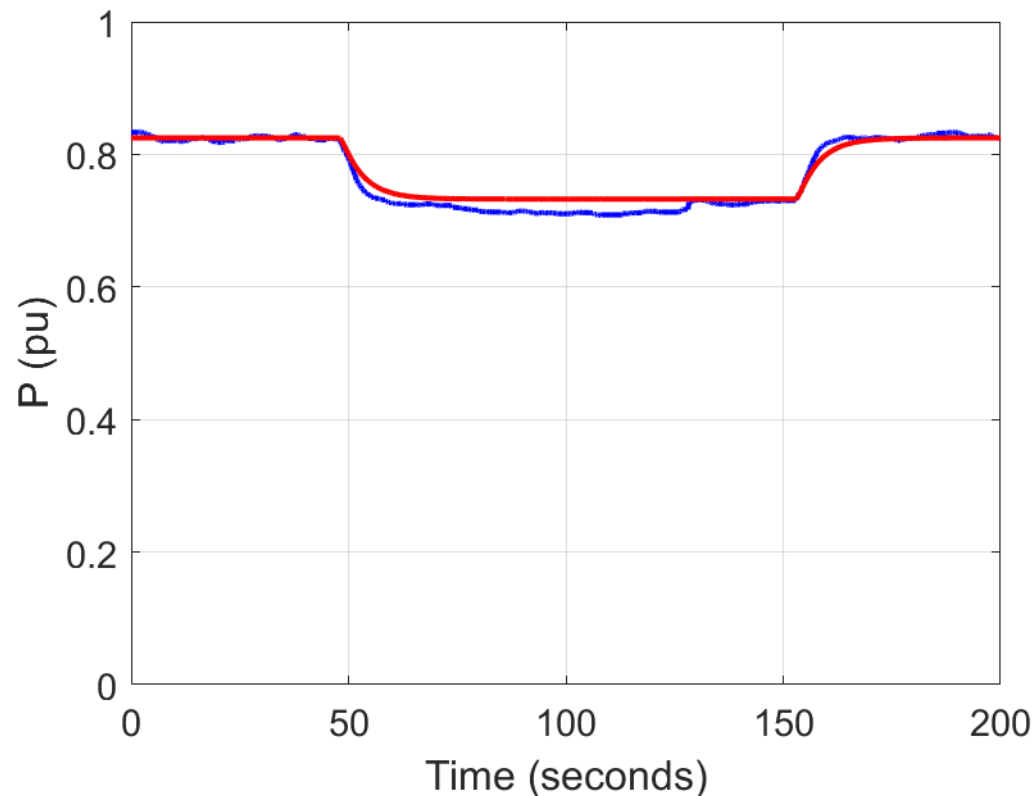
- WTG (type 3 in this case) with actual primary frequency response controls enabled
- Validation with Freq. Ref. Step test using 2nd generation generic models



Frequency Response Step Test



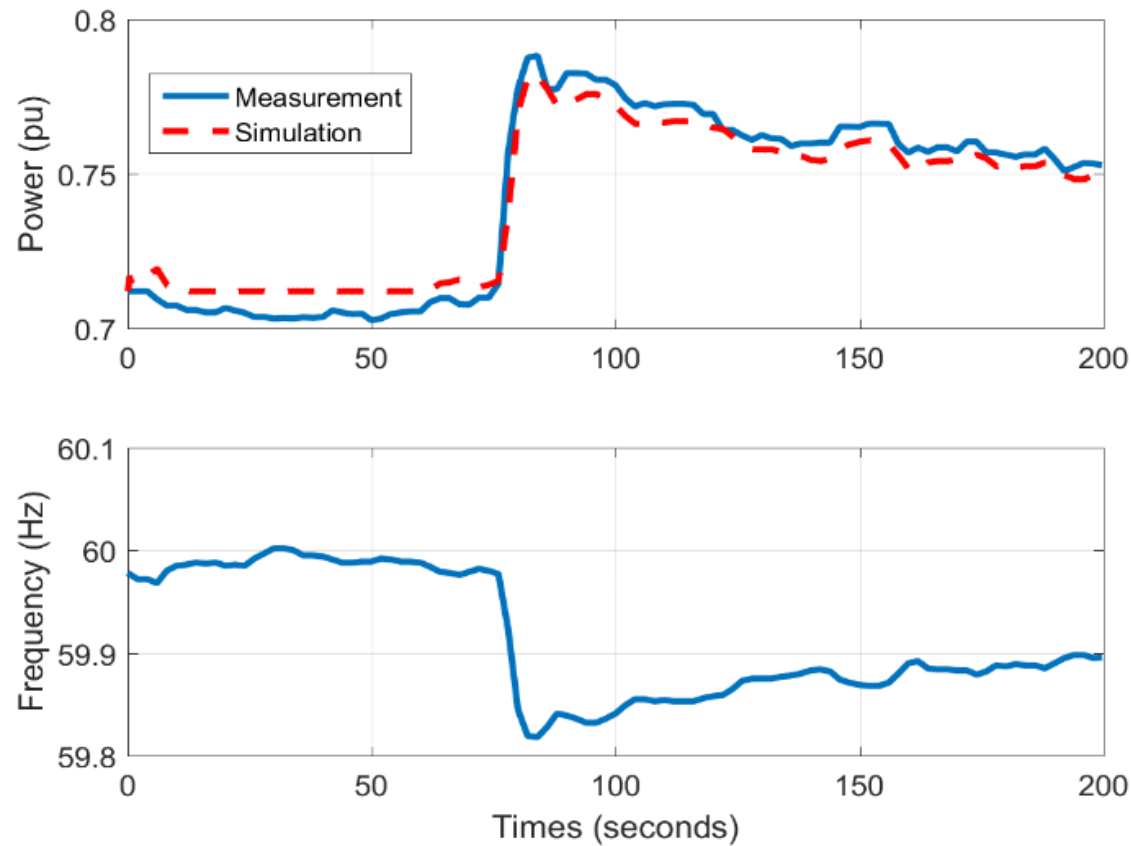
Large IBR plant, using detailed vendor specific user-written models for IBR units and PPC



Disturbance Monitoring



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



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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



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
- Moderation is the Key:
 - Do not get stuck in the details so as to lose sight of the purpose of modeling
 - Do not brush over simple yet important details



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. Zadehkhosht, 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/>

