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Coordinated Design of Master Power Plant Controllers in Renewable / Hybrid Plants with different OEM Controls

WECC MVS Meeting, May 16th, 2022

Virtual

BACKGROUND

- Hybrid Power Plants (HPPs) are becoming increasingly popular across the world.
- Definition: HPP is a resource comprising of multiple generation technologies that are controlled as a single entity and operated as a single resource at the POI.[1] HPPs could either be AC coupled or DC coupled.
- Modeling HPPs accurately is of utmost importance to represent the exact (or closest possible) dynamic behavior of the equipment at the site.
- User written Master Power Plant Controllers (MPPCs) have been developed in both RMS [2] and EMT [2] platforms to study the dynamics of HPPs and renewable plants with different OEM controls.

1. NERC, Reliability Guideline of performance, modeling and simulations of BPS-connected battery energy storage system and hybrid power plants
2. RMS: Root Mean Square, EMT: Electromagnetic Transient

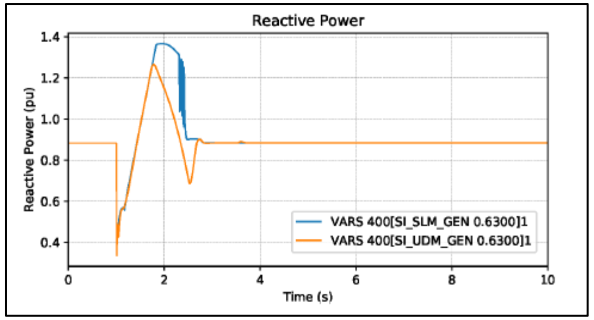
DYNAMIC MODELS AND SELECTION

- The end user has a tool set to choose from for simulation studies:
  - Use of Generic open-source Vendor neutral models: Being mindful of known limitations, but also acknowledging that these can be tuned to represent OEM model under certain operating conditions.
  - User written OEM models: typically developed by original equipment manufacturers (OEMs) which aim to closely represent the equipment's physics / response as is in the real world / operating site in the field
- Both the generic and User Defined Models (UDM) are important for simulation studies, the end user (simulation engineer) however has to apply judgement to understand the limitation and application of either set of models.

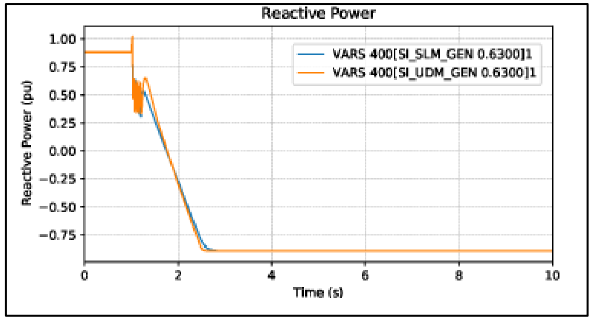
Note: The same generic model can be tuned to represent the behavior of Manufacturer A under a certain operating condition, the same model is also capable to mimicking the response of Manufacturer B under a different operating condition. An example is the Static Exciter ST4C model that represents the Basler DCS, Eaton or Emerson static excitation system.

BENCHMARKING OEM AND GENERIC MODELS

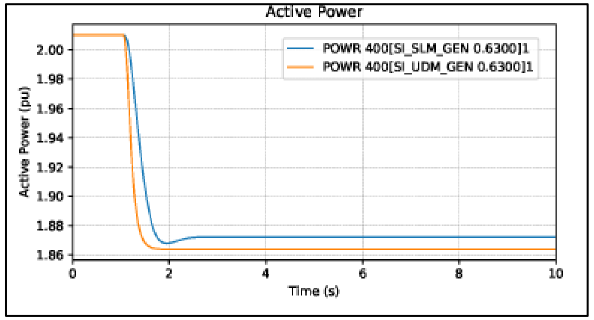
- Several OEM Models benchmarked to generic models.
- Similar responses (%age of error?) are achieved for different operating conditions.
- Considerations to keep in mind: Some OEM models have hysteresis control, allowing the model to enter and exit voltage ride throughs at different voltage stages. Helps in reducing oscillations when switching between control modes.
- Important to know which time constants and gains translate to user tunable parameters.



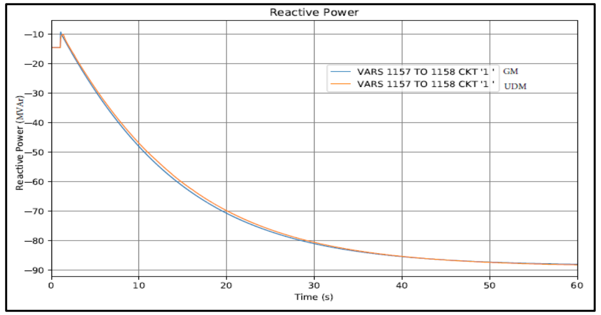
Lagging Power Factor LVRT test



Lagging Power Factor HVRT test



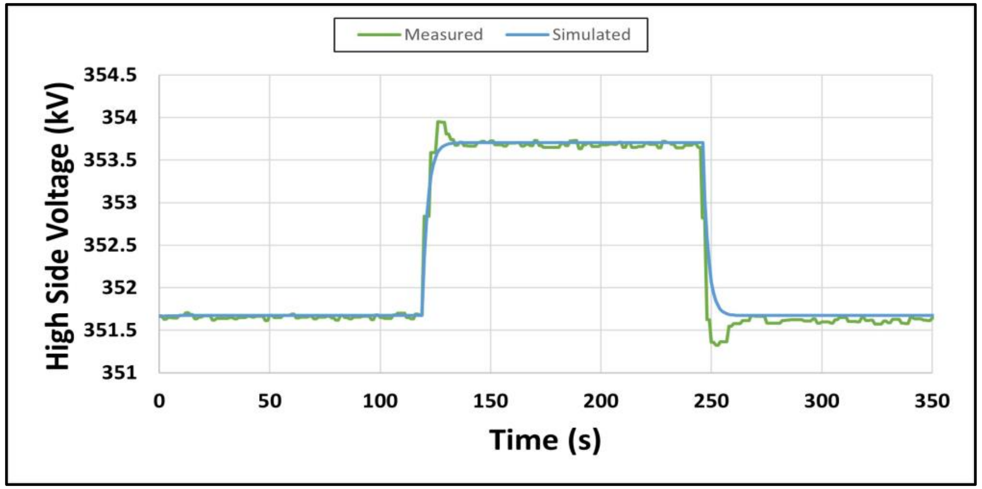
PFR Step up test



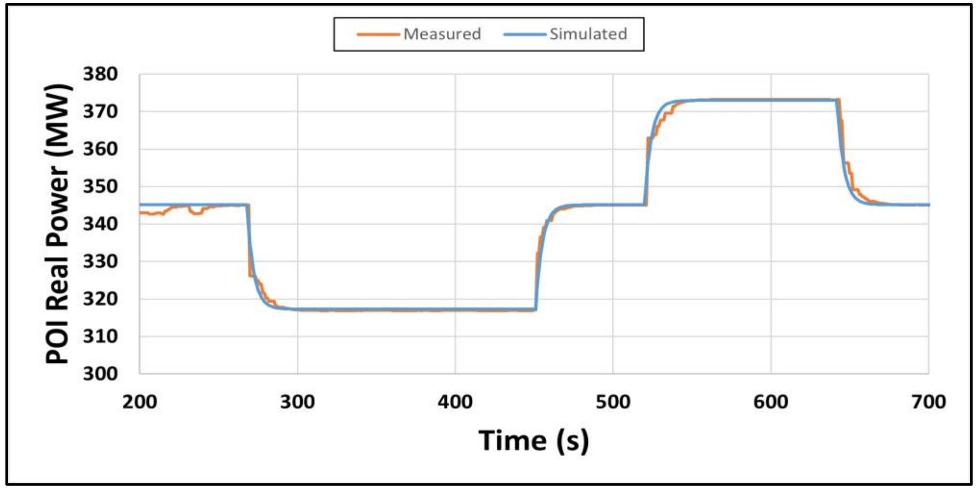
Voltage Step up test

K. S. Shetye, B. Yancey and T. J. Overbye, "Benchmarking Standard Library and User Defined Models of Renewable Generation," 2021 North American Power Symposium (NAPS), 2021, pp. 1-6, doi: 10.1109/NAPS52732.2021.9654662.

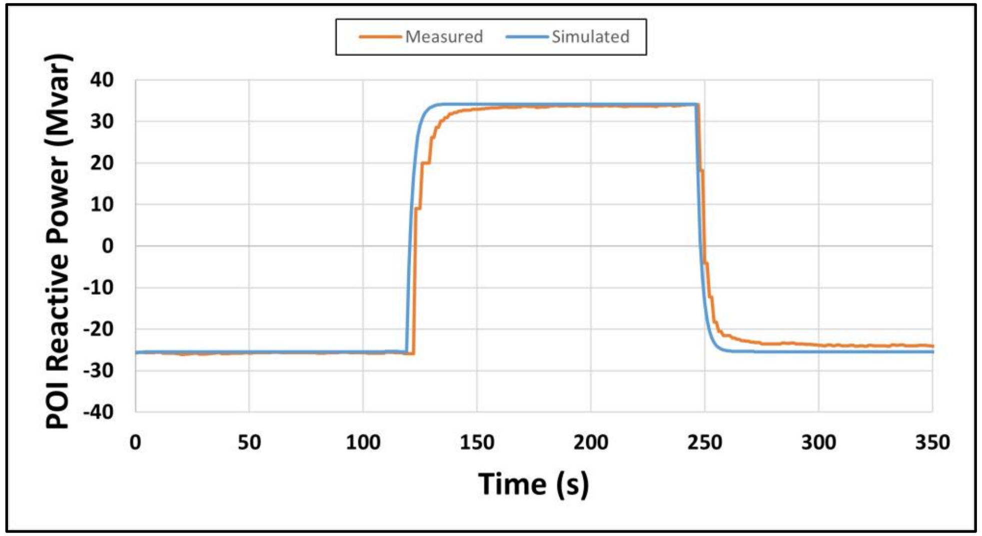
EXAMPLE OF OEM1 UDM MOD STUDY



MOD 26 Test: Voltage at high side of MPT



MOD 27 Test: Active Power at high side of MPT



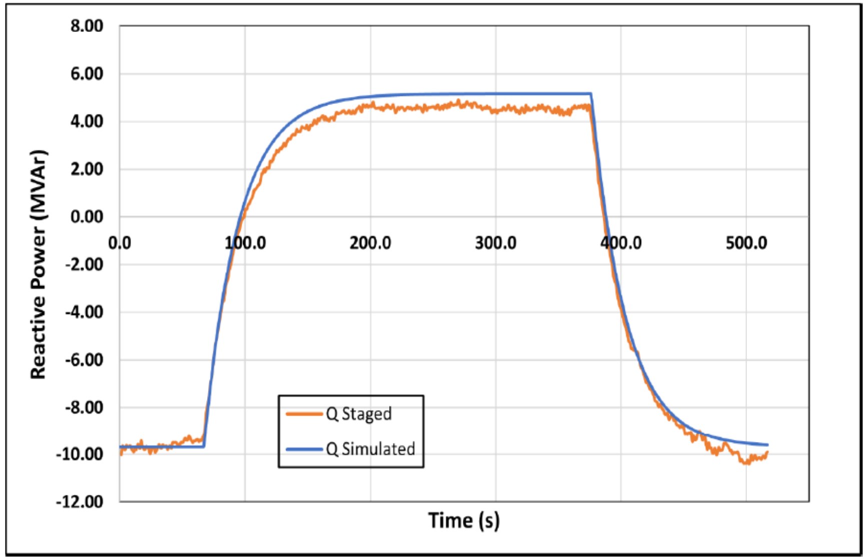
MOD 26 Test: Reactive Power at high side of MPT

- 420 MW Solar Plant in Texas consisting of 135 solar inverters.
- All the WTG models are OEM specific user models. The PPC model was developed as a user written model in PSSE that replicates the as built controller at site. The control structure was built in consultation of the PPC supplier.
- MOD-26, 27 test data and model validation simulations shows close match.

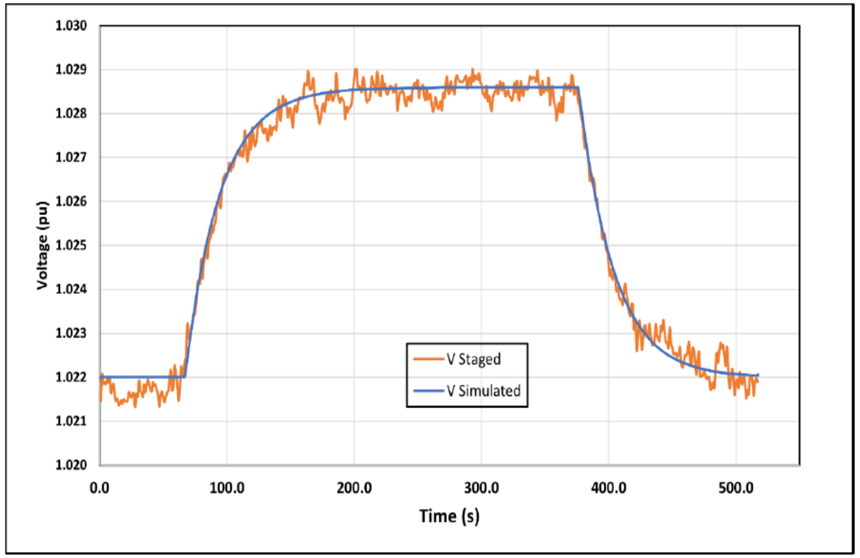
PSSE : Power Systems Simulator for Engineering

EXAMPLE OF OEM2 UDM MOD STUDY

- Case study: A 200 MW wind plant in Texas consisted 100 wind turbines of a certain OEM. The plant was designed in two sections controlled by one PPC as this was the preferred control implementation by the OEM.
- PPC parameter dump file was provided by the OEM from the site. The OEM confirmed that the PSSE UDM and the product code is a one-to-one match.
- MOD-26 test data and model validation simulations shows close match.



MOD 26 Test: Reactive Power at high side of MPT



MOD 26 Test: Voltage at high side of MPT

EXAMPLE OF OEM2 UDM MOD STUDY

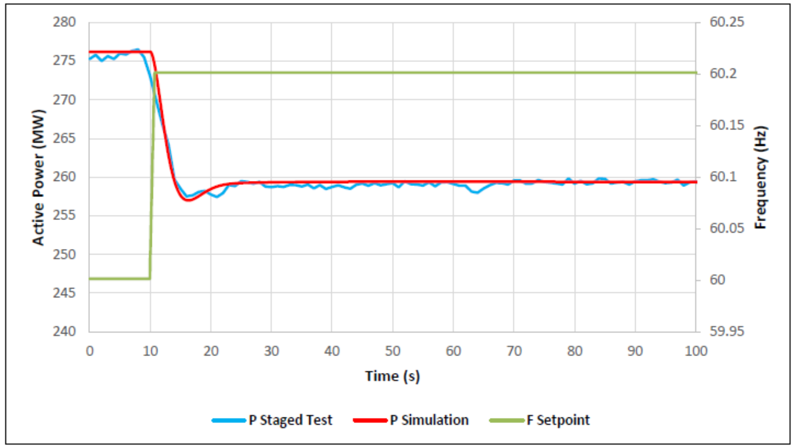
- Encountered sites with dynamic Var compensation (either in slave or master mode) , which cannot be modeled from the as now available library models.

- Have modeled sites with generic models with dynamic Var compensation in slave mode and capable of receiving commands from the PPC.

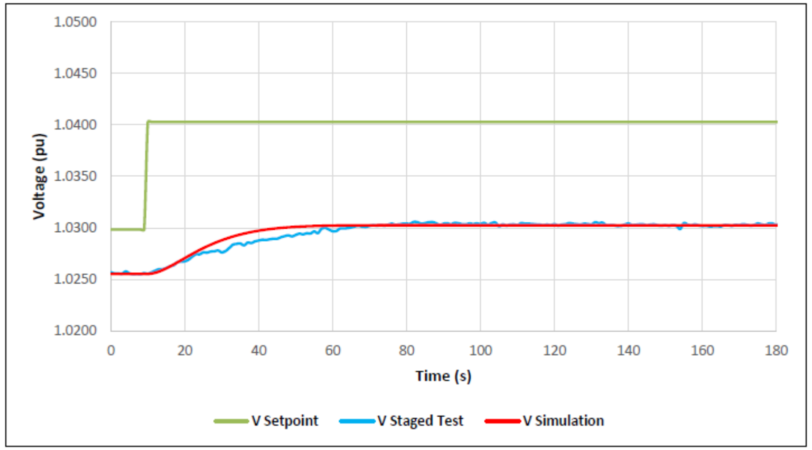
- Requirements for some sites where a custom power plant controller is required that coordinate with multiple devices and in order. Eg: one site encountered where it is mandated that on command from the MPPC, the WTGs first provide Q base on their capability, then the dynamic var device comes into action and finally if required cap banks are switched on. For such cases site specific MPPCs need to be designed and developed as an UDM in consultation of the plant owners, WTG, STATCOM OEMs.

EXAMPLE OF GENERIC MODELS MOD STUDY

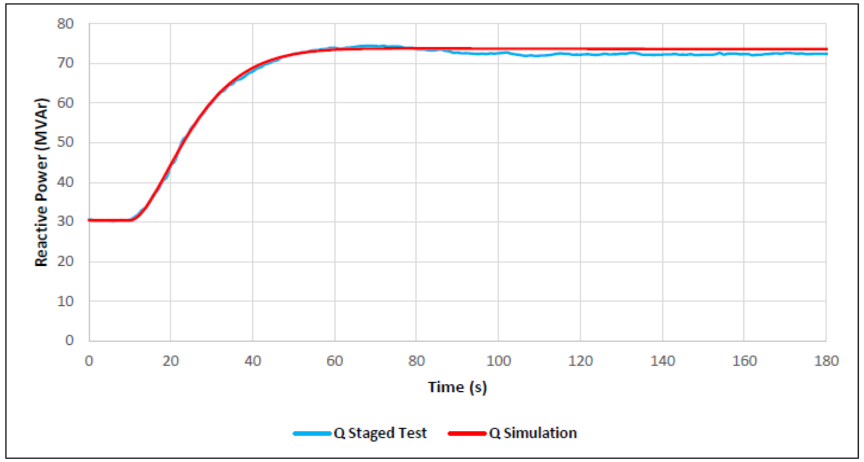
- 300 MW Wind Plant in Texas consisting of 162 WTGs.
- All the WTG models and associated control model are generic library models. There is one PPC that controls two units; in this case the PLNTBU1 PPC model in PSSE is utilized.
- MOD-26, 27 test data and model validation simulations shows close match.
- Obtained close match to test data using Generic Models.



MOD 27 Test data with Simulation results



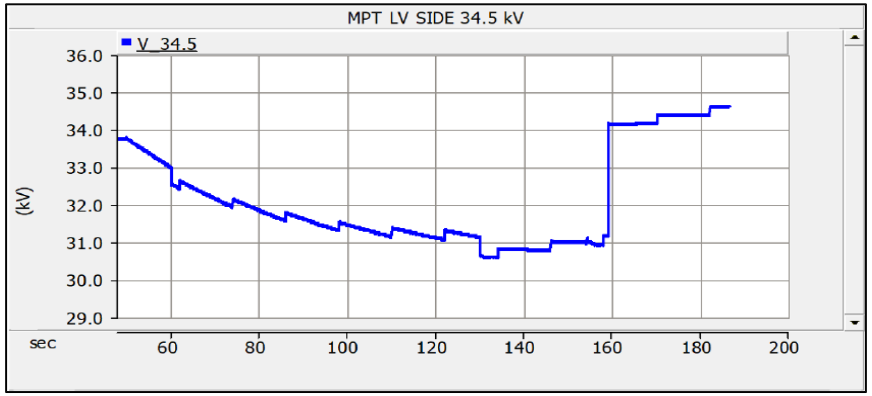
MOD 26 Test: Voltage at MPT HV side



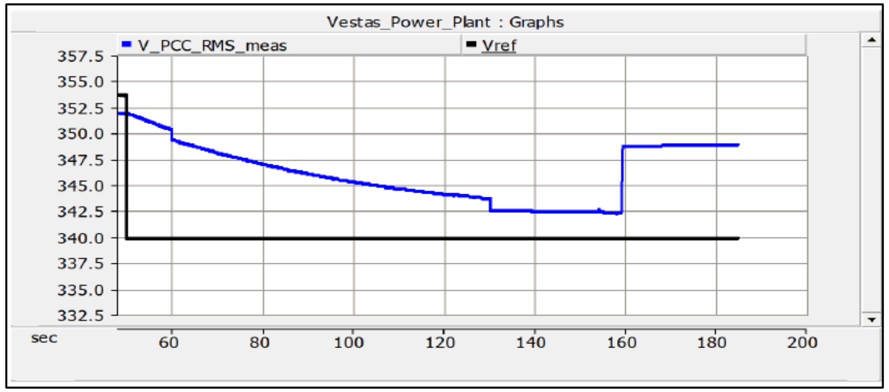
MOD 26 Test: Reactive power at MPT HV side

POWER PLANT CONTROLLERS DESIGN ISSUES

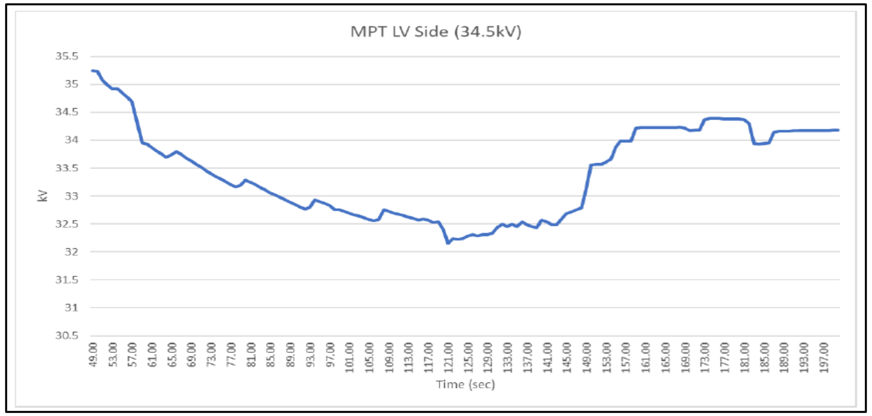
- Forensic Case Study: Investigate cause of WTG tripping during ERCOT AVR Tests. Latency of Load Tap Changers (LTCs) and Automatic Voltage Regulator (AVR) response for a wind plant. Detailed wind farm designed in PSCAD to investigate the response of the plant to real world test data. Coordination between LTCs (mechanical parts, slow) and the OEM AVR controls (fast) becomes important.



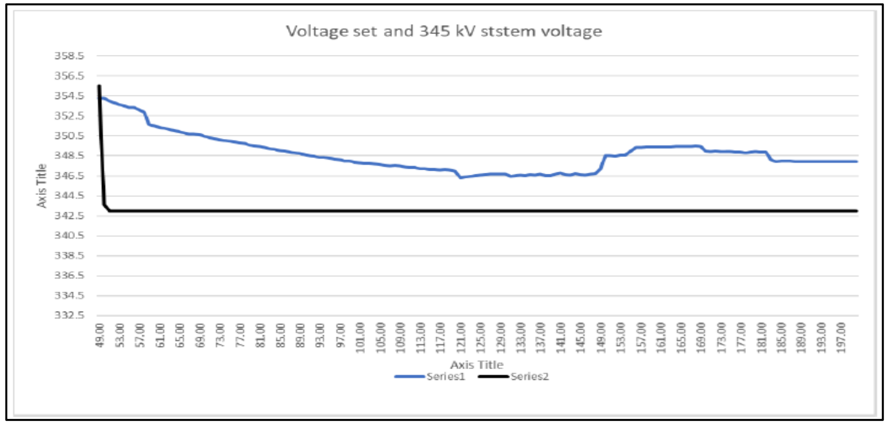
PSCAD Simulation: Voltage at LV side (34.5 kV)



PSCAD Simulation: Voltage at HV side (345 kV)



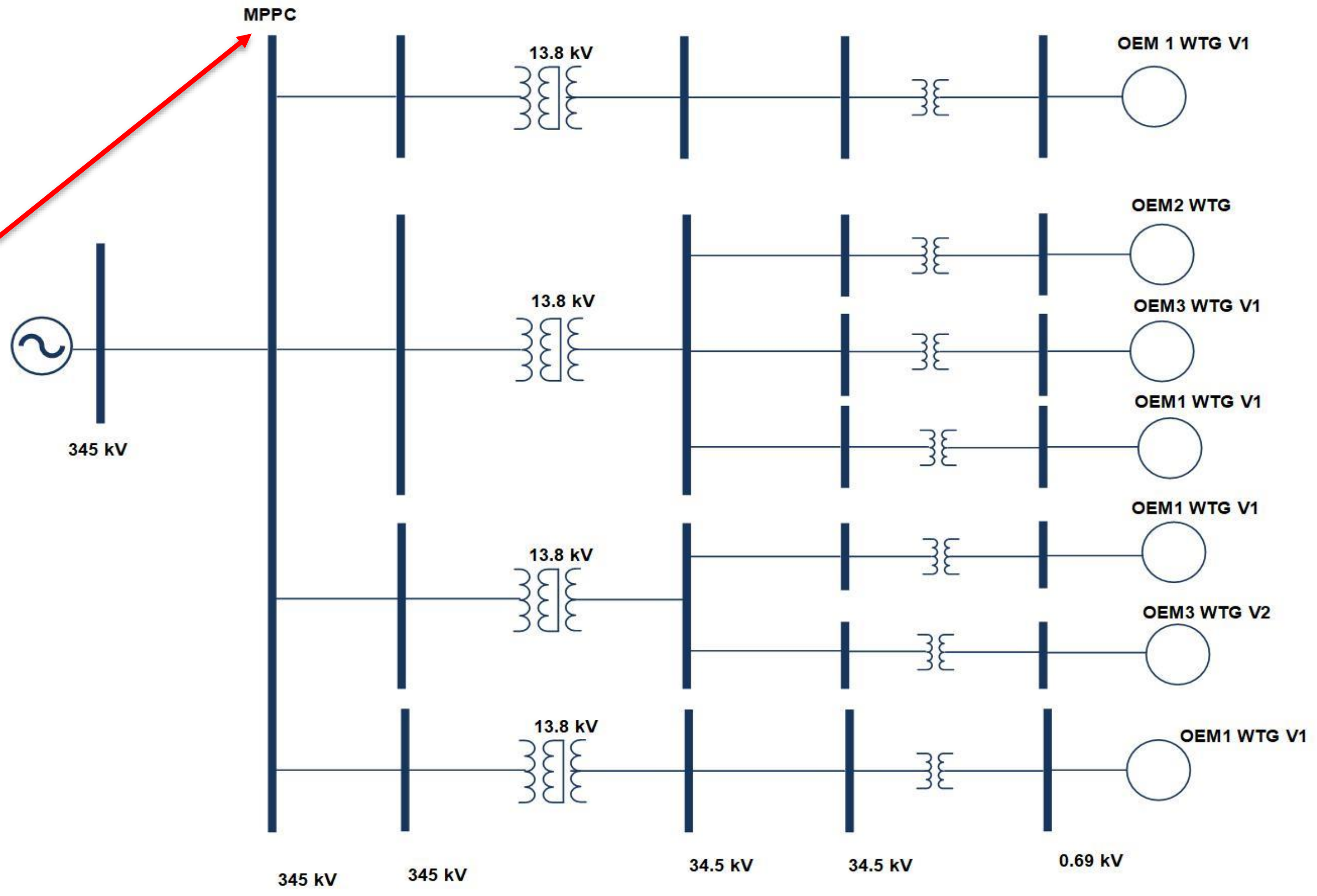
Test Data: Voltage at LV side (34.5 kV)



Test Data: Voltage at HV side (345 kV)

MASTER POWER PLANT CONTROLLER DESIGN

- 300 MW Wind Plant with three different OEM controls.
- Each of the OEM WTGs' PPCs are modeled to control the medium voltage side of the respective transformers.
- An overarching Master Power Plant Controller (MPPC) user written PSSE model is developed as per specifications from the on site RTAC.
- The MPPC is designed to send setpoints to individual OEM PPCs. All the models used for the simulation studies are detailed OEM UDMs.

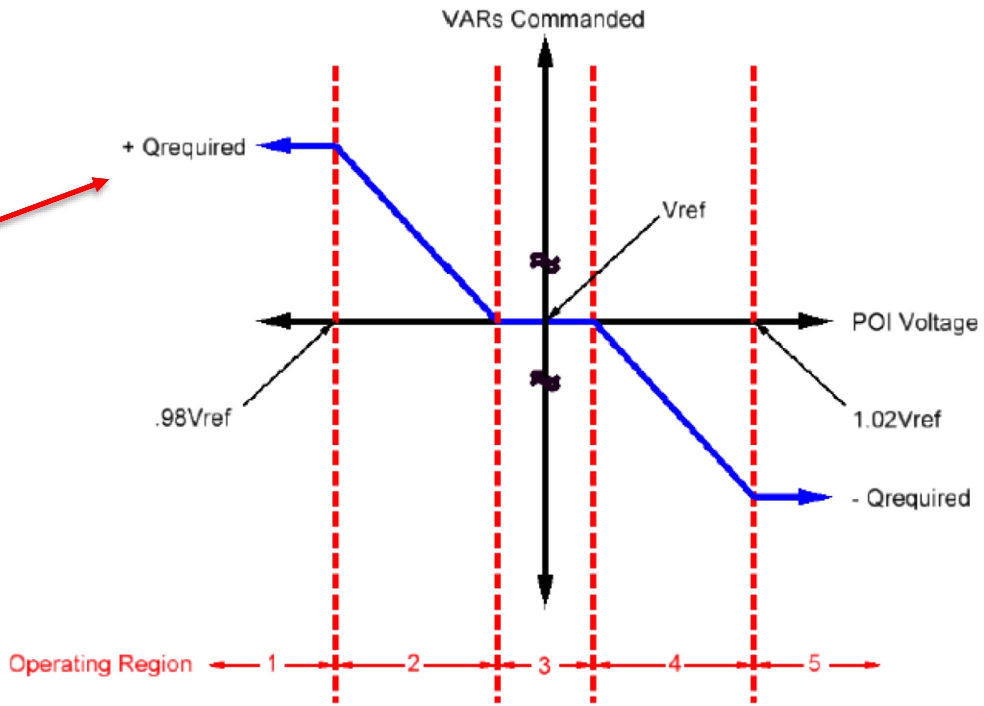


RTAC : Real Time Automation Controller

Layout of the 300 MW wind plant

MASTER POWER PLANT CONTROLLER DESIGN

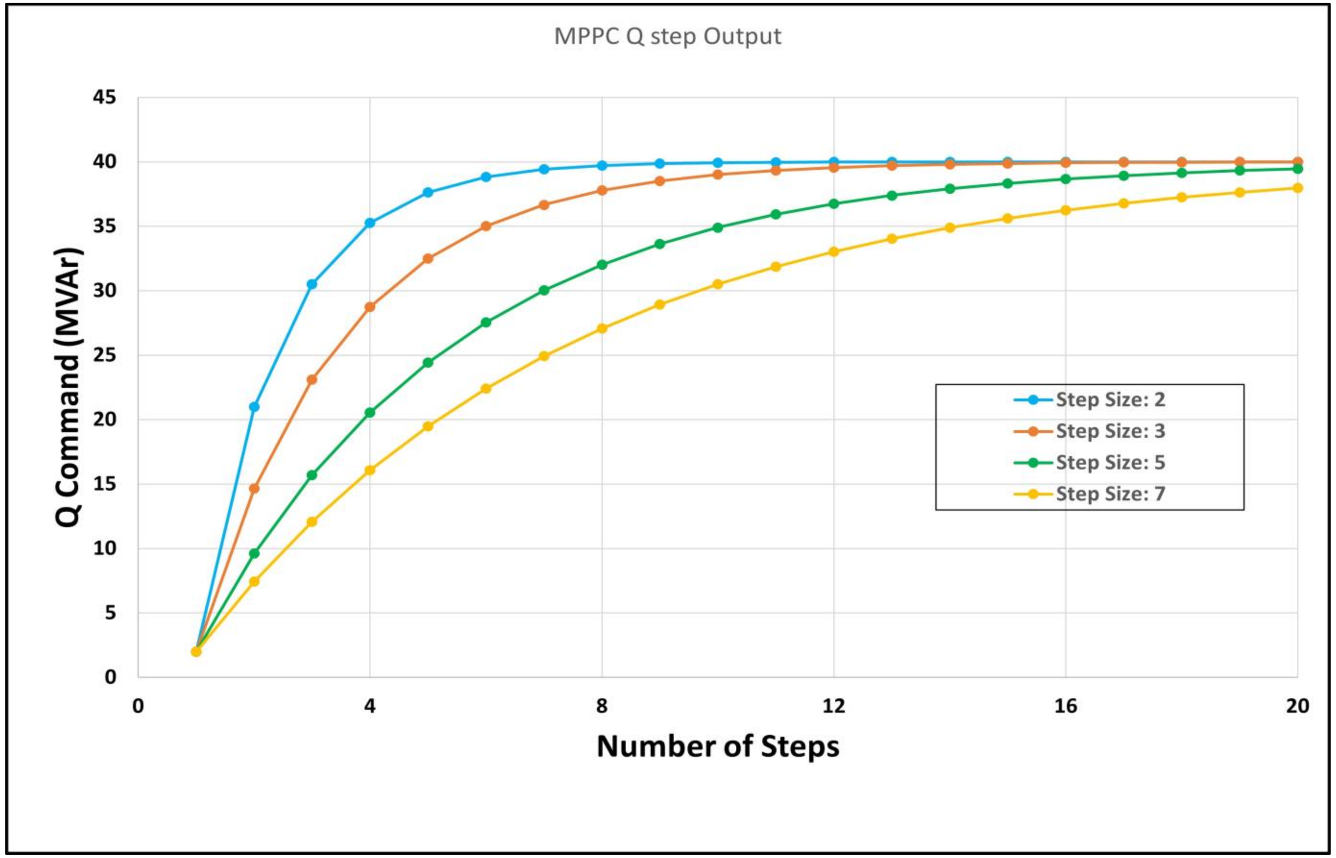
- The MPPC is designed as an outer loop control for the individual OEM PPCs. The MPPC feeds commands to the OEM PPCs for slower events (voltage and reactive power step tests).
- For faster events like LVRT, HVRT, the OEM PPCs respond on their own. The MPPC is blind to such fast events.
- The MPPC uses voltage droop control to select the reactive power output level.
- The MPPC implements a Q step size calculation to determine the Q setpoint of the MPPC
- The MPPC senses the voltage at the high side through a timer (in the order of 1-2 seconds).
- The MPPC Qcommand is distributed to the different OEM PPCs proportional to the rating of the different aggregated WTGs.



Droop control in MPPC

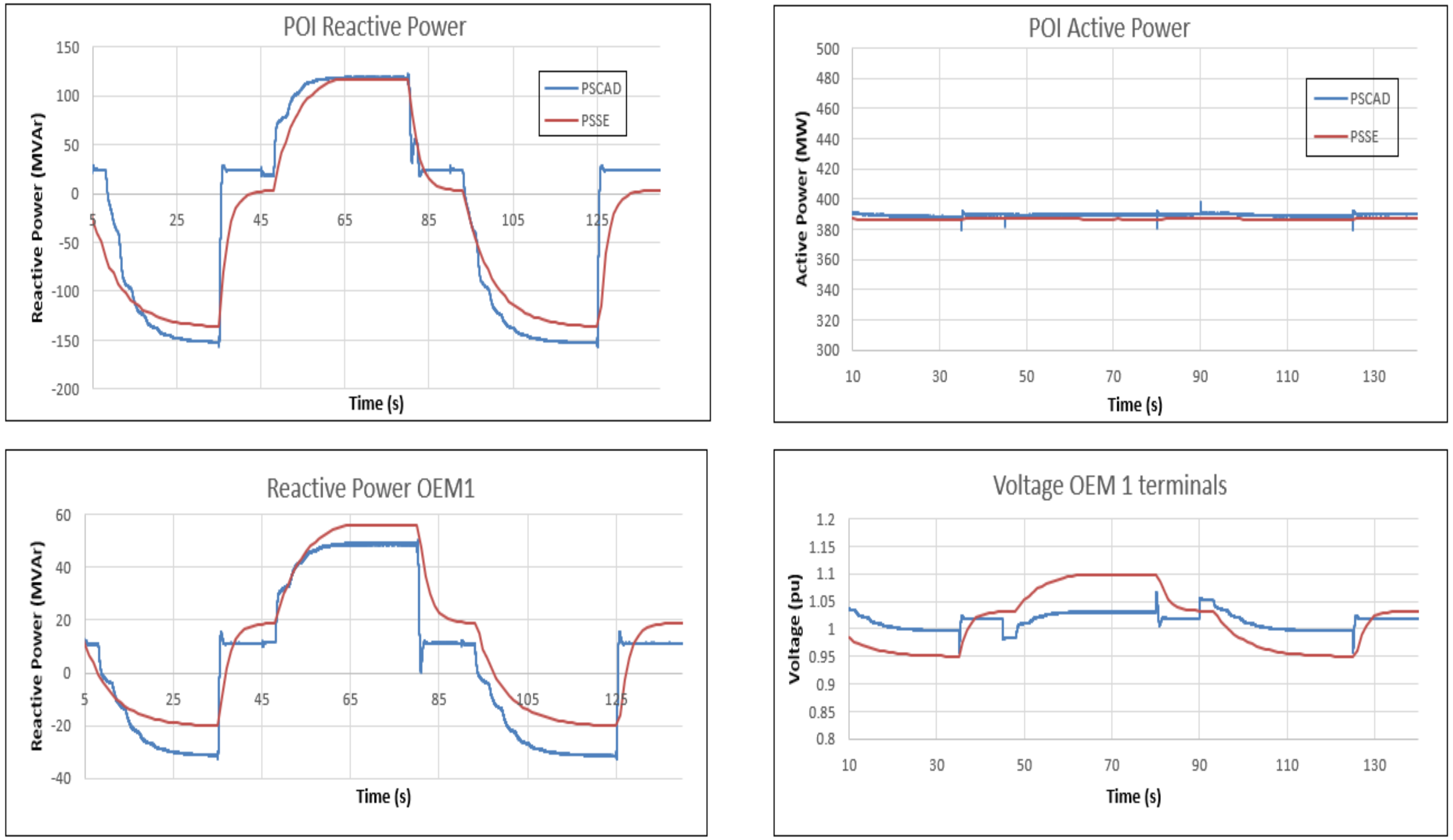
MPPC Q STEP RESULTS

- The MPPC Q setpoint is calculated with an algebraic function that calculates the output based on a fraction of the difference between the desired output and the actual output.
- The setpoint is commanded to seek an increase by a fraction of the difference in desired and actual output, thus leading to the slow but steady response.
- A user written PSCAD model was also developed to benchmark the response vs PSSE (next slide).



MPPC example operation with varying step size

RESULTS USING MPPC – PSCAD VS PSSE

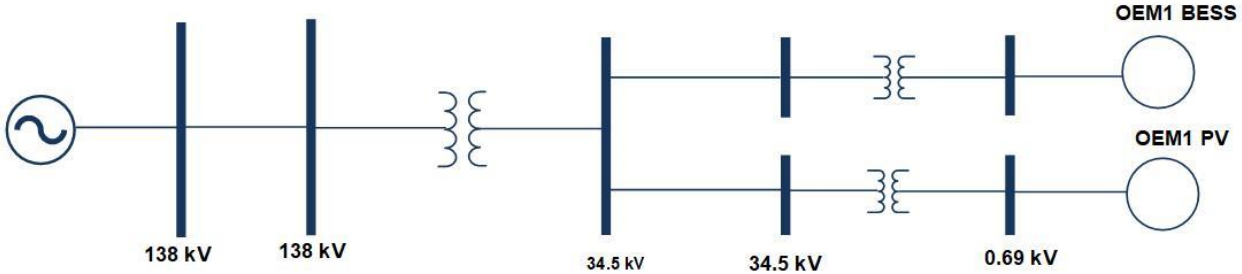


PSSE vs PSCAD comparison for MPPC Q control logic

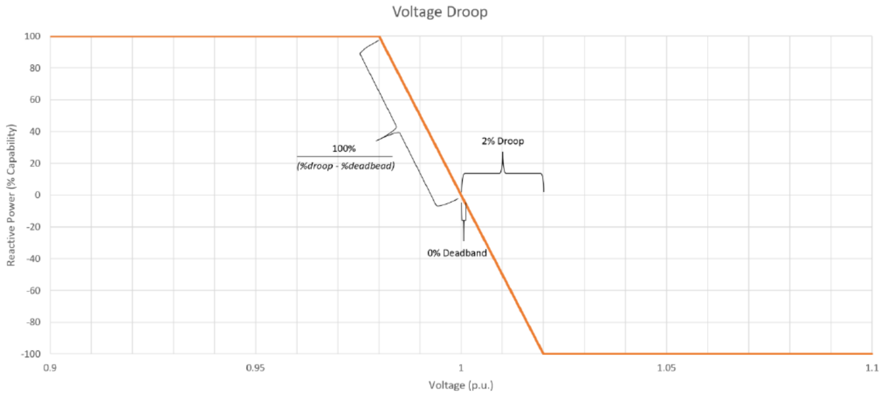
- Noticeable difference across the two software platforms.
- This project is part of an ongoing effort. Actively working for a closer match very soon.
- One OEM confirmed that their PSSE and PSCAD model are identical.
- Filter time constants and implementation different in RMS vs EMT?
- Noticing and understanding the differences is key. More often its why rather than how.

POWER PLANT CONTROLLER FOR HYBRID PLANT

- Hybrid Plant with co-located PV, BESS
- The primary purpose of the MPPC: regulate and control both the PV and BESS. Closed loop control utilizing feedback from POI.
- Three different modes for Q (Voltage, Power factor and Q-V droop control) and PFR control (droop plus dead-band combination). Additional Plant ramp rate control.
- MPPC UDM model developed in PSSE for this site-specific functionality. Consultation with OEM personnel to tune parameters both at PPC and Inverter Level to meet the grid code requirements.



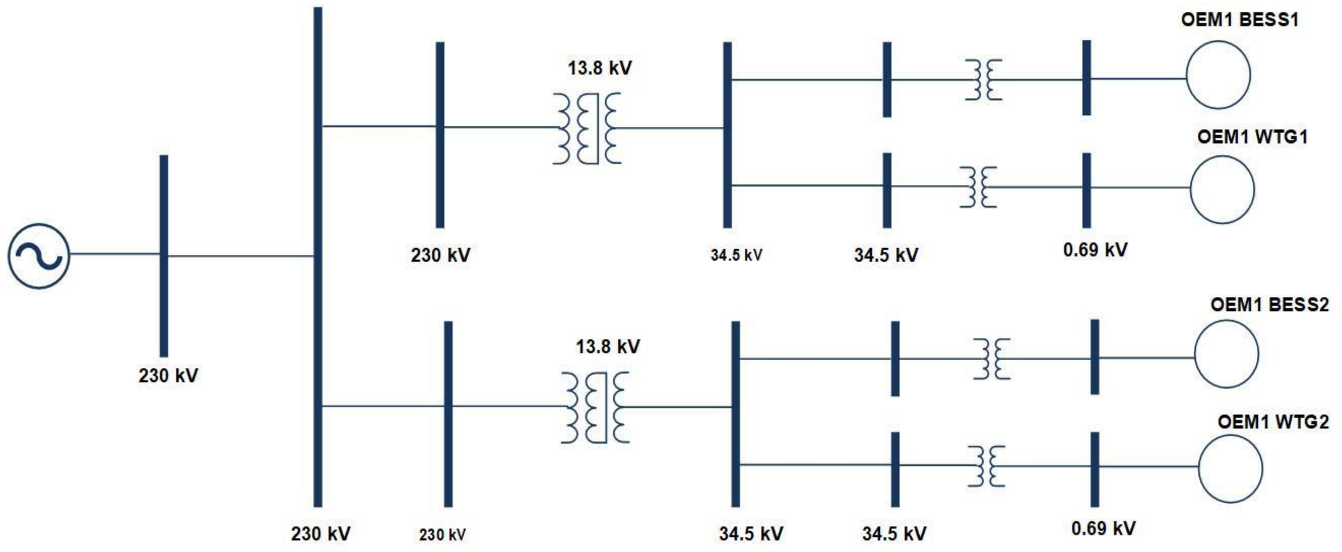
Hybrid plant consisting of BESS and PV



Q-V droop functionality

POWER PLANT CONTROLLER FOR HYBRID PLANT

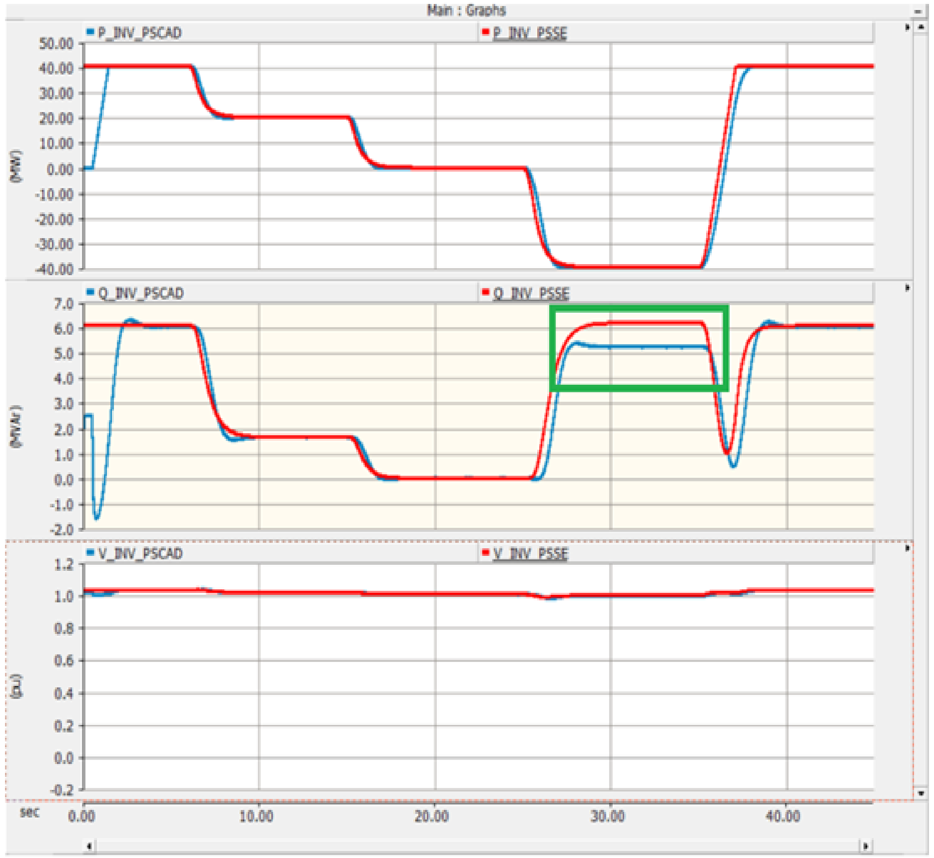
- A master power plant controller was developed for a manufacturer that could control both the BESS and send signals to the OEM WTG's PPC for a hybrid power plant in Australia.
- The MPPC had various control modes including remote active power control, local P/Q control for external project, frequency droop control, dynamic Q control (Power factor and V control) and power firming dispatch.
- Both PSSE and PSCAD user written PPC models were developed working closely with the manufacturer.
- Having different OEM controls increases complexity of developing such user written models.



Hybrid plant consisting of Wind and BESS

POWER PLANT CONTROLLER FOR HYBRID PLANT

- Available generic power plant controller models were not adequate to represent the various function of the MPPC, thus user written models was the go-to option.
- A close match was obtained across PSSE and PSCAD when subjected to network events and step changes for the developed user models.
- Differences were observed (within certain %age; marked in green), however were later resolved.



PSSE vs PSCAD comparison plots.

KEY TAKEAWAYS AND FUTURE THOUGHTS

- Both generic and user written models are important, end user must make the right judgment call before performing simulation studies.

- Master Power Plant Controllers are becoming popular with installation of hybrid plants. Such controllers have site specific functions which have to be developed as user written models to study the response of the plant.

- Recent projects show requirements of MPPCs used in conjunction with grid forming control. Predominant in Hybrid plants that combine Wind with grid forming BESS.

- Differences will be present across RMS and EMT platforms, however its possible to get almost similar response.

- Much time should be spent on understanding the differences between the simulation plots across RMS and EMT platforms.

- Real code compiled models are now the Industry standard for PSCAD OEM models. The same technique can be applied for developing MPPCs.

Questions and Discussions

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