The Challenges of Inverter Modeling Related to IEEE 1547-2018

Barry Mather Ph.D. (on behalf of David Narang)

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Background: The Evolution of IEEE 1547

- IEEE 1547-2018 is **136 pages long compared to 16** for the “original” version – telling of the increased complication and choices.
- Over **50 responsibilities** have been identified in IEEE 1547-2018 including: distribution utilities, transmission operators, ISOs, etc.
- IEEE 1547-2018 can be implemented to **support distribution** by providing voltage support, fault response coordination, generally aids increasing the amount of DER.
- IEEE 1547-2018 can be implemented to **support transmission** reliability by providing enhanced DER ride-through capability for transmission events, frequency support and dynamic voltage support.
When in this mode, the DER shall actively control its reactive power output as a function of voltage following a voltage-reactive power piecewise linear characteristic.

- DER measures grid voltage at terminals and absorbs or produces reactive power
- Intended to supply vars only when needed, push local voltage back towards nominal

(Informative) Example voltage-reactive power characteristic

**Figure: 1547-2018, H-4**
When in this mode, the DER shall actively limit the DER maximum active power as a function of the voltage following a voltage-active power piecewise linear characteristic.

- Can reduce the prevalence of very high voltages

Figure H-6 — (Informative) Example voltage-active power characteristic
When in this mode, the DER shall actively control the reactive power output as a function of the active power output following a target piecewise linear active power–reactive power characteristic, without intentional time delay.

Figure: 1547-2018, H-5

Example active power-reactive power characteristic
When in this mode, the DER shall actively control its reactive power output as a function of voltage following a piecewise linear characteristic.

- DER measures grid voltage at terminals and absorbs or produces reactive power
- Intended to supply vars only when needed, push local voltage back towards nominal

\[ V_{\text{Ref}} (V_2,Q_2) \]

Voltage (p.u.)
Reactive Power (% of Stated Capability)
Injection / over-excited
Absorption / under-excited

\( V_L : \) Voltage Lower Limit for DER Continuous operation
\( V_H : \) Voltage Upper Limit for DER Continuous operation

these piecewise linear control methods don’t help from a model convergence standpoint either

Figure: 1547-2018, H-4

(Informative) Example voltage-reactive power characteristic
Known methods to improve* convergence:

• Limit the step-by-step maximum movement along the piece-wise linear volt/var functions per convergence step – tries to effectively reduce the gain of such systems during convergence while still allowing a full range of overall functionality

• Intentionally flatten the piece-wise linear volt/var functions and slowly increase the gain (back to normal) as the solution converges – tries to “ease” into a solution with the system being modeled with full proper settings in the final convergence step (very much related to the above)

• Develop linear approximations of the piece-wise linear functions

• Artificially limit the volt/var gain of all systems incrementally until convergence is attained (convergence is nearly guaranteed but results may not be accurate)

* Methods do not necessarily guarantee convergence of models
Recent PV Bulk Sys. Impacts – Informative for DER Concerns

Findings: mis-measurement of system frequency and momentary cessation on low voltage, inconsistency in requirement interpretation

Findings: no erroneous frequency measurements, continued use of momentary cessation, interpretation of voltage trip requirements, PLL operation...
We are combining the worlds of transmission and distribution system modeling to determine the reliability impacts and tradeoffs for regional voltage issues in areas with high amount of DER (PV)

- Requires some form of co-simulation or reliance on aggregated DER models in positive-sequence dynamic tools
- Ride-through functionality is relatively easy to model but what the DER does during the actual fault/disturbance is not (at least currently)
- We are modeling voltage-induced impacts stemming from transmission – this is difficult and many models are worth questioning

Transmission Model Determines Area of Impact

Overall Co-Simulation Gives Generation Lost Due to Event

Aggregate DG Output Under Varying Ride Throughs
Path 61: Lugo 500 kV Substation
6,150 Controlled Inverters at 123 Feeders

Note: these are not final results – just food for thought
Thank you for your attention

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Barry Mather Ph.D. – barry.mather@nrel.gov