The Challenges of Inverter Modeling Related to IEEE 1547-2018

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DOE SETO Challenges for Distribution Planning, Operational and Real-time Planning Analytics Workshop

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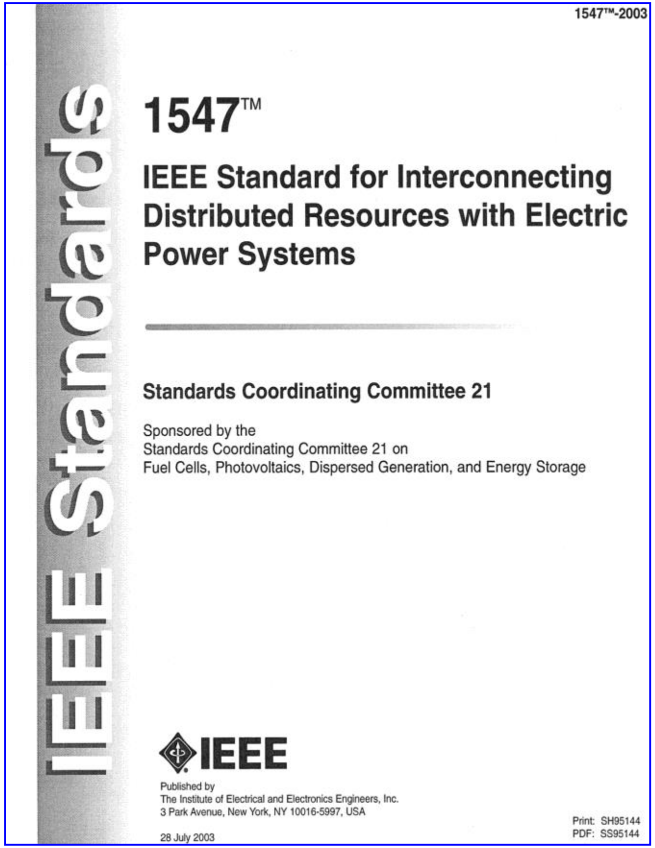
Background: The Evolution of IEEE 1547


1547™-2003

IEEE Standards

1547™

IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems

Standards Coordinating Committee 21

Sponsored by the
Standards Coordinating Committee 21 on
Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage

IEEE

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3 Park Avenue, New York, NY 10016-5997, USA

28 July 2003

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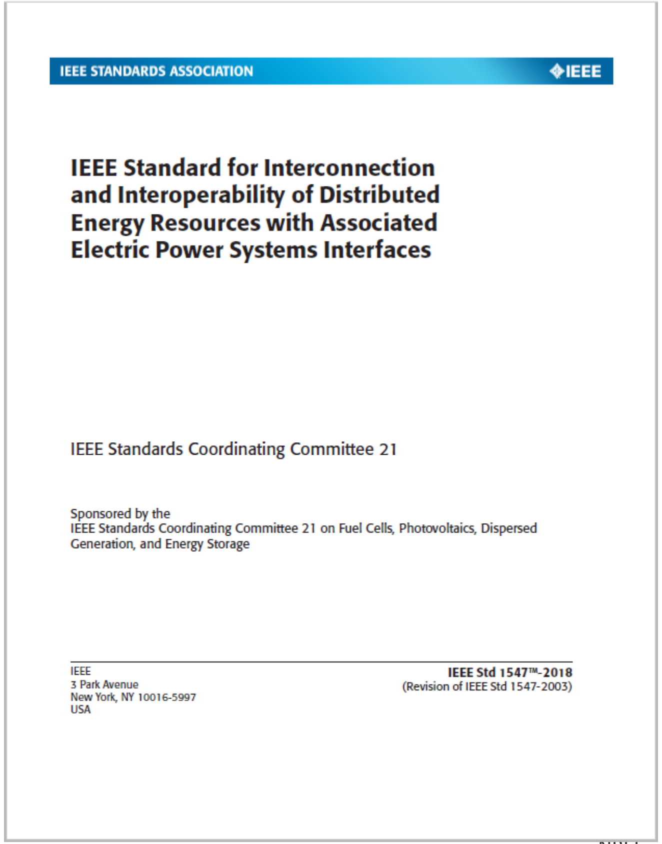
- IEEE 1547-2018 is **136 pages long compared to 16** for the "original" version –telling of the increased complication and choices
- Over **50 responsibilities** have been identified in IEEE 1547-2018 including: **distribution utilities, transmission operators, ISOs, etc.**
- IEEE 1547-2018 can be implemented 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


IEEE STANDARDS ASSOCIATION

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IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

IEEE Standards Coordinating Committee 21

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IEEE Std 1547™-2018
(Revision of IEEE Std 1547-2003)

Voltage-Reactive Power (Volt/Var) (IEEE Std 1547-2018 Clause 5.3.3)

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

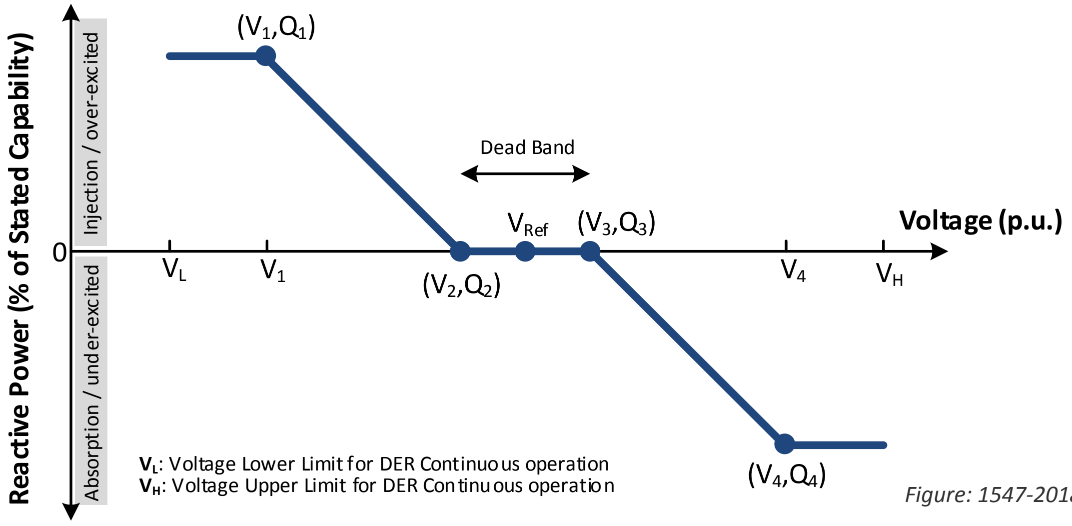


Figure: 1547-2018, H-4

(Informative) Example voltage-reactive power characteristic

Voltage-active power (volt-watt) (IEEE Std 1547-2018 clause 5.4.2)

Category B DER

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

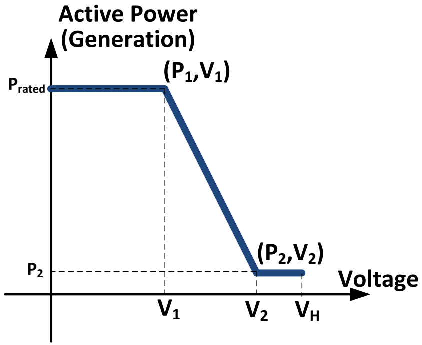


Figure: 1547-2018, H-6

V_H: Voltage upper limit for DER continuous operation

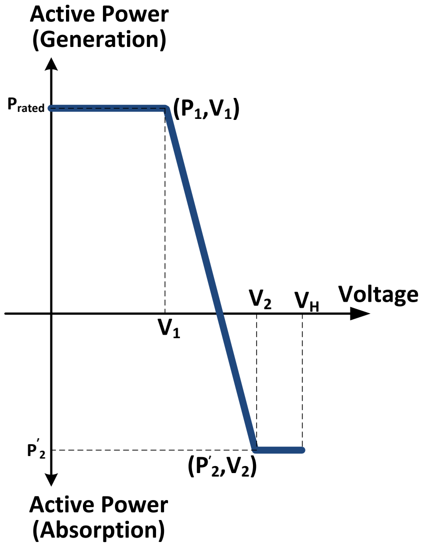


Figure H-6 —(Informative) Example voltage-active power characteristic

Active Power – Reactive Power (Watt-Var, P-Q) (IEEE Std 1547-2018 Clause 5.3.4)

Category B DER

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.

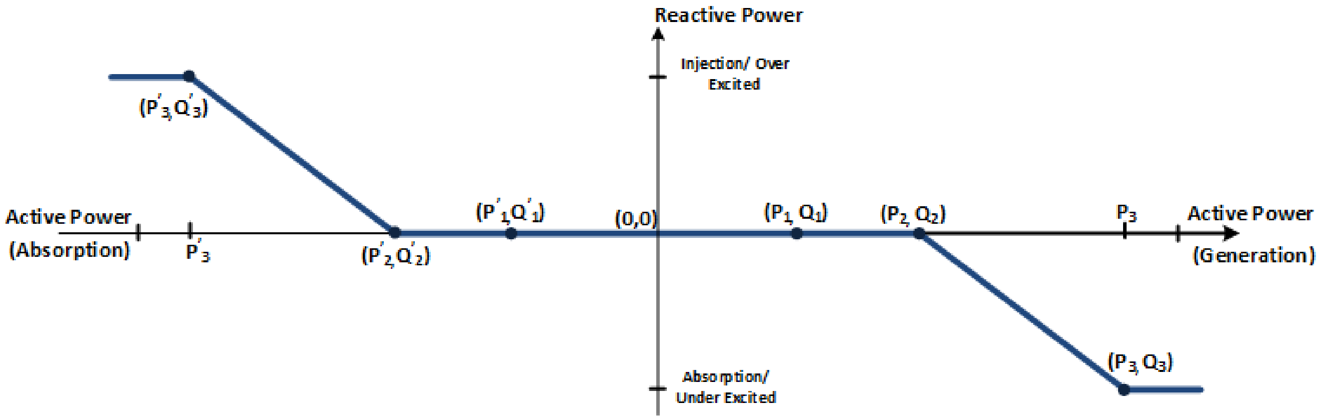


Figure: 1547-2018, H-5

Example active power-reactive power characteristic

The Challenges of Modeling 1547-2018 Inverters (Dist.)

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

very inverter becomes an active, responsive, model – even during solution convergence

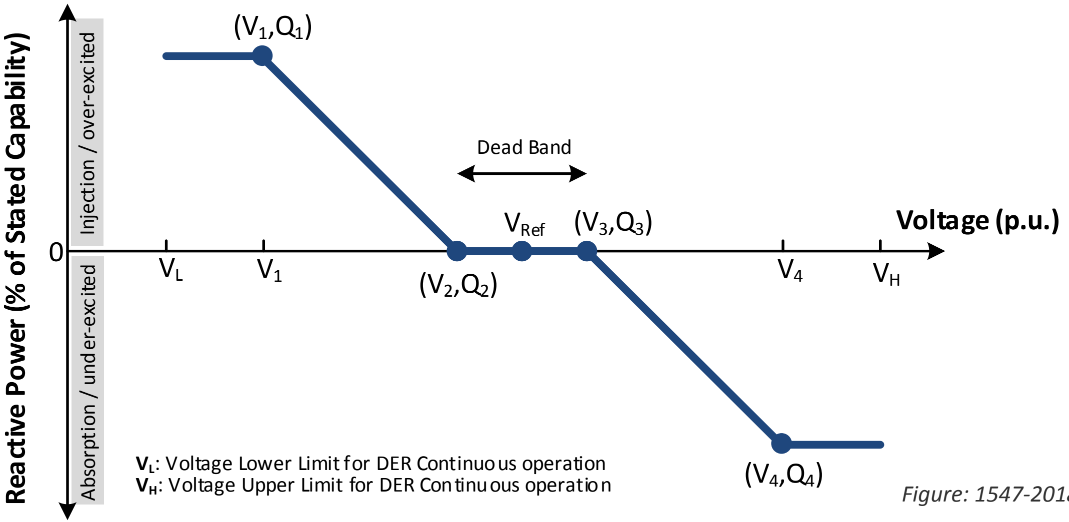


Figure: 1547-2018, H-4

(Informative) Example voltage-reactive power characteristic

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

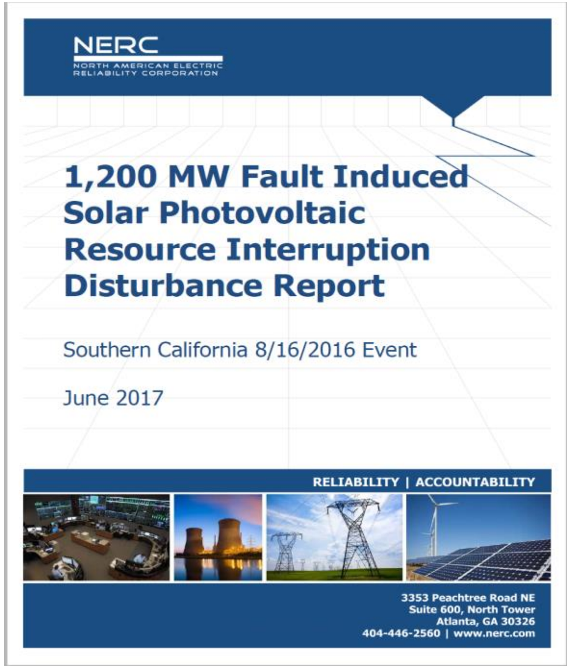
Potential Paths Forward for Modeling 1547-2018 Inverters?

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

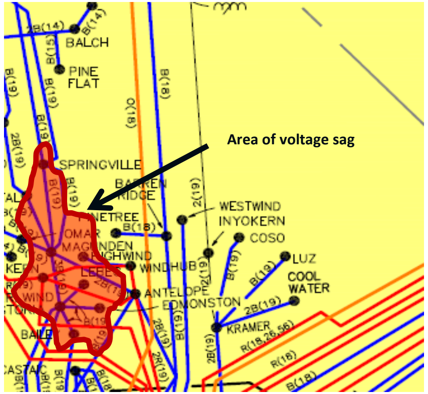


Findings: mis-measurement of system frequency and momentary cessation on low voltage, inconsistency in requirement interpretation

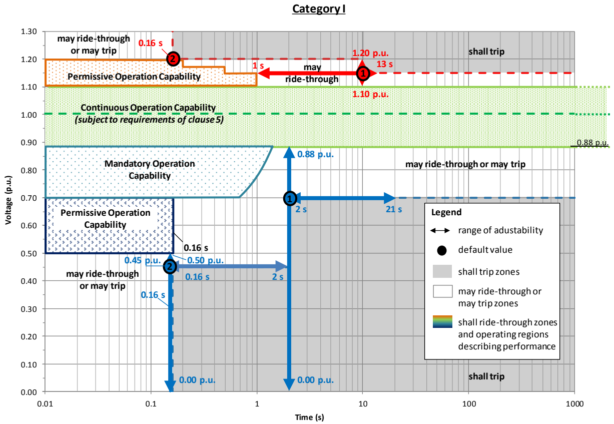
Findings: no erroneous frequency measurements, continued use of momentary cessation, interpretation of voltage trip requirements, PLL operation…

Investigating Tradeoffs of IEEE Std 1547-2018 Voltage Settings (Trans.)

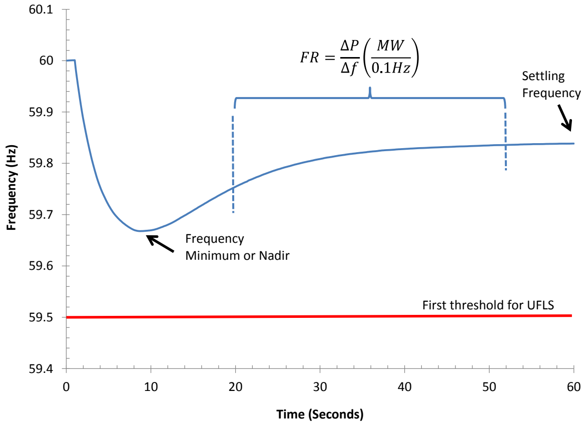
Transmission Model Determines Area of Impact



DER and Distribution Models Determine DER Response



Overall Co-Simulation Gives Generation Lost Due to Event

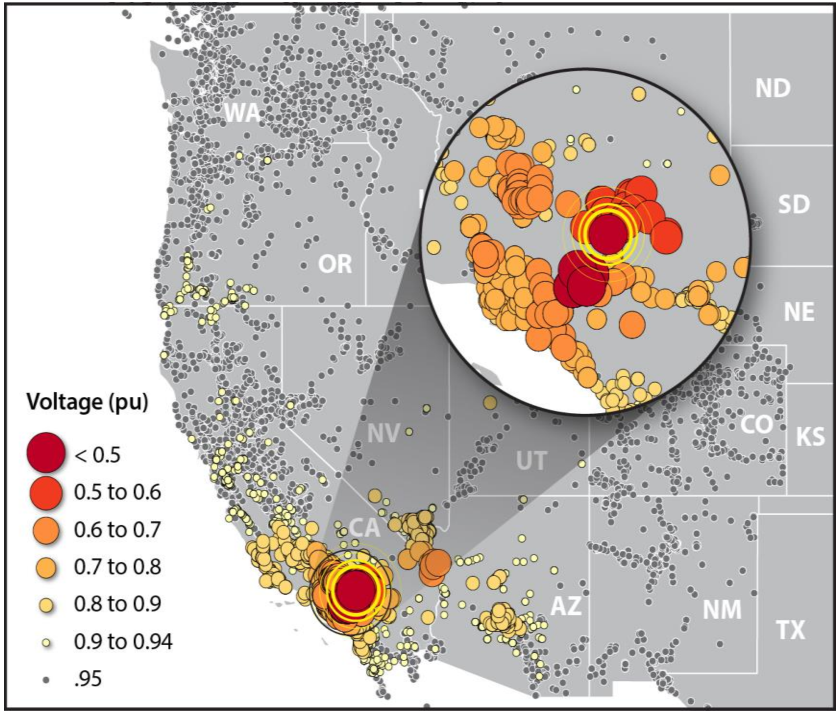


We are combining the worlds of transmission and distribution system modeling to determine the reliability impacts and tradeoffs for regional voltage issues in areas with high amount of DER (PV)

- Requires some form of co-simulation or reliance on aggregated DER models in positive-sequence dynamic tools
- Ride-though 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

Investigating Tradeoffs of IEEE Std 1547-2018 Voltage Settings (Trans.) Cont.

Transmission Model
Determines Area of Impact



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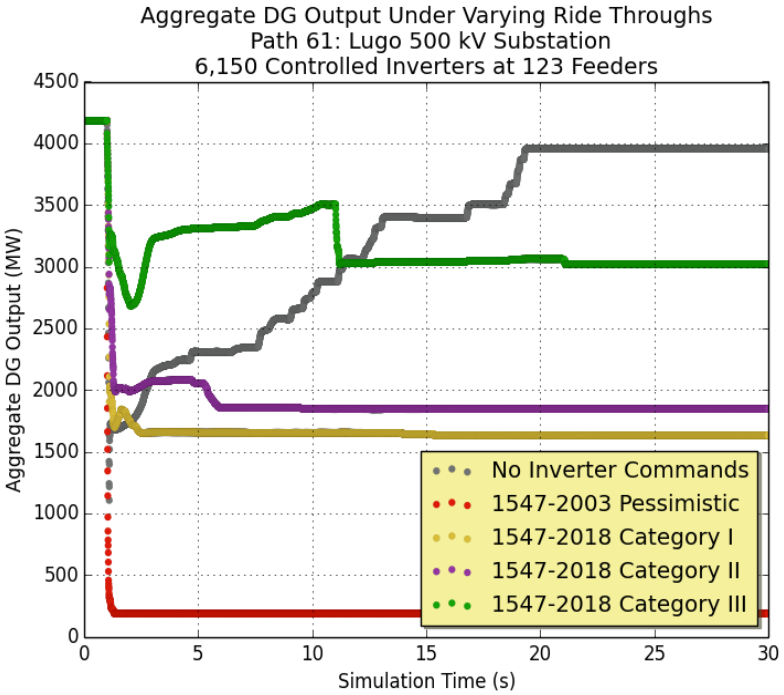

Note: these are not final results – just food for thought

Thank you for your attention

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