EXPERTISE TO ENABLE GRID TRANSFORMATION

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Voltage Regulation

- ✓ Context
- ✓ Background
- ✓ Experience
- ✓ Recommendations

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Context

1. **IEEE-1547 2018** inverters based on this new equipment standard will be available soon. States and utilities are making decisions now.
2. **Capabilities vs. Requirements**. 1547 is an equipment capabilities specification, not a prescriptive standard.
3. **Voltage is contested**. Ride through settings are uncontroversial. Voltage settings have tradeoffs.
4. **Harmonize**. If we can agree on settings for mass-market systems, we reduce complexity for installers, utilities, manufacturers.

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Context *(Continued)*

1. **Communications** capabilities are required in 1547-2018, but autonomous settings may provide acceptable grid support at lower cost than communications. Voltage settings that work for most systems, most of the time, will not require updating.
2. **Our approach**. Find common ground between grid needs and customer needs. Balance utility requirements for voltage management while minimizing real power curtailment.

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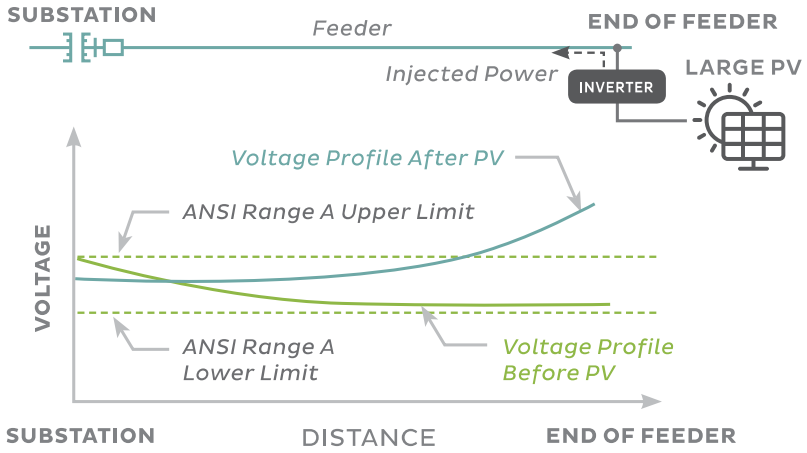
Background

- Earlier versions of IEEE-1547 did not allow inverters to ride through faults or operate at non-unity power factors.
- Increased deployment of inverter based DER raises concern for voltage management on distribution circuits



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IEEE 1547-2018 Voltage Management Modes

One of these modes:

1. Constant Power Factor (default, unity)
2. Voltage-Reactive Power (**volt-var**)
3. Active Power-Reactive Power (**watt-var**)
4. Constant Reactive Power

With the potential addition of:

- Voltage-Active Power (**volt-watt**)

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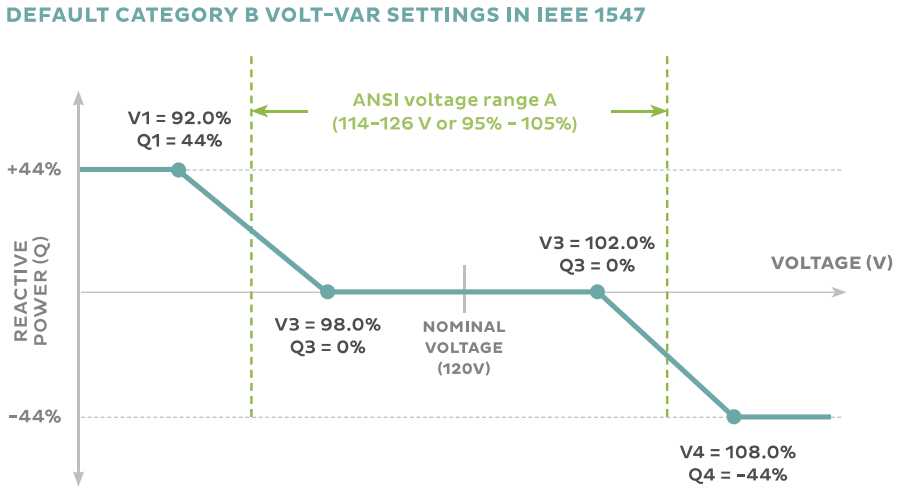
Voltage Management: volt-var



- **Pro:** Can address both high and low voltage impacts, does not create reactive power
- **Con:** Can result in curtailment w/o headroom, may challenge coordination with traditional voltage management

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Voltage Management Modes

Voltage-Active Power (**volt-watt**)

- **Pro:** Mitigates impacts from reconfiguring circuits, can increase hosting capacity
- **Con:** May result in curtailment

Constant Power Factor

- **Pro:** Simple, Can mitigate voltage
- **Con:** Absorbs reactive power at all times, even when not needed, can curtail active power if no "headroom"

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Lessons Learned

Does volt-var affect output?

- Losing real power would mean high voltage coinciding with peak output
- NREL's work in HECO shows real power loss is in the range of 0.5% during high voltage periods
- Headroom in inverters can help

Does volt-var conflict with voltage regulation or IVVC?

- NREL 2016 study of PG&E and HECO
- Ameren and ComEd studies

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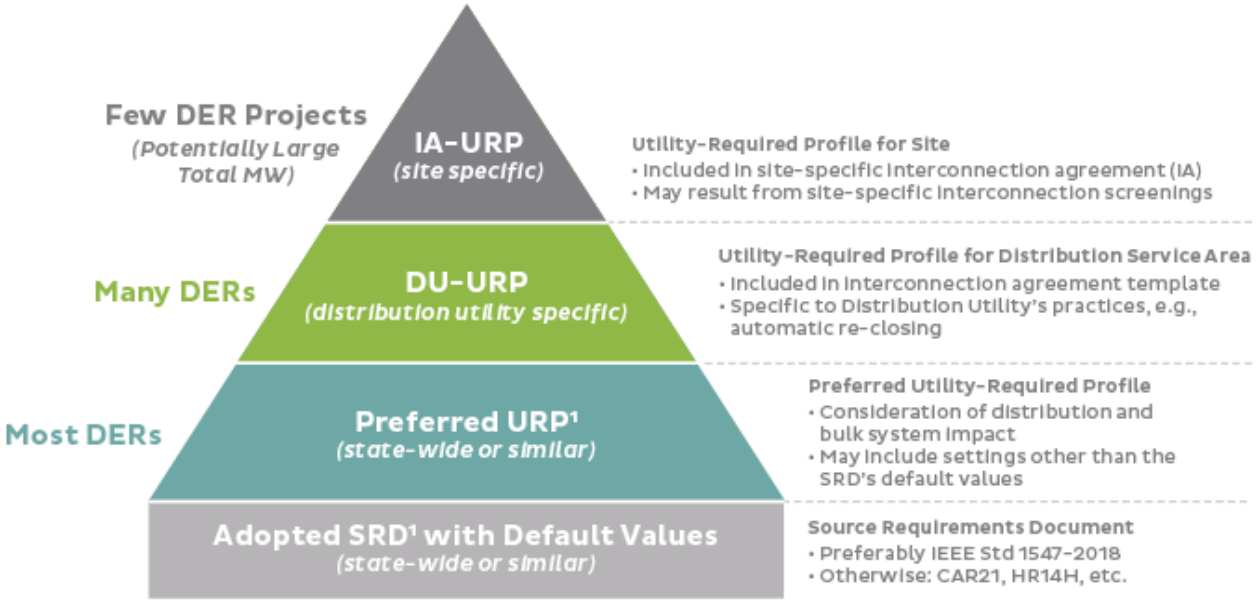
Recommendations: For "Most DER"



Source: EPRI

[1]Based on decision by Authority Governing Interconnection Requirements (AGIR)

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Recommendation: volt-var

- Manges voltage using the lowest reactive power
- Does not appear to conflict with other voltage management
- Setting this now, even with low penetrations, helps in the future
- Consider inverter headroom to reduce potential real power losses
- Standardized settings reduce confusion
  - *Recommend IEEE 1547-2018 standard volt-var settings Category B*

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Recommendation: volt-watt

- Curve starts to curtail outside of 1.06 pu
- Provides "backstop" for high voltage events
  - Allows grid planners to increase hosting capacity
  - Should eliminate need for direct control
- Experience from HECO as well as modeling shows limited curtailment from volt-watt
- Needs vigilance from utilities and good reporting on voltage issues
- Regulators should consider voltage reporting if requiring volt-watt

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THANK YOU

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