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# High Penetration PV – A Transmission Perspective

Abraham Ellis, PhD, PE

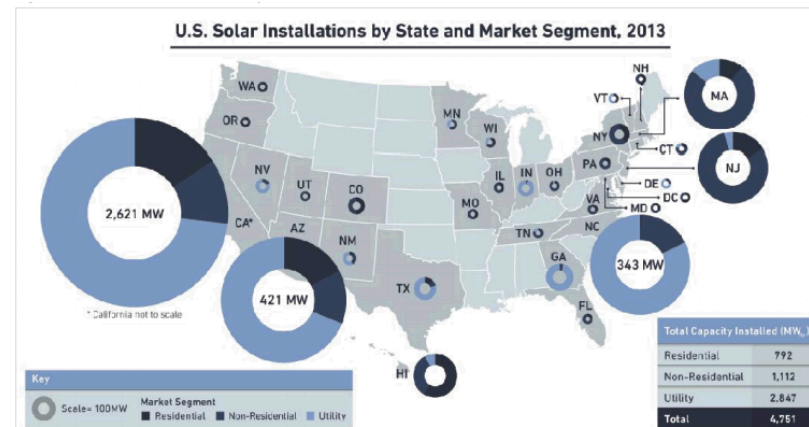
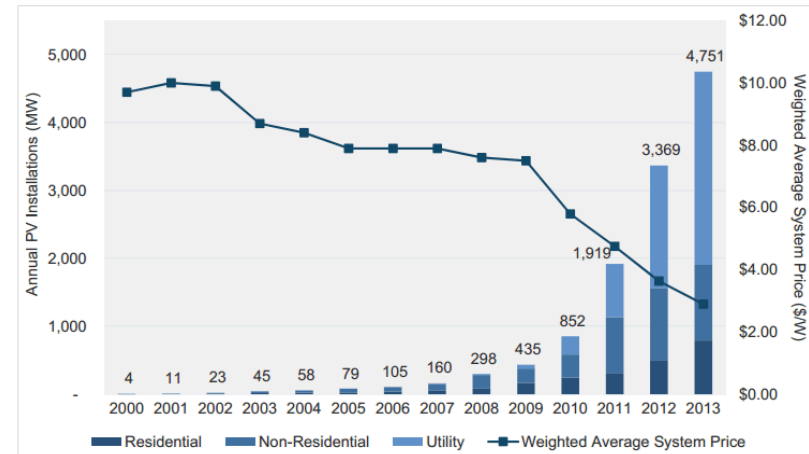
Photovoltaics and Distributed Systems Integration Department



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# PV capacity is growing fast!

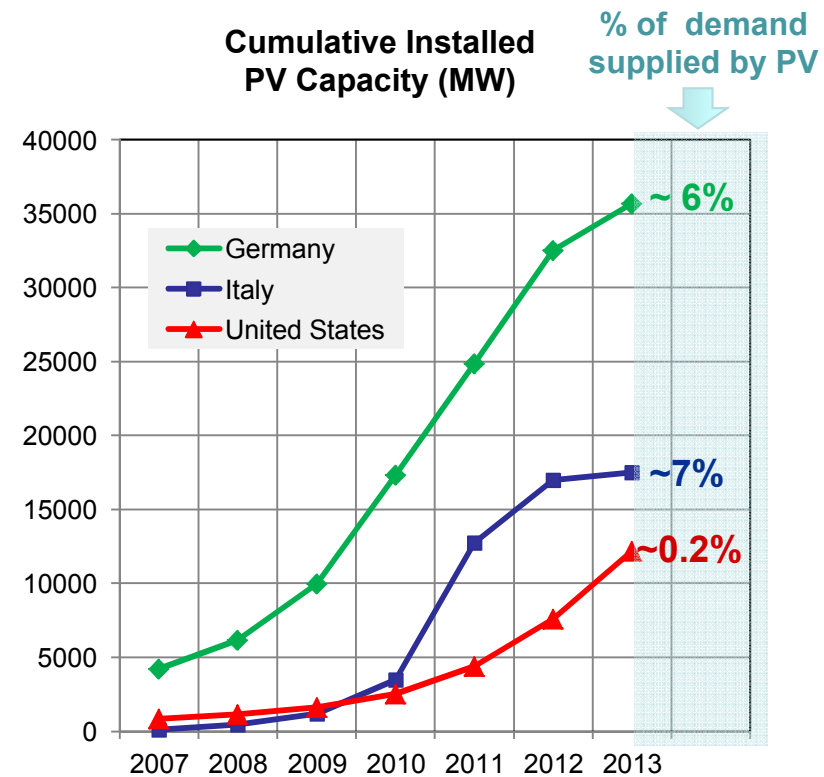
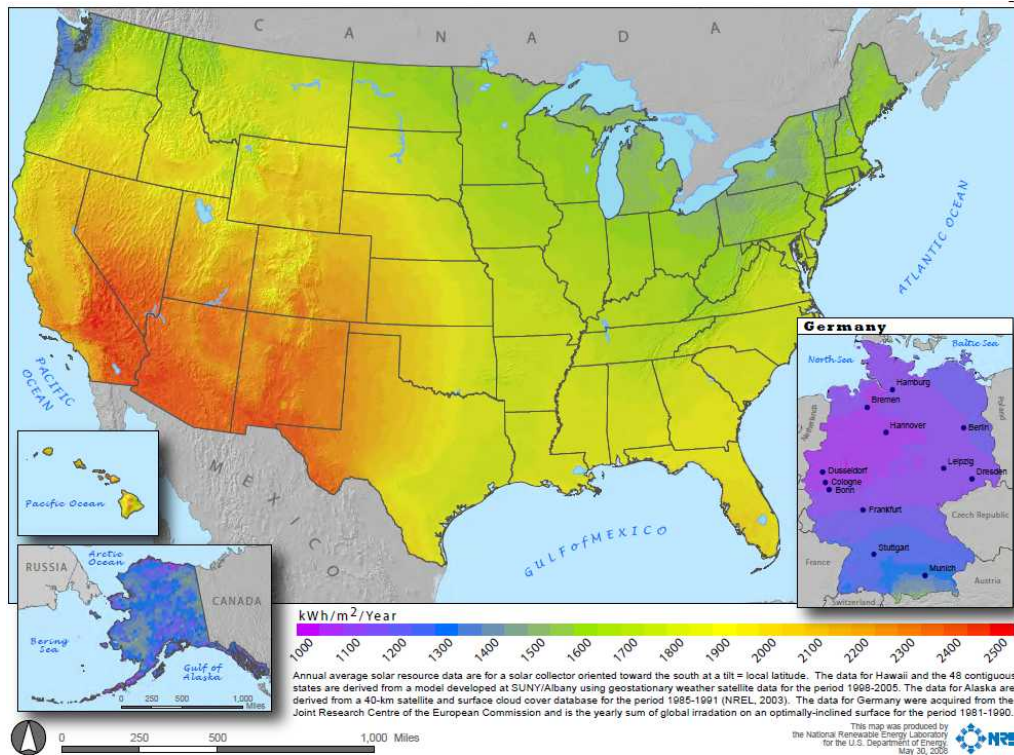
- Total installed capacity is 12.1 GW total; 4.7 GW installed in 2013
  - Installed capacity projected to triple in the next 2-3 years
- High-Pen Scenarios developing in several areas
  - California
    - ~2 GW of distribution-connected PV
    - Aiming for 12 GW of DG (PV) by 2020
  - Hawaii
    - Half of distribution circuits are at 100% of daytime minimum load
    - Highest penetration at the balancing area level (island grids)



Source: GTM Research, US Solar Market Insight 2013 Year in Review

# Huge potential for further growth!

- A slow start, but the trends accelerating, and the ultimate deployment potential is very high



# Interconnection Level

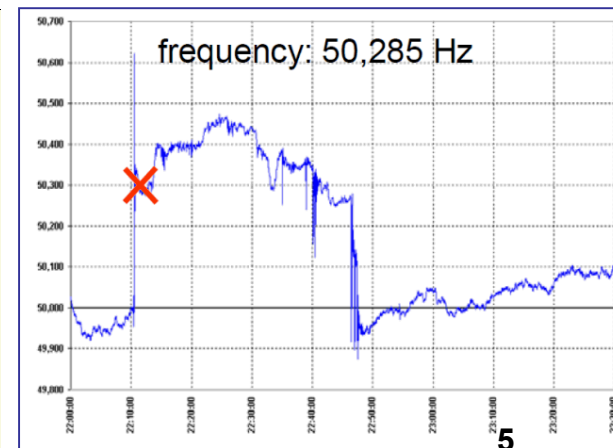
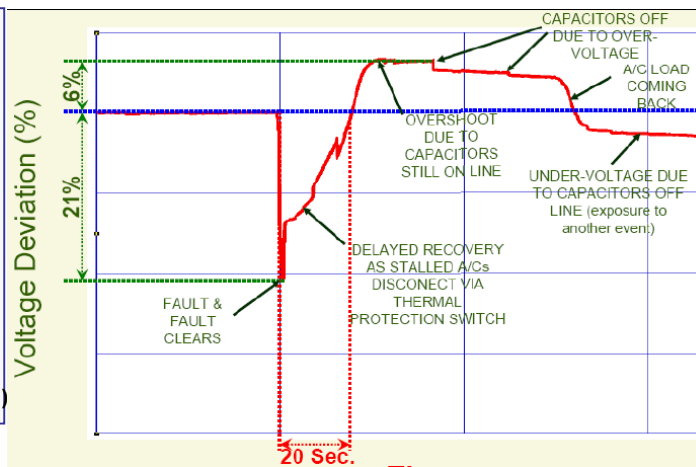
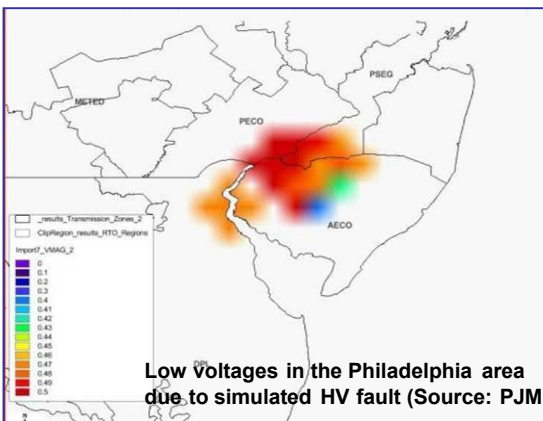
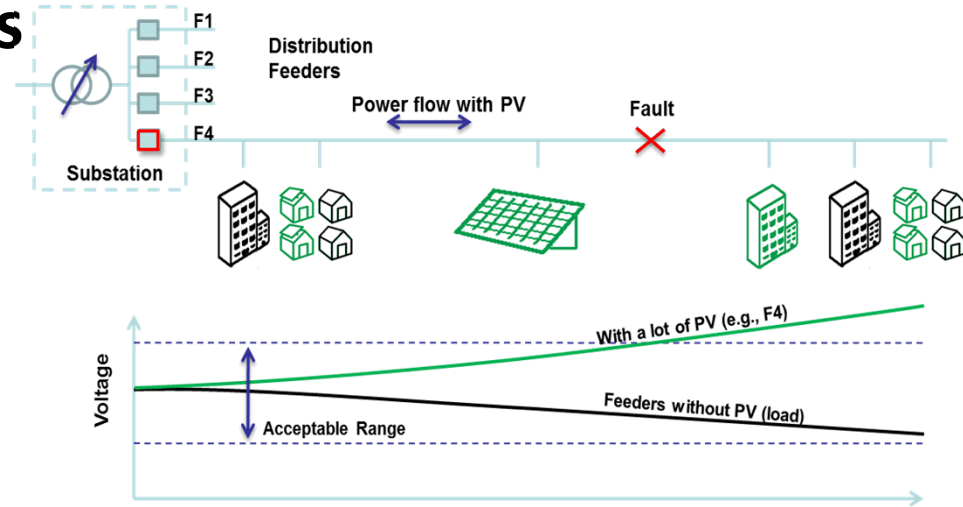
- Distribution-connected
  - Residential, Commercial
- Transmission-connected
  - Numerous 100+ MW PV plants are operating, under construction, or planned



# High Pen PV... What is the Problem?

## Near-term technical issues

- Distribution-level voltage control and protection
- Bulk system stability
  - Possible loss of DG during disturbances



# Minimum V/FRT for DER

- Why do we need it?
  - Prevent grid security impacts of high pen. DER
  - Provide more clarity and uniformity to equipment design
  - Avoid potentially overly-onerous requirements
  - Clarify certification requirements
  - Other: Prevent “limits”, retrofits and high integration cost to future DG; enhance DER value to system reliability
  
- Why incorporate minimum requirements in IEEE Std. 1547?
  - IEEE Std. 1547 is the most widely adopted interconnection standard in North America – codified in State Interconnection Rules, FERC SGIP
  - Compatibility with other interconnection requirements can be intrinsically addressed

# Where are we?

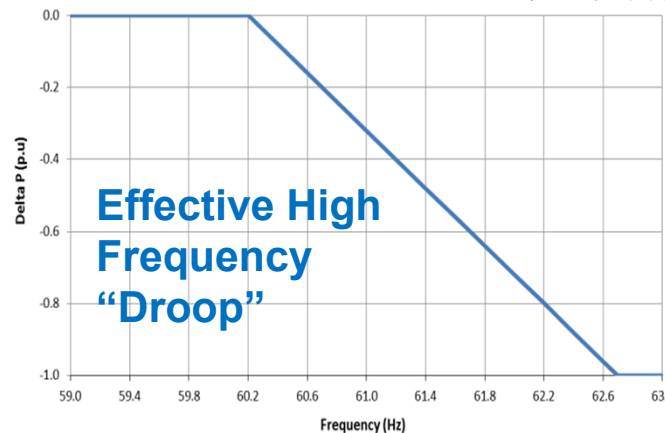
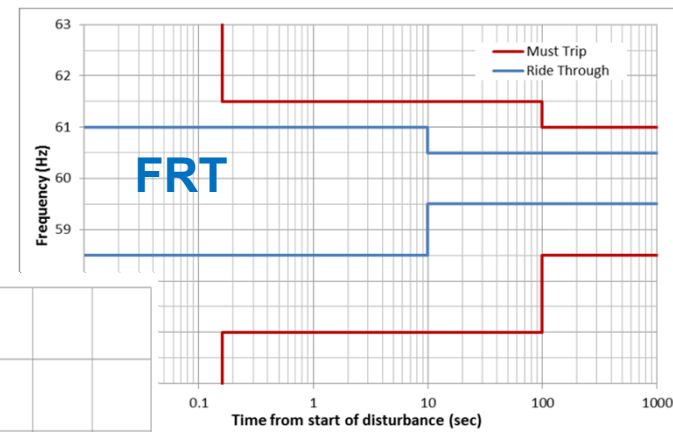
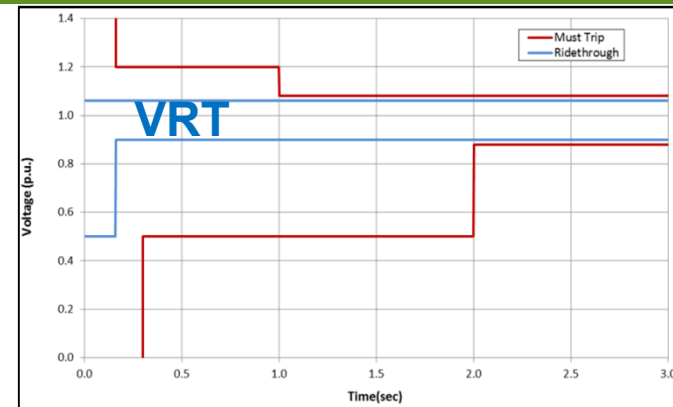
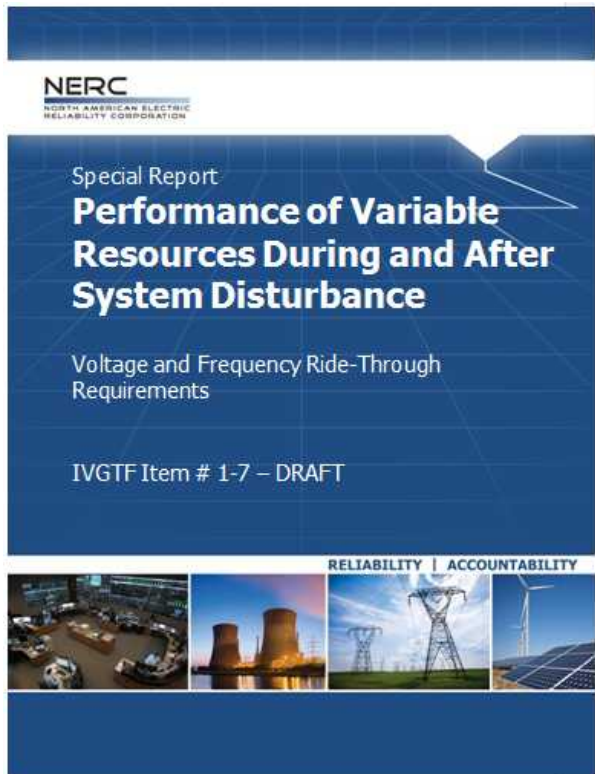
- IEEE Std. 1547a does not go far enough

IEEE 1547-2008	IEEE 1547a (2013)
Shall not regulate voltage [no volt/var allowed]	May participate in voltage regulation [no specification]
Shall not regulate frequency [no freq/watt allowed]	May participate in frequency regulation [no specification]
Restrictive voltage and frequency must-trip range [opposite of V/FRT]	More widely adjustable voltage and frequency must-trip range [No V/FRT requirement]

- Does not fully address the problem, and will likely lead to lack of harmonization and over-specification
- Sets stage for future standards harmonization problems
  - CPUC Rule 21, PJM, others starting to develop own standards addressing advanced functions

# NERC IVGTF1-7 Recommendations

- Add explicit minimum VRT/FRT requirements
- Add high frequency droop requirement



# V/FRT Implementation Challenges

## There are challenges...

- Equipment Limitations
- Fault Detection
- Islanding Detection
- Reclosing Coordination
- {Technology neutrality?}

## ...they can be overcome

- Potential grid compatibility “conflicts” can be minimized by ensuring that minimum V/FRT are reasonable
- Technology innovation and creativity
- Recent Sandia Report offers ideas for consideration

### SANDIA REPORT

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### Implementation of Voltage and Frequency Ride-Through Requirements in Distributed Energy Resources Interconnection Standards

Reigh Walling, Walling Energy Systems Consulting, LLC  
Abraham Ellis, Sandia National Laboratories  
Sigifredo Gonzalez, Sandia National Laboratories

Technical Report  
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# Discussion



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