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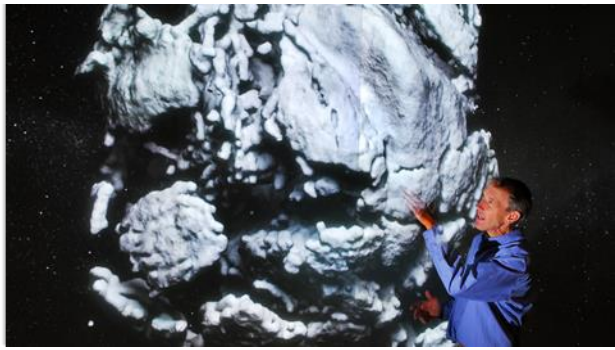

On the Potential Impact of Distributed Generation

Abraham Ellis
Sandia National Laboratories
aellis@sandia.gov

November, 2015

U.S. DEPARTMENT OF ENERGY
NNSA National Nuclear Security Administration

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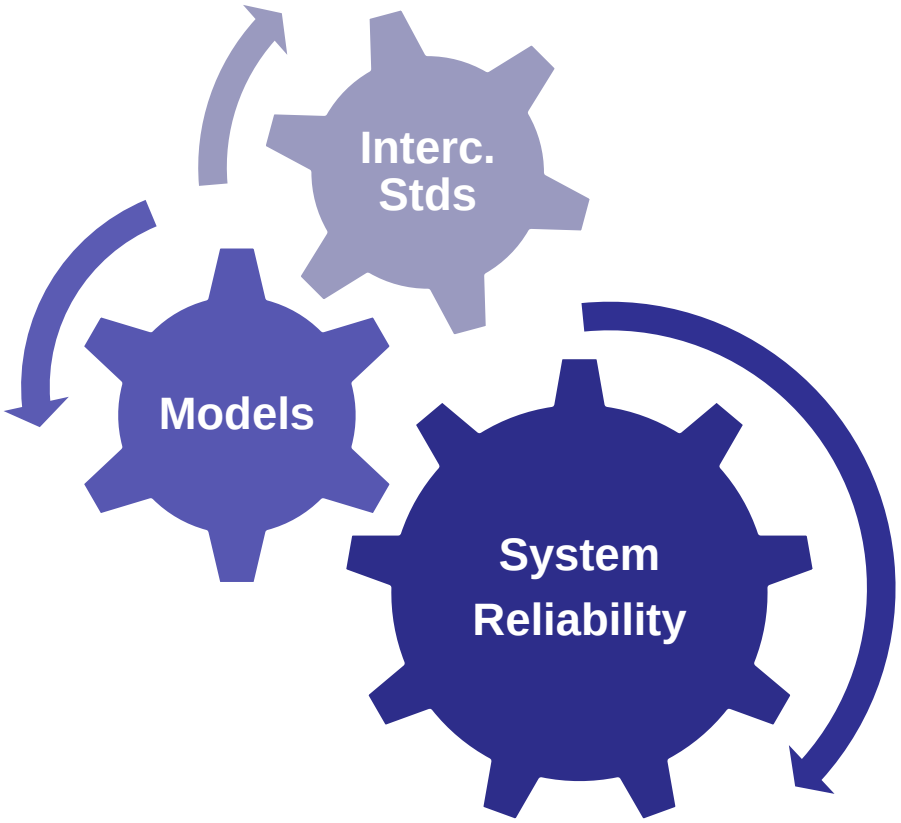
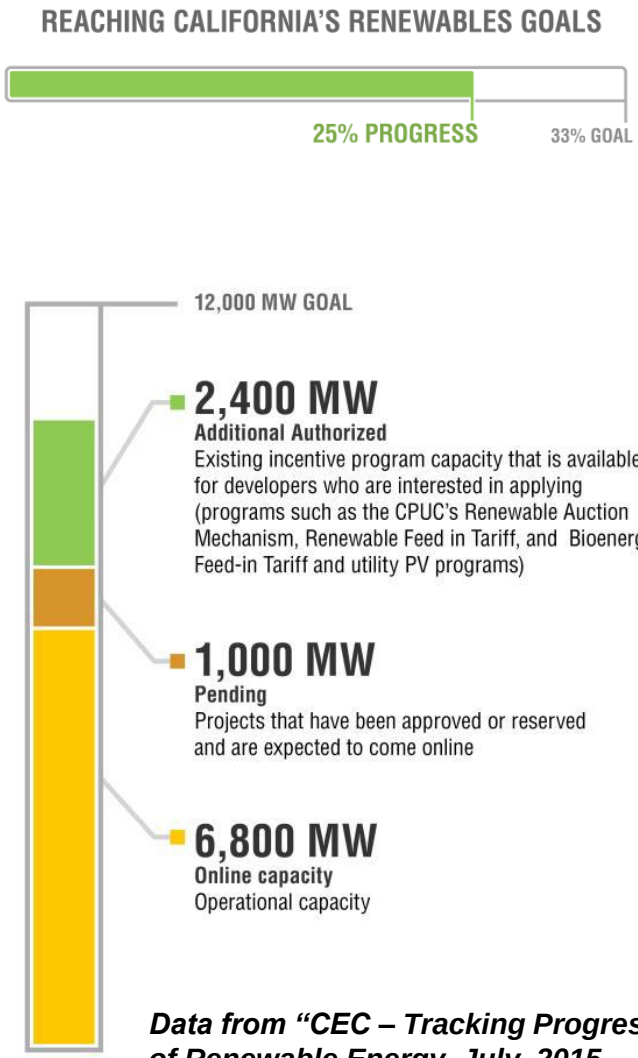
Outline

- Context
- Potential bulk system impacts
- Standards
- Modeling
- Discussion



CA snapshot

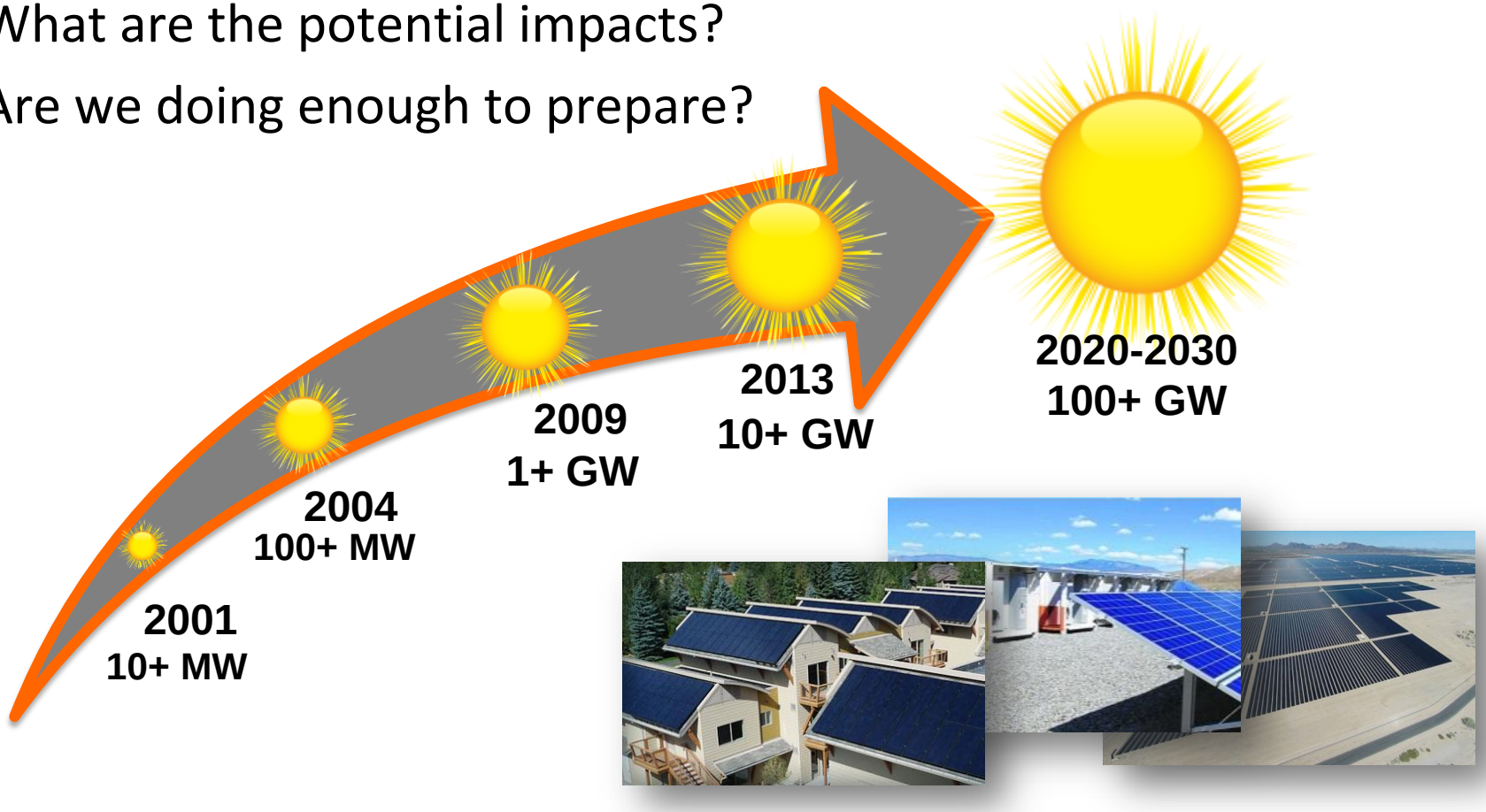
- CA RPS (%by energy)
  - 33% by 2020; 50% by 2030
  - As of 2015, at 25% penetration by energy
    - This represents ~25 GW of installed capacity
- CA Distributed Generation Goal
  - 12 GW of renewable distributed generation (<20 MW) by 2020
  - As of June 2015, counting systems >1 MW:
    - 6.8 GW of DC installed
    - 4.8 GW is PV
    - + ~2.5 GW of NEM PV
- The system has a lot of PV, mostly DG
  - Forecast: More of the same



Data from "CEC – Tracking Progress of Renewable Energy, July, 2015

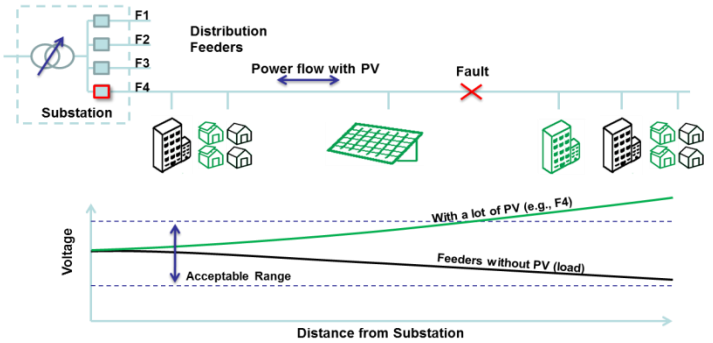
PV will continue to grow very fast

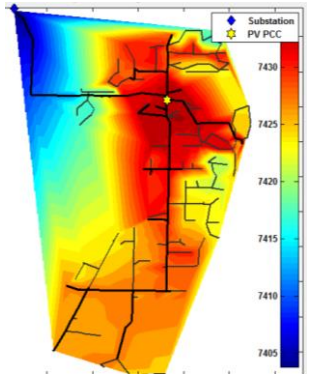
- With cost still falling, future deployment potential is very high…
  - Much of it is going in distribution systems
- What are the potential impacts?
- Are we doing enough to prepare?

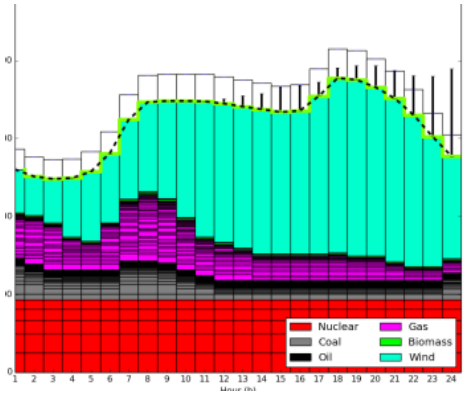


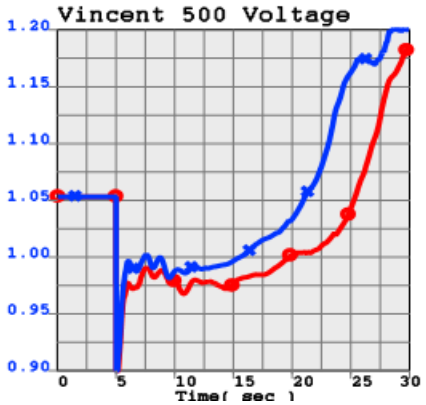
Possible technical impacts of DG

- Distribution system
  - Voltage control
  - Protection coordination
  - Planning process
- Bulk system impacts
  - Operations (dispatch, etc.)
  - System performance
    - Voltage stability
    - Frequency stability
    - Small stability





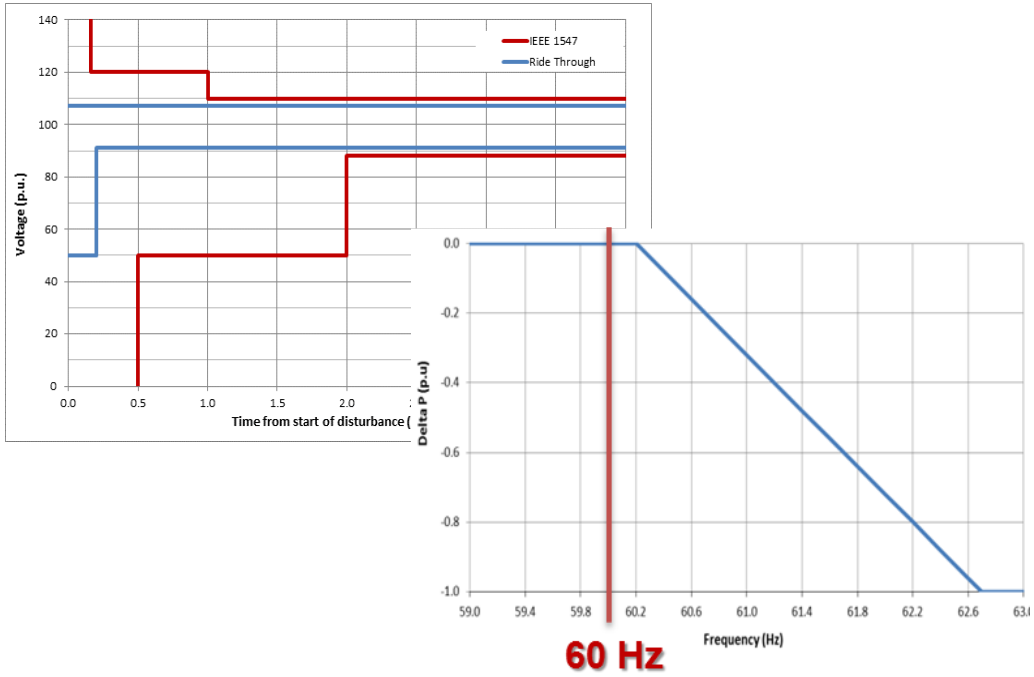


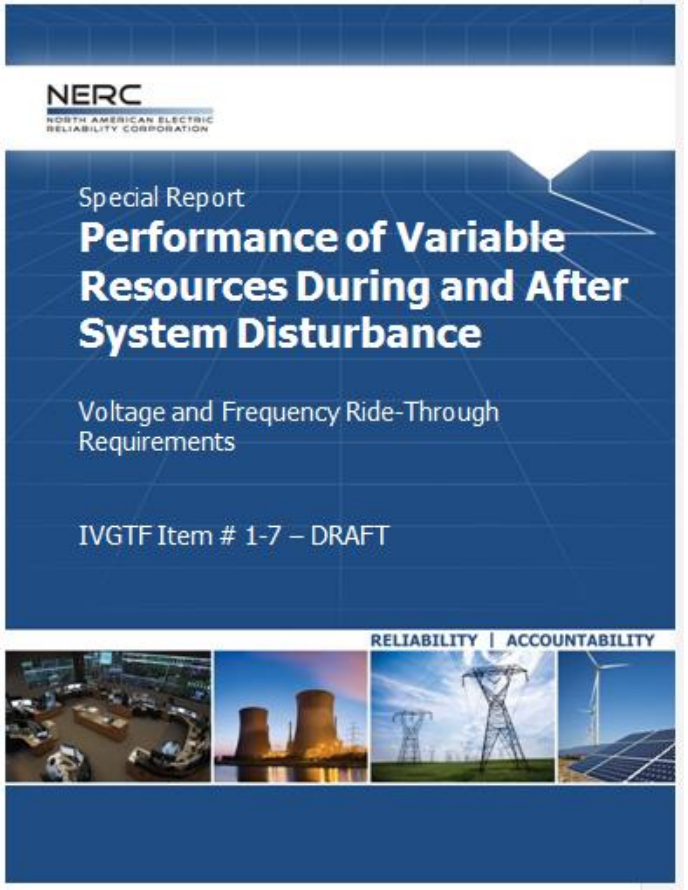


- DG can affect bulk system performance.
  Two issues of current interest:
  - DG disturbance tolerance
  - Representation of DG in planning studies

NERC paying attention…

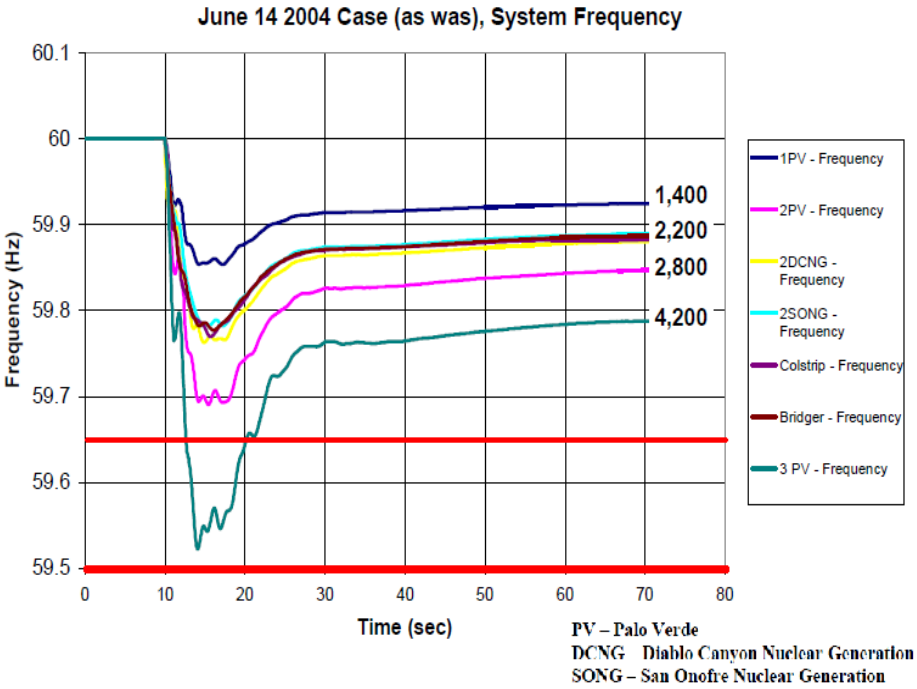
- NERC identified DG tripping as a potential reliability issue to the bulk system
- NERC IVGTF 1.7 report recommended that IEEE Standard 1547 be revised
  - Require *voltage ride-through*
  - *Require frequency ride-through*
  - Establish minimum *default* settings



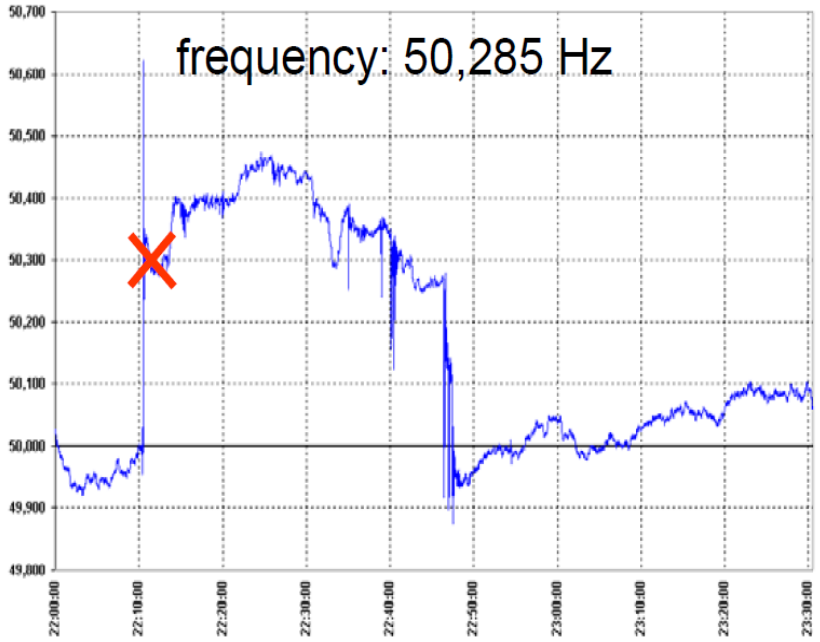


Disturbance tolerance

- Low and High Frequency can also pose a system reliability risk…



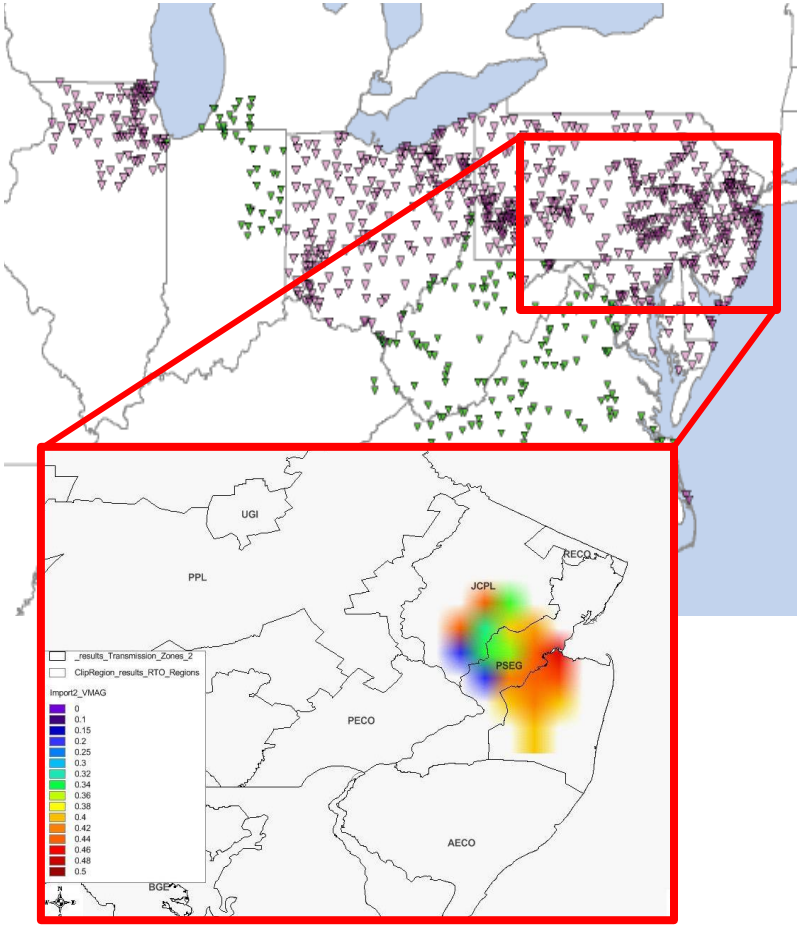
N. Miller and Z. Ye., *Distributed Generation Penetration Study*

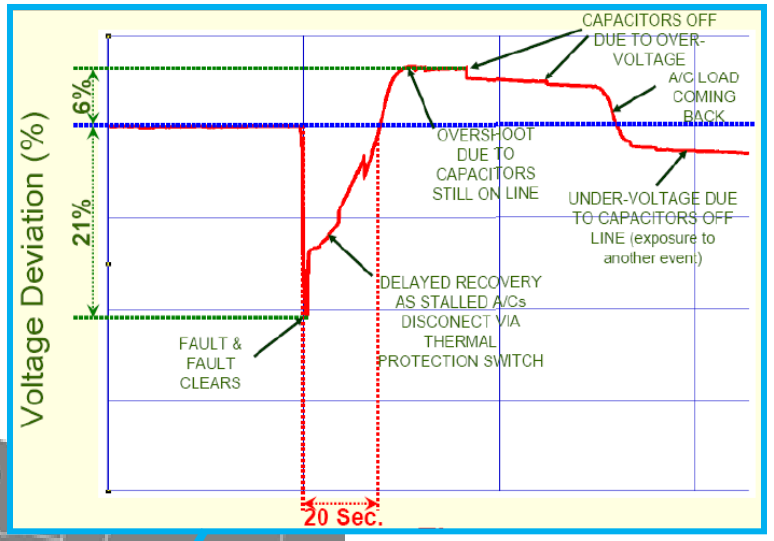


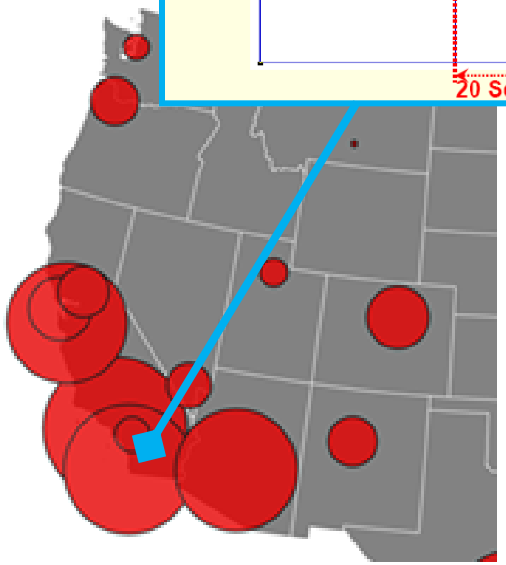
High frequency in Eastern Europe, after Nov. 2006 UCTE system breakup

Disturbance tolerance

- DG tripping due to high or low voltage can pose a system risk…

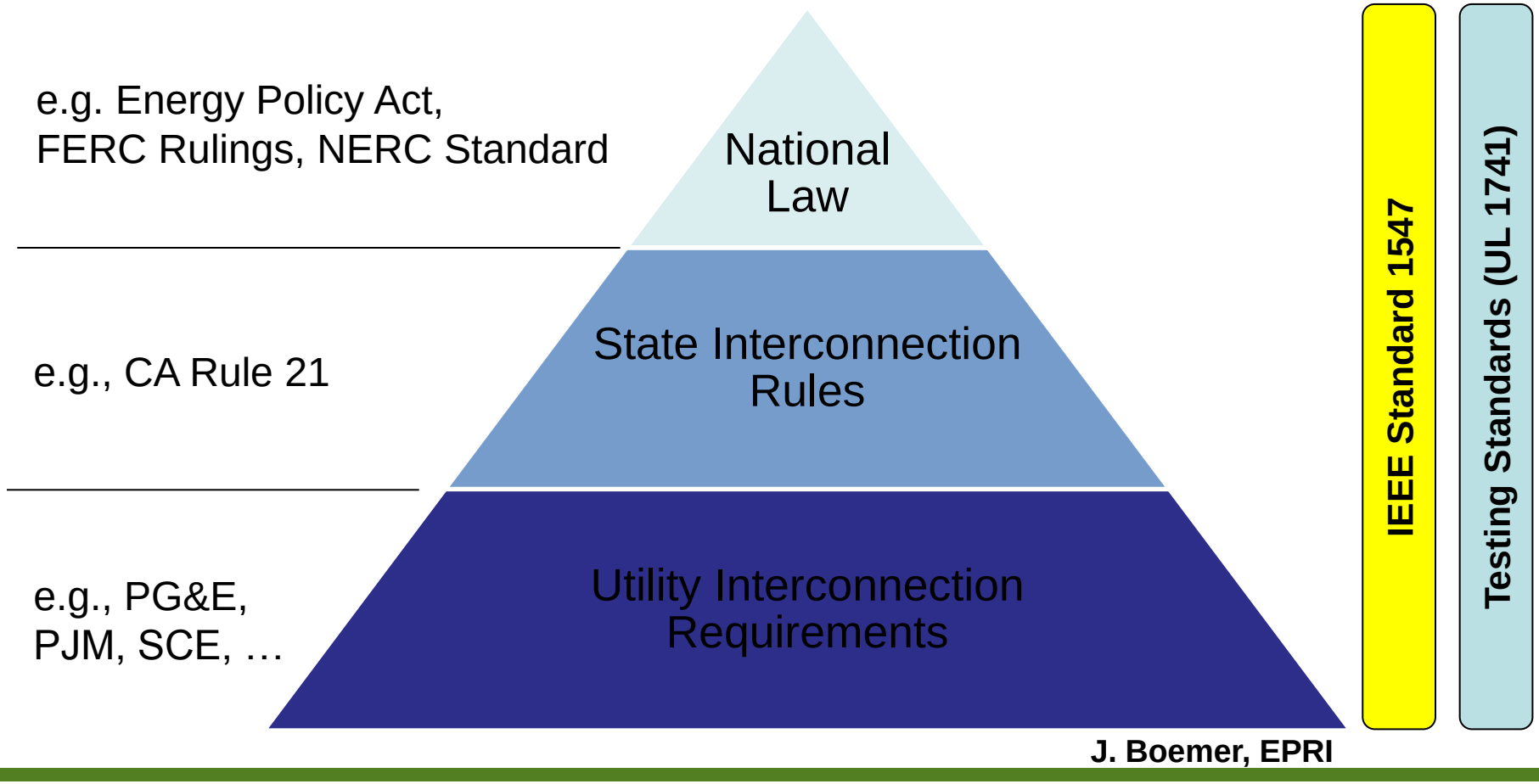






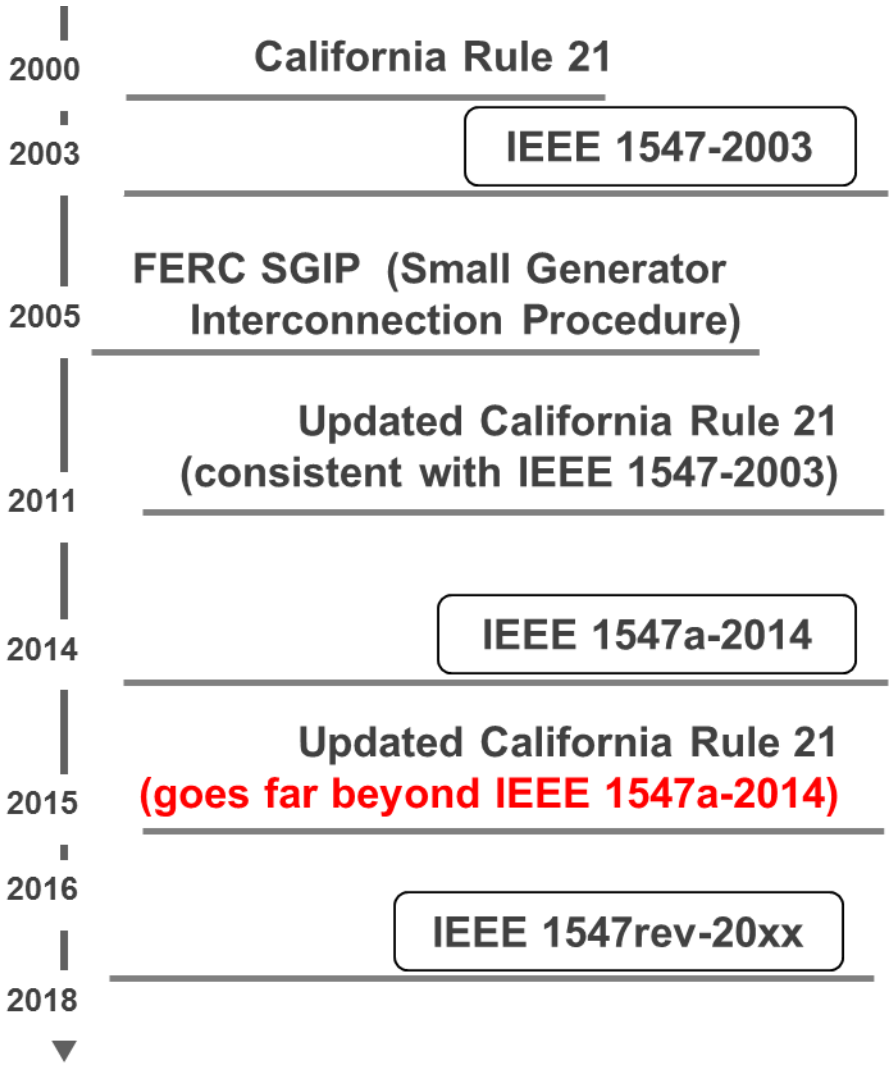
Changing standards is difficult…

- IEEE 1547 is part of a complex set of laws, rules, requirements, standards, subject to multiple jurisdictions and processes



J. Boemer, EPRI

…but progress is being made



IEEE 1547 (2003)

- **Assumed low penetration scenario**
- **Narrow must-trip settings put the bulk system at risk in high-pen scenarios**
- **Did not allow voltage control**

Revisions in IEEE 1547a-2014:

- **"Allows" voltage support**
- **"Allows" frequency/watt functions**
- **Optional widening of trip limits and clearance times**

Working on IEEE 1547Rev-20xx:

- Ride-through requirement
- Voltage support definition
- Communication/control functions
- Anti-islanding detection

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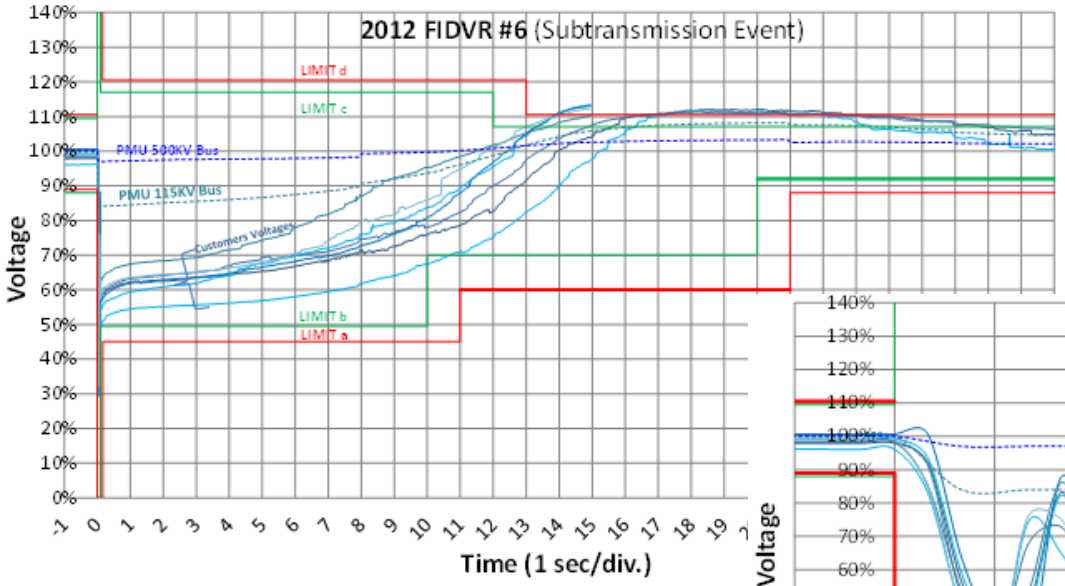
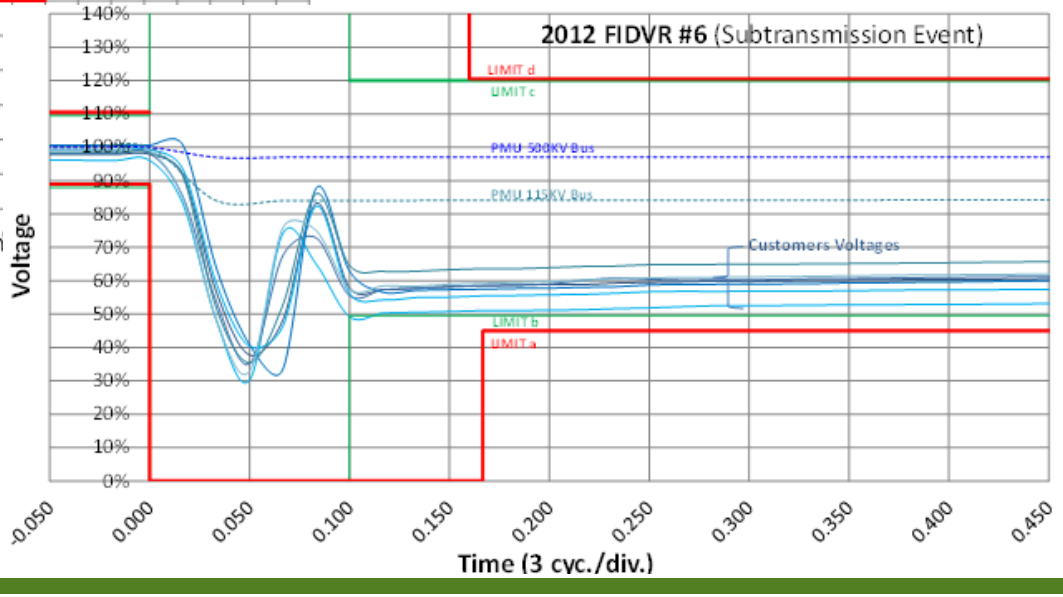
Disturbance tolerance technical basis

- CA Rule 21 V/FRT requirements are inverter-specific
- Proposed IEEE Std. 1547 revision has three performance levels





R. Bravo

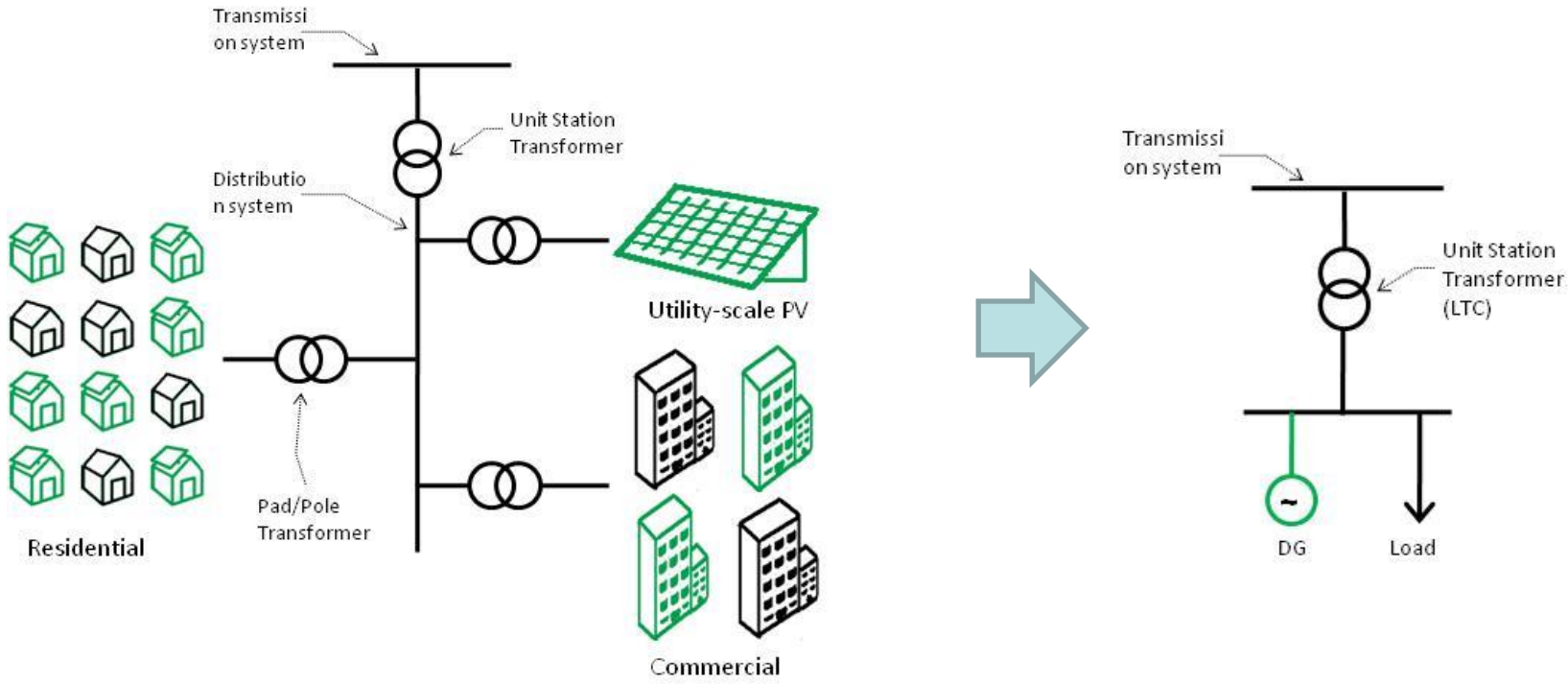
More DG-related challenges ahead…

- CA Rule 21 requires inverter-based DG to have additional control capabilities, in addition to V/FRT
  - Functions to be rolled out in phases
  - Full impact on bulk system performance is the subject of studies

	Function or Communication Verifica
Phase 1	Anti-Islanding Protection (AI)
	Low/High Voltage Ride-through (L/HVRT)
	Low/High Frequency Ride-through (L/HFRT)
	Volt-Var Mode with Watt-Priority
	Ramp Rates
	Fixed Power Factor
	Soft Start
Phase 2	Communication Interface
	Transport Protocols
	Data Model
	Mapping to Application Protocols
	Transport Cyber Security
	User Cyber Security
Phase 3	Monitor Alarms
	Monitor DER Status and Output
	Limit Maximum Real Power
	Connect/Disconnect
	Provide DER Information at Interconnection/Startup
	Initiate Periodic Tests of Software and Patches
	Schedule Output Limits at PCC
	Schedule DER Functions
	Schedule Storage
	Frequency-Watt Mode
	Voltage-Watt Mode
	Dynamic Current Support
	Limit Maximum Real Power
	Set Real Power
	Smooth Frequency Deviations

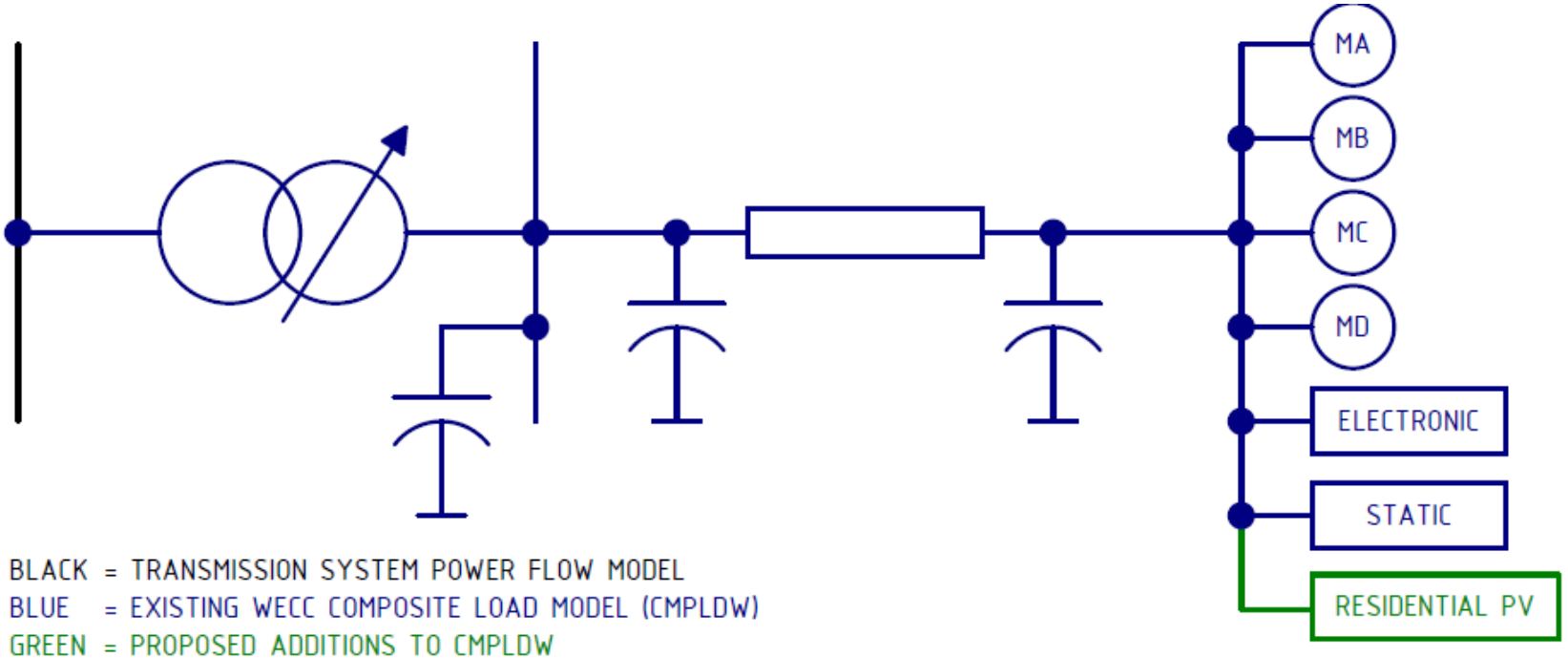
WECC improving DG modeling

- WECC REMTF Recommendations for power flow representation
  - Represent as a generator (required for generators >10 MVA)
  - For significant DG aggregation, represent as part of the load record
  - Move load and DG to MV bus, behind transformer



WECC improving DG modeling

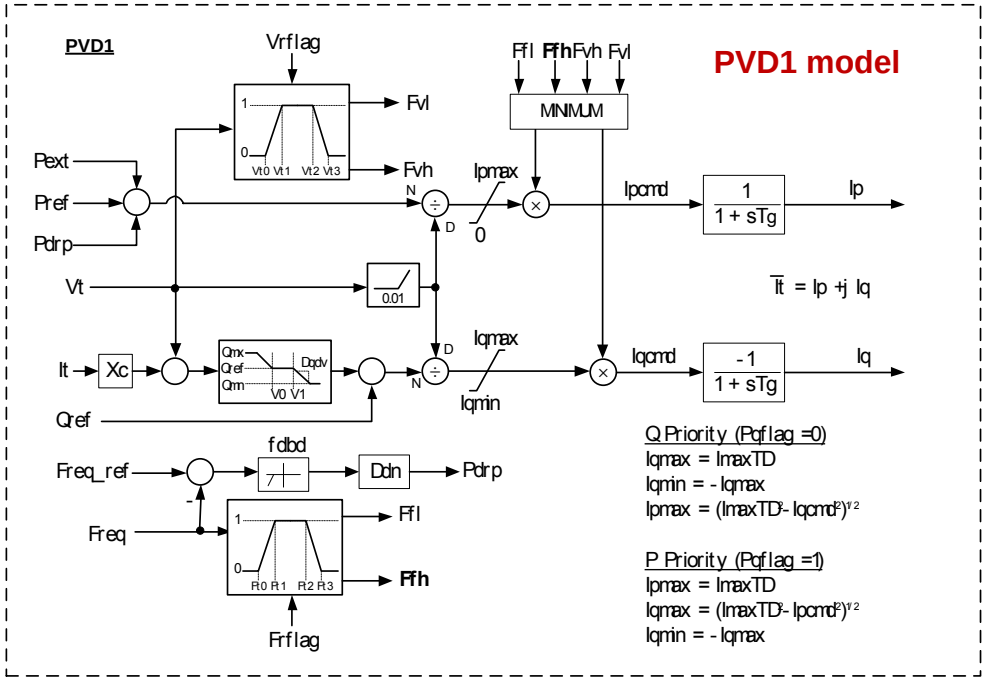
- WECC REMTF Recommendations for dynamic representation
  - For DG represented explicitly in power flow, use simple ***PVDX*** model
  - For DG aggregated DG, use DV(PV) option in ***CMPLDW*** model
  - NOTE: Both models are WECC-approved

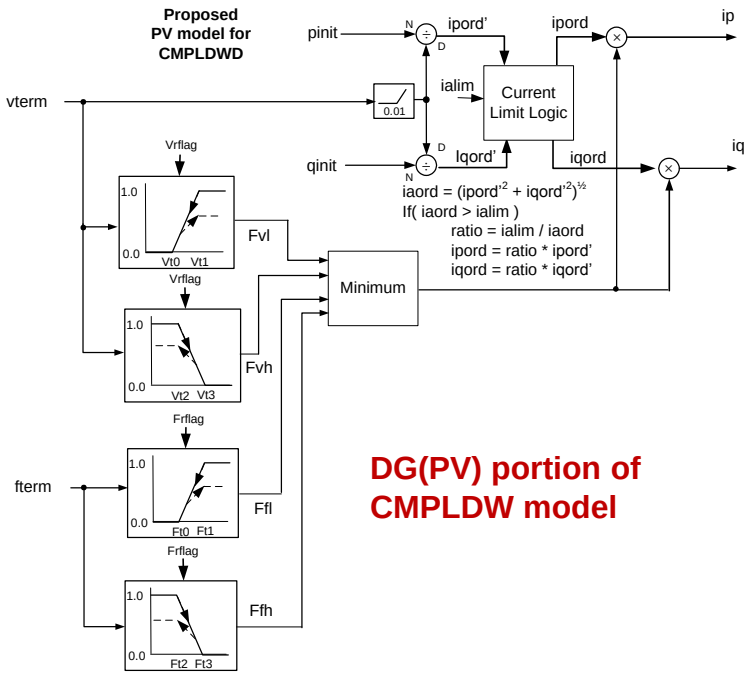


CMPLDW model with DG (PV) option

WECC improving DG modeling

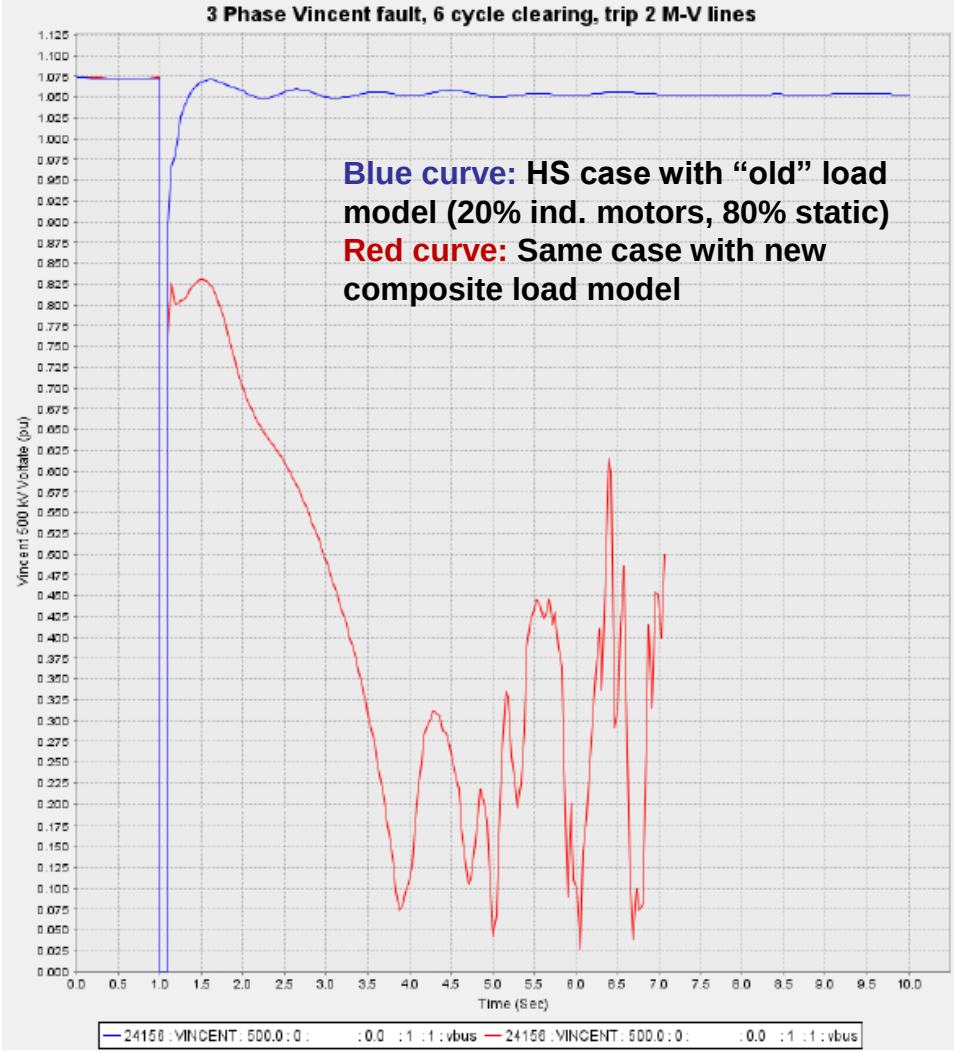
- WECC REMTF ***PVDX*** and ***CMPLDW*** models are evolving
- Existing functionality includes
  - Emulation of aggregated DG tripping as a function of voltage & frequency
  - Current limits (inverter-based model)
  - Basic volt/var and high frequency droop (***PVD1*** only)





Diving in to the unknown

- Models are required to drive performance standards for generators…
- At the same time, more accurate load and DG modeling may require that we revisit system planning criteria.



From K. Clark, NREL

Have a DG model, now what?

- WECC models need to be…
  - Expanded to other DG and to include new functionality
  - Field-validated (hard problem)
  - Improved over time
  - Used in planning base cases
  - Used to perform DG sensitivity analyses (e.g., WWSIS III)
- Data support will be required, similar to load model