SAND2012-8425P

A UVIG short course on the integration of Variable Generation into Electric Power Systems.

Session 15: DG Interconnection Screening, Study Procedures and IEEE 1547 Interconnection Requirements.

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September 19, 2012

Albuquerque, NM

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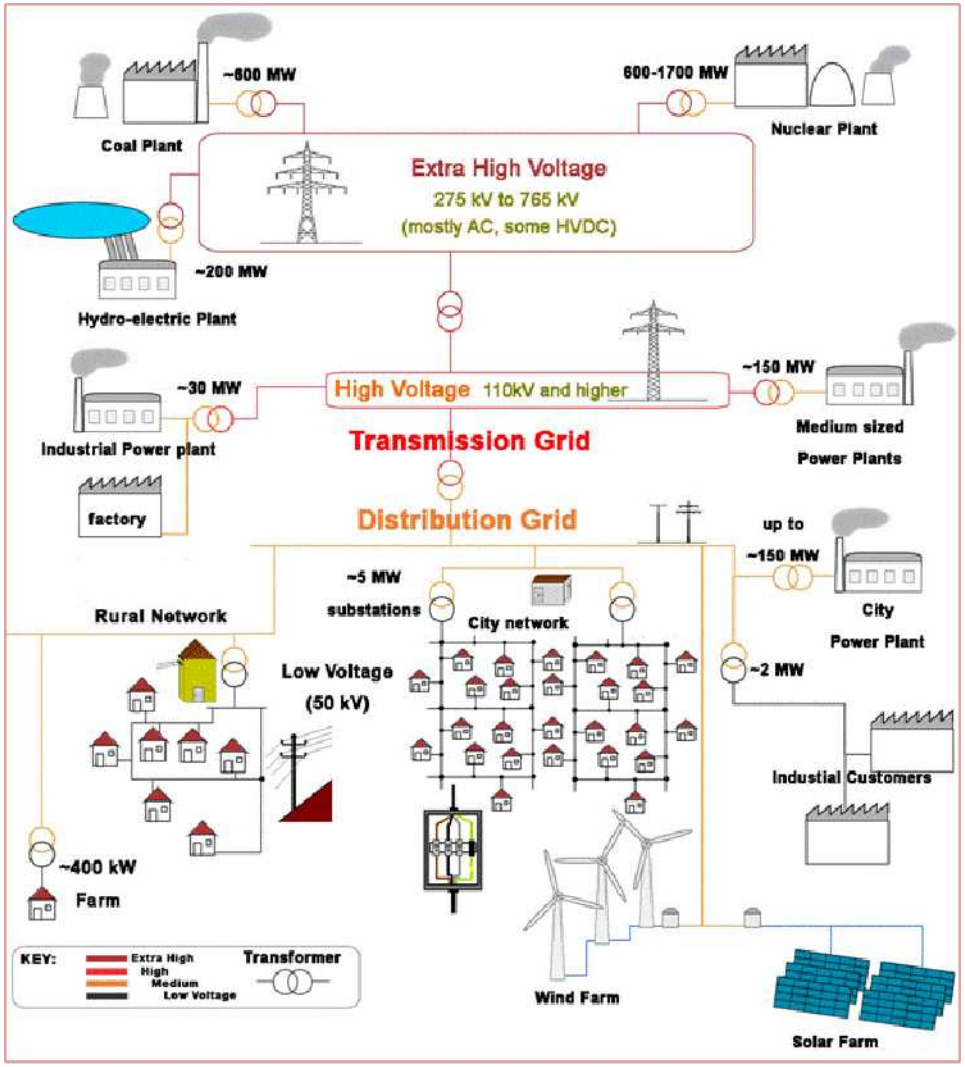
One system, different rules



Bulk System Guidelines
NERC, FERC
ANSI, IEC, NESC

Plenty of technical and jurisdictional overlap, confusion, contradiction…

Distribution System Guidelines
IEEE 1547, PUC/PRC
ANSI, IEC, NEC

Distributed Generation Interconnection

- Applicable rules & procedures depend on jurisdiction
- FERC jurisdiction: generation on utility side (wholesale)
  - Must follow an Open Access Distribution Tariff, i.e., FERC Order 2006 – SGIP for systems < 20 MVA (GIP for California IOUs)
  - Applies to Non Qualifying Facilities, Wholesale electricity sale
  - Distribution connected or transmission connected
- State Jurisdiction: generation on customer-side (retail)
  - Must follow state interconnection rule (e.g., CPUC Rule 21)
  - Qualifying facilities of any size
    - Some state rules establish capacity limits such as 10 MW
    - New CPUC Rule 21 does specify a system size for fast track
  - Distribution connected or transmission connected

Distributed Generation Interconnection

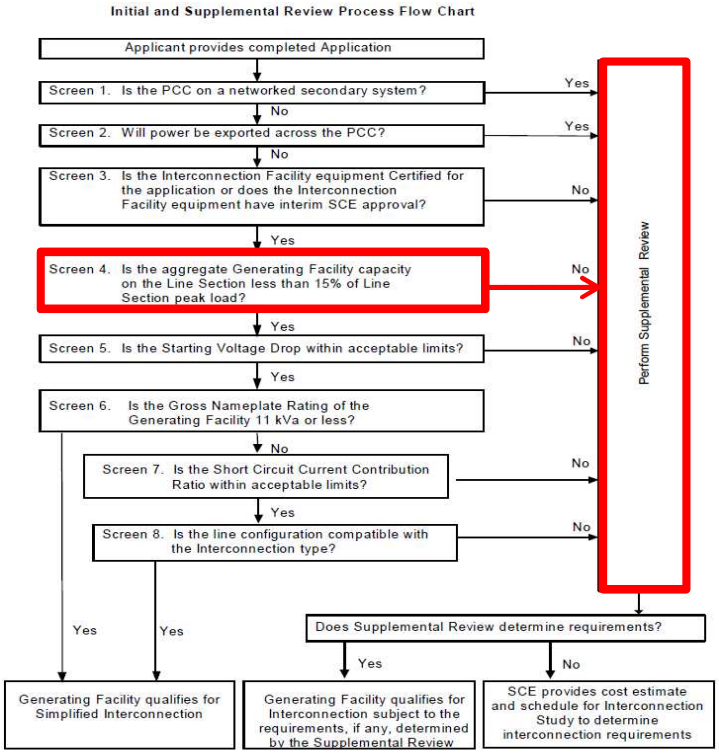
- Under the procedures, DG often qualifies for expedited interconnection provided that…
  - No system upgrades are required
  - Safety and reliability are not materially affected
  - ***Avoid unnecessary cost & processing time***
- SGIP / GIP Initial Review
  - "Fast Track Process" screens applicable to DG based on 2MW threshold **or** on a threshold based on the voltage class of distribution line at the point of interconnection. For example PG&E in California has proposed: ≤2 MW for 12KV class feeders, ≤3 MW for 21KV class feeders, ≤5 MW for <60KV class feeders.
  - "10 kW Inverter Procedure" applicable to DG < 10kW
- CPUC Rule 21 Initial Review
  - Old rule with 8-step screening procedure for all applications replaced with a New rule using a 13-step screening procedure.
  - "Fast Track Process" screens applicable to exporting DG facilities based on MW threshold and voltage class of feeder at point of interconnection: Threshold varies with utility: SCE= 3MW for 12KV-33KV, SDG&E= 1.5 MW for 12KV and PG&E =3MW for 12KV and higher.

Screening Criteria

- SGIP / GIP “Fast Track Process” Screens
  1. <15% of peak load on line section
  2. <5% of peak load or <50 kW on spot networks, must be inverter
  3. <10% of total short circuit current at nearest primary voltage
  4. <87.5% protection device short circuit interrupting capacity-breakers etc.
  5. Compatible transformer connection to avoid over-voltages
  6. < 20kW (aggregated) if connected on single-phase secondary
  7. < 20% imbalance when connected to tap neutral of 240V service
  8. < 10 MW where there are known or posted transient stability issues
  9. No construction facilities required on the host system
  10. Point of interconnection must be on a portion of the providers distribution system subject to tariff.
- If pass all screens, an Interconnection Agreement is offered; else, Supplemental Review is offered and/or an Interconnection Study is offered (project is not rejected)

Old Rule 21 Screening Criteria

- CPUC Rule 21 Initial Review
  1. Not a secondary network
  2. Not exporting across PCC
  3. Certified equipment
  4. <15% of peak load in line section
  5. Starting voltage drop within limits
  6. <=11 kVA nameplate rating
  7. Short circuit contribution ratio within limits
  8. Compatible transformer connection

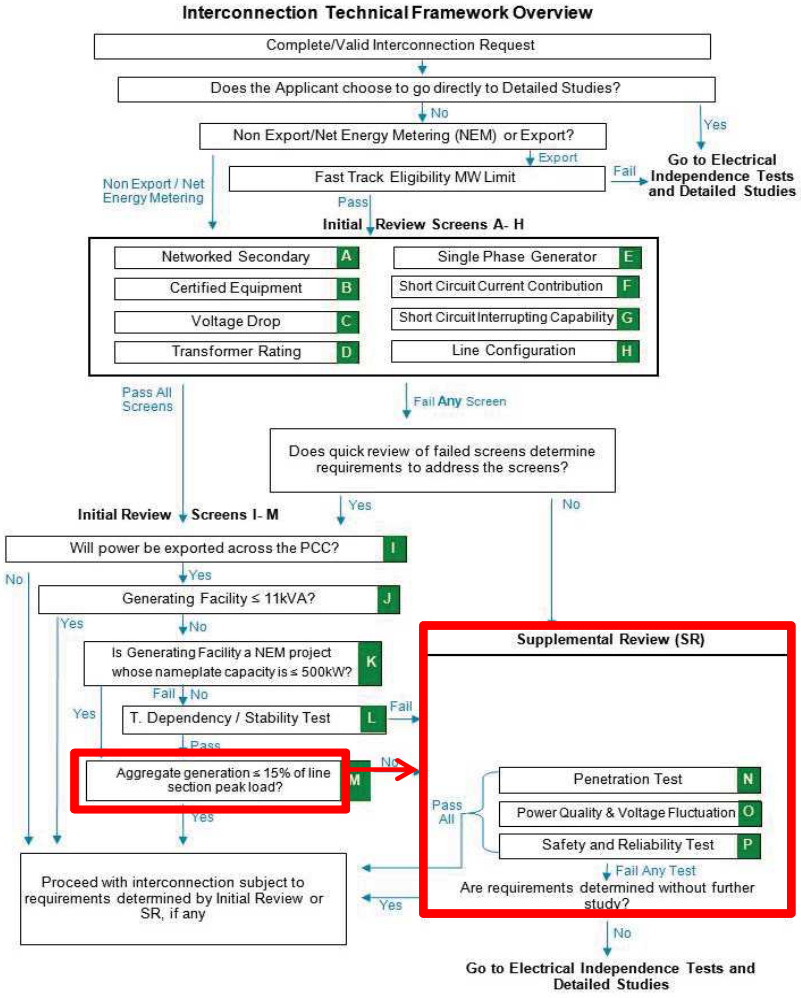


Source: SCE Rule 21 – Generating Facility Interconnections, August 2004

New Rule 21 Screening Criteria

Key Changes:

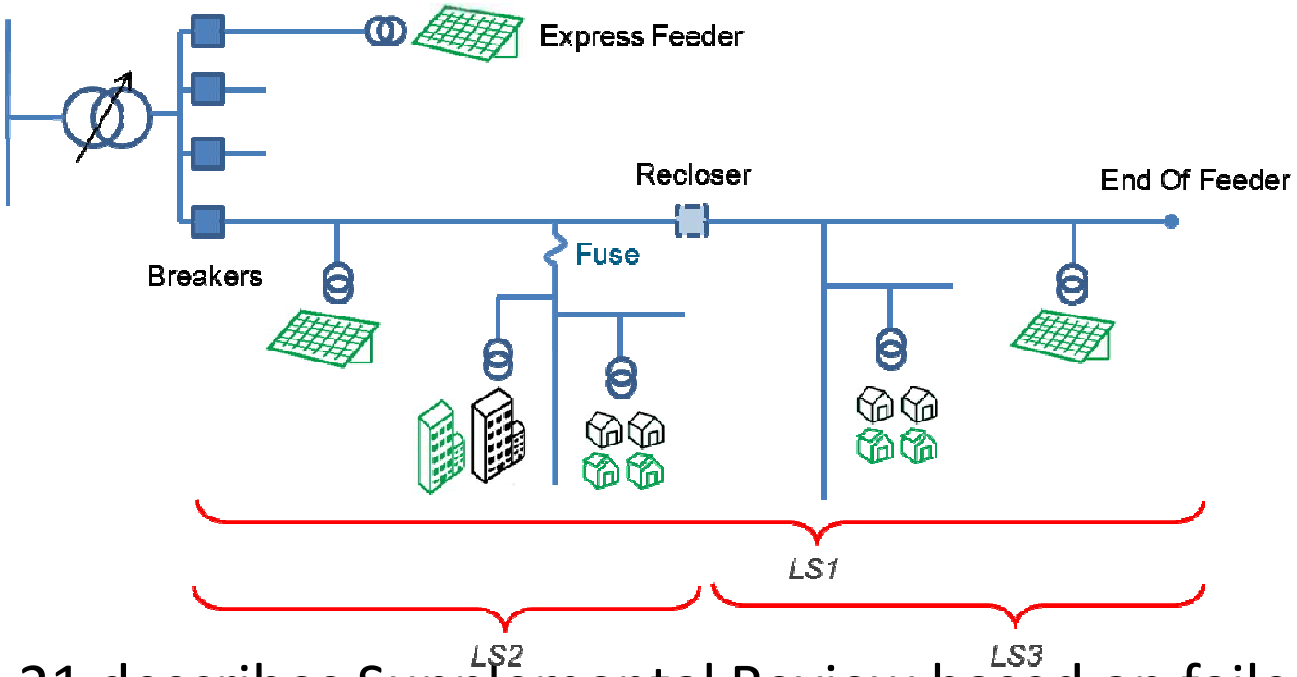
- Number of Screens= 8 original plus 8 additional.
- Fast track screening is more detailed with 13 screens in the initial review and **3 new screens added to supplemental review.** New fast track eligibility MW limit.
- Supplemental Screen "N"- Penetration Screen:
  1. Where 12 months of line section minimum load data is available: Is the aggregate Generating Facility capacity on the Line Section less than **100% of the minimum load** for all line sections upstream of the Generating Facility
  2. Minimum load period takes into account type of generation: if PV, **use daytime minimum load (10 am – 4 pm),** otherwise absolute minimum load.
  3. Aggregate generation capacity does not count generation that is counted as load reduction (e.g., NEM systems) and for systems that do export**, the capacity is based the net export not the nameplate capacity.**
- Supplemental Screens "O" and "P" address PQ and Voltage fluctuation issues and Safety and Reliability issues.



Source: CPUC Rule Making 11-09-011
Proposed Rule 21 settlement agreement- March 2012

Screening Criteria

- Definition of Line Section
  - *Portion of the distribution system bounded by automatic sectionalizing devices (sometimes includes fuses) and the end of the feeder*



- Rule 21 describes Supplemental Review based on failed screens

Failed a Screen—Now What?

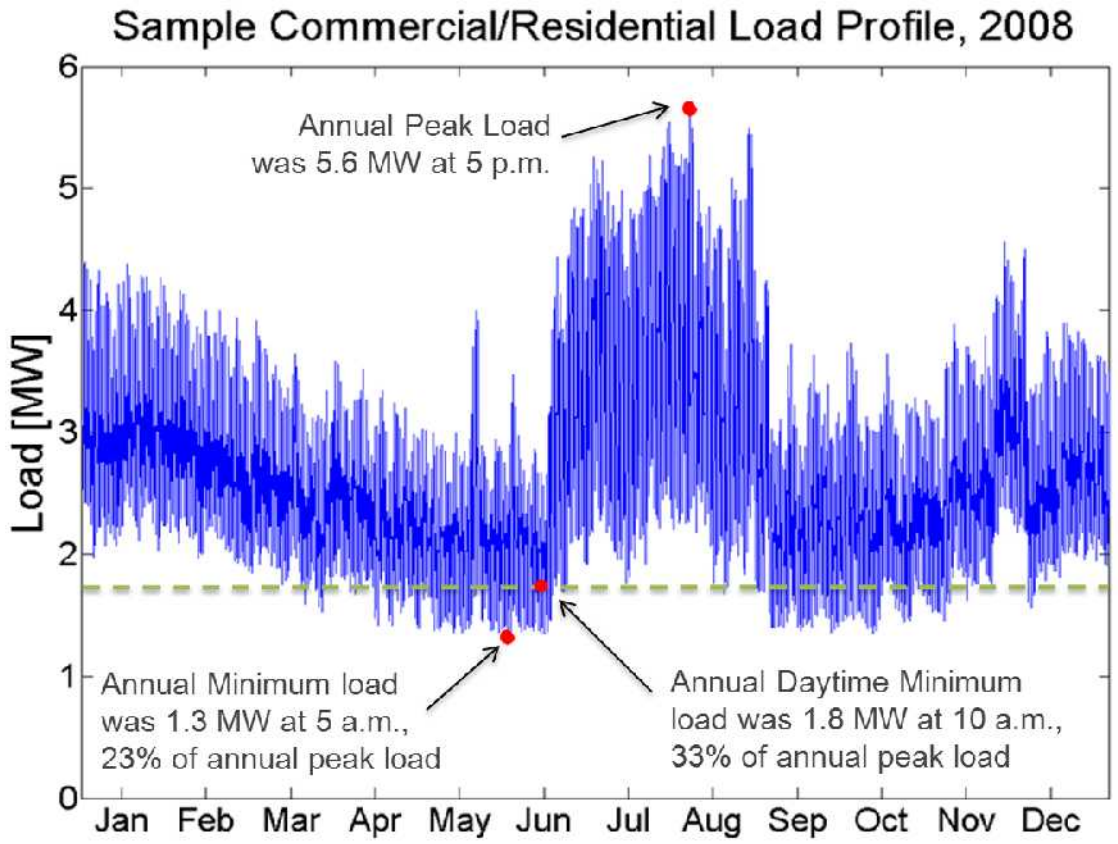
- SGIP / GIP: Several Options
  - Project could be tendered an Interconnection Agreement anyway, possibly with minor facility modifications
  - Proposed supplemental review (scope not defined in procedures)
  - Unabridged Interconnection Study process (scope vaguely defined)
- CPUC Rule 21: if Supplemental Review is failed-> detailed study:
  - Load flow study, normal & abnormal circuit configurations
  - Voltage profile study
  - Equipment loading studies
  - Review of voltage regulator control settings
  - Review of other connected DG units on Line Section
  - Review of recloser intervals at sectionalizing device
  - Fault study

Origin of the 15% Screening Criterion

- Quoting from CPUC Rule 21 Supplemental Review Guide:
  - *The 15% line section peak load screen is meant as a catchall for a variety of potential problems that can occur as the level of penetration of generation within the distribution system increases.*
  - *If one can assume as a rule of thumb that the typical line section minimum load will be at least 30% of the peak load, at 15% aggregate, the generating capacity would be no more than 50% of the minimum load of the Line Section. In this case, the generation would be adequately swamped out by the load during an islanded condition.*
  - Rules based on limited experience with PV and limited access to information (e.g., indirect reference to minimum load)

Origin of the 15% Screening Criterion

– Min load to peak load ratio—an example



Source: Sandia National Laboratories, The 15% Screen Technical Background, August , 2011

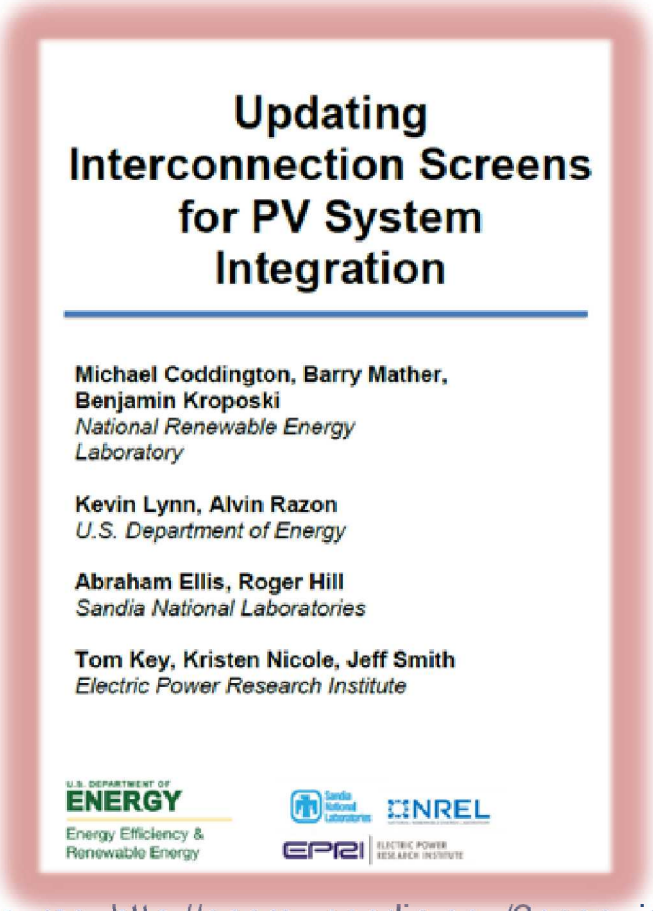
Significance for PV

- Vast majority of DG interconnections are solar PV
  - Inverter-based (low short circuit current, built-in anti-islanding, etc.)
  - Diurnal cycle, variable output
- Potential system issues that could apply to PV
  - Steady-state voltage control and LTC/VR tap operations
  - Power quality, e.g., customer flicker *
  - Risk of unintentional islanding (PQ, reclosing, safety?)
  - Protection (e.g., coordination, relay desensitization, TOV, etc.) *
  - Distribution system operations (feeder reconfiguration, CVR)
  - Transmission impacts and (e.g., sympathetic tripping for transmission faults)

  * Lesser concerns in most cases
- Increasing PV penetration → more PV systems are failing initial screen; 15% screen often triggers first
  - Based on recent experience, 15% screen may be too conservative for PV

Focus on the 15% Screen

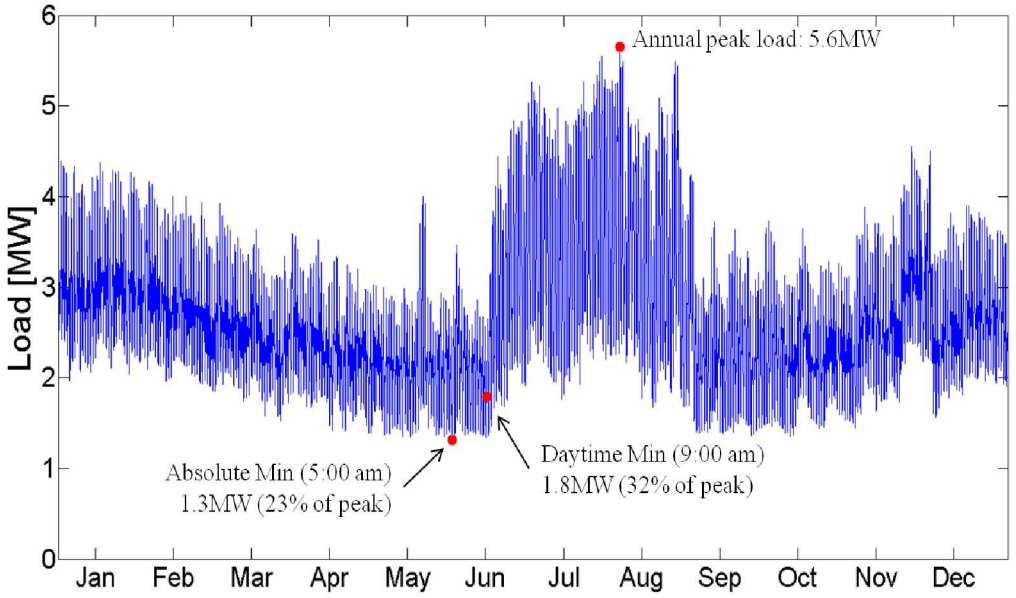
- Why focus on the 15% screen?
  - Relates to PV deployment level more than other screens
  - Shows up in majority of interconnection procedures
  - Field experience tends to challenge significance of the 15% screen
- SEIA petition FERC to revise the SGIP 15% screen in FERC Docket No. AD12-17-000



Source: http://energy.sandia.gov/?page_id=2886

Possible Alternatives

1. Increase threshold with respect to peak load (e.g., 25% to 35%)
2. Threshold based on a high percentage of minimum load (e.g., 80% to 100%)
   - Based on absolute minimum load
   - Based on daytime minimum load



Source: Sandia National Laboratories, The 15% Screen Technical Background, August , 2011

Possible Alternatives

3. Increase threshold as in 1 or 2, and supplement with other screens
   - Basic voltage drop screen
   - Basic islanding screen
   - Basic protection screen
4. Redefine "line section" provision (e.g., use voltage control device as boundary)
5. Other ideas?

Pictures show some examples of screens that could be made part of the Initial Review

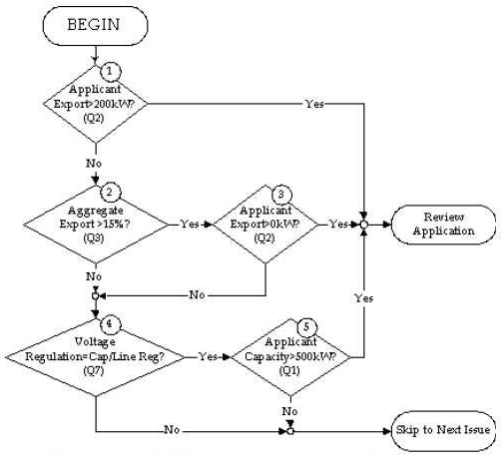
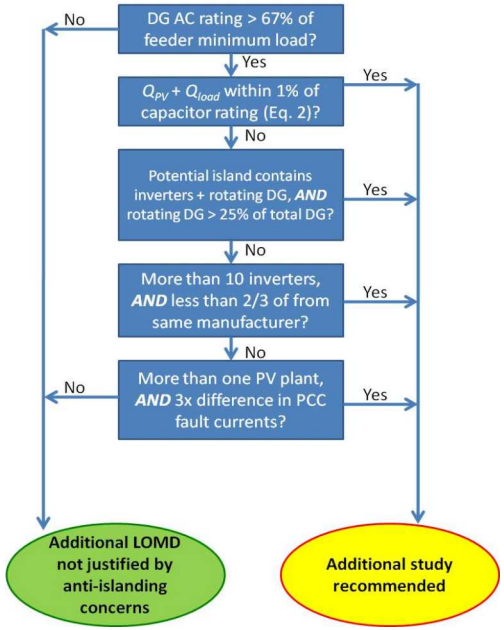


Figure 8. Voltage Regulation Review Process

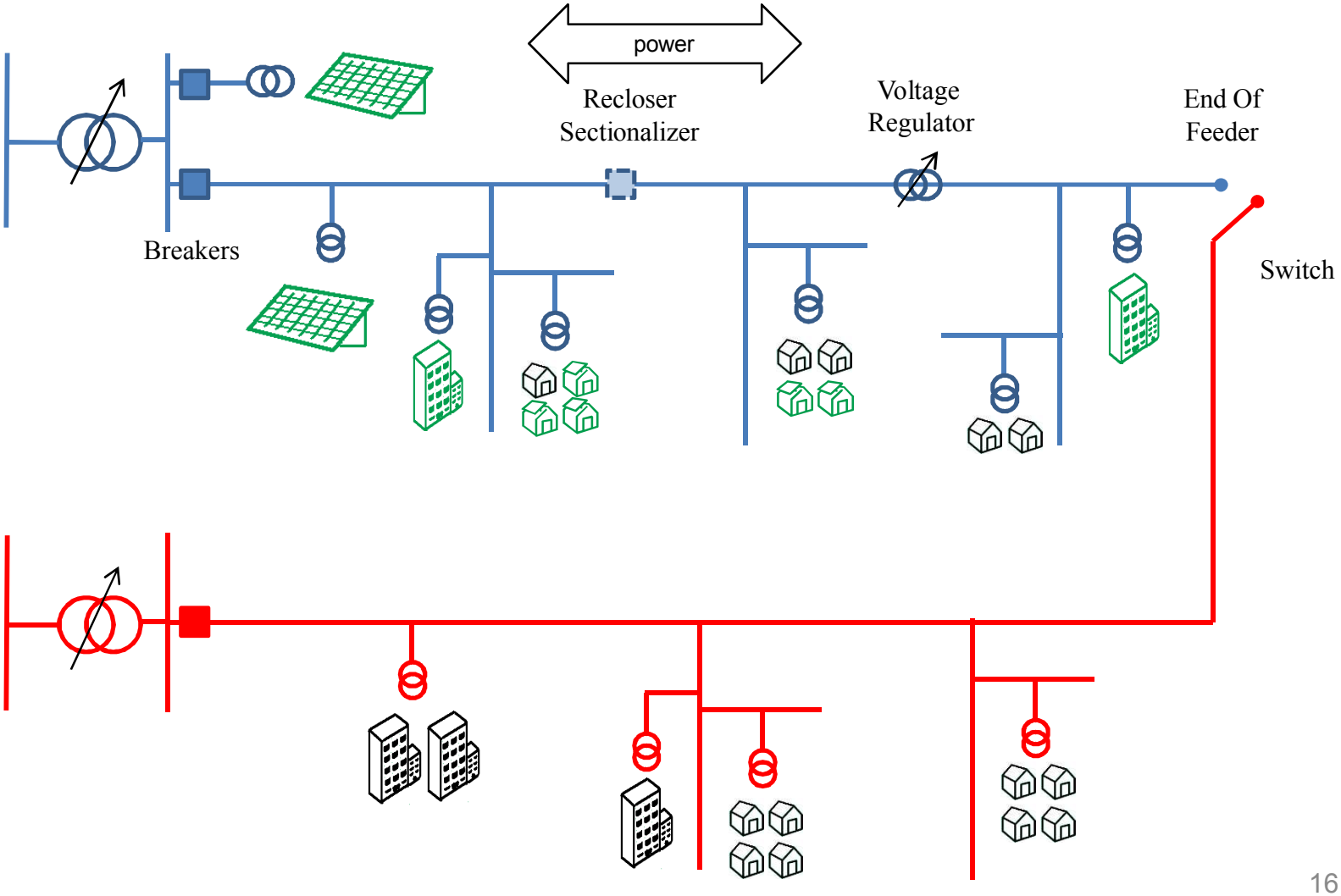
Source: California Electric Rule 21 Supplemental Review Guideline, Rule 21 Working Group, August 2005

Evaluation of Islanding Risk



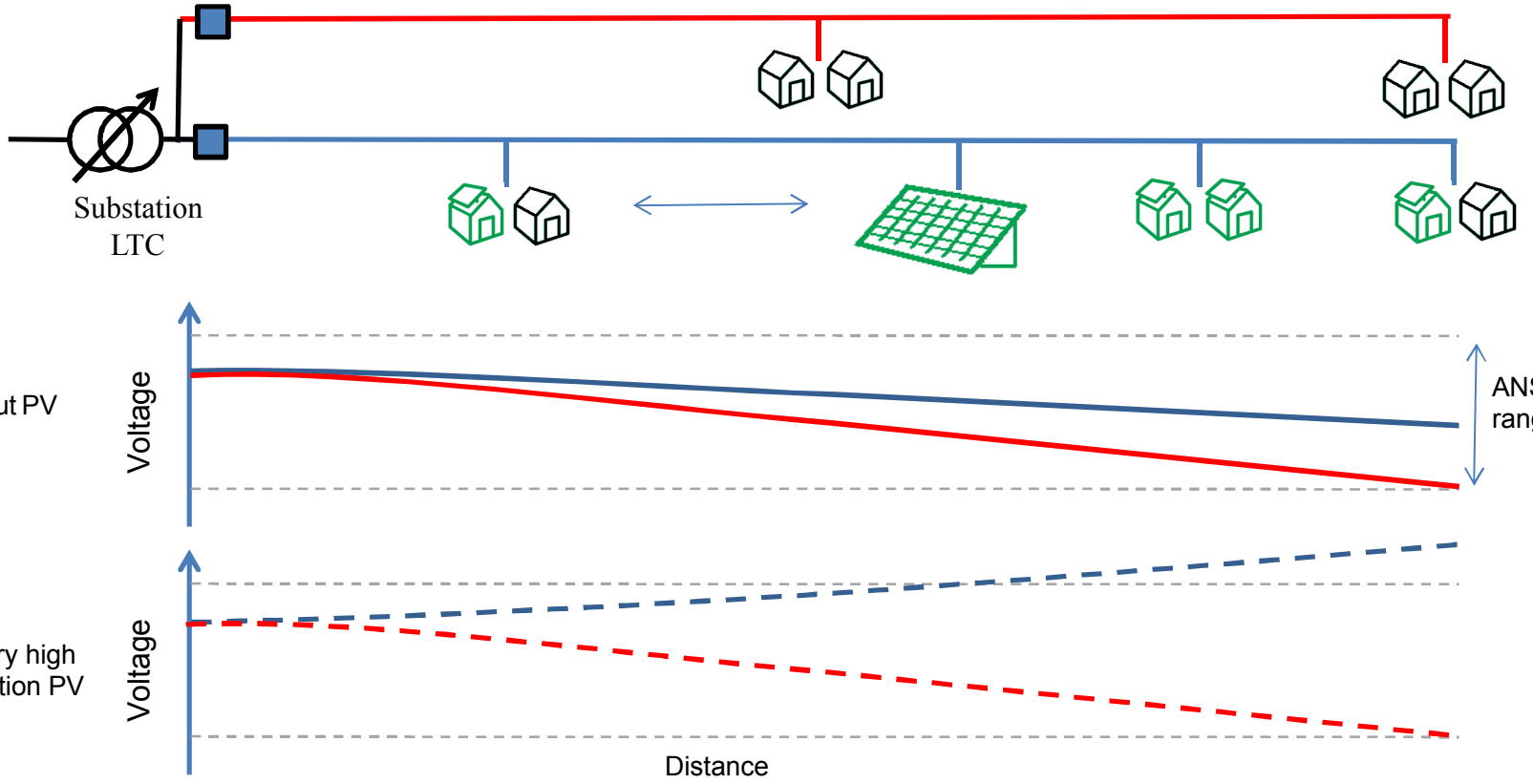
Source: Sandia National Laboratories, Guidelines for When Additional Islanding Protection or Studies May be Considered, SAND Report, August 2011

Voltage Control in Distribution Systems with High Penetration PV



Voltage Control in Distribution Systems with High Penetration PV

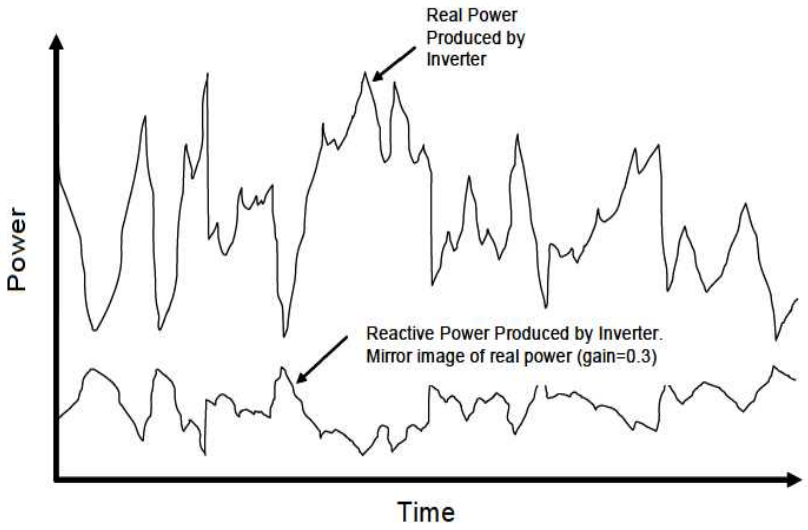
- High voltage at end of feeder
  - Most commonly encountered issue for high penetration PV
  - Worse on long feeders with PV at the end



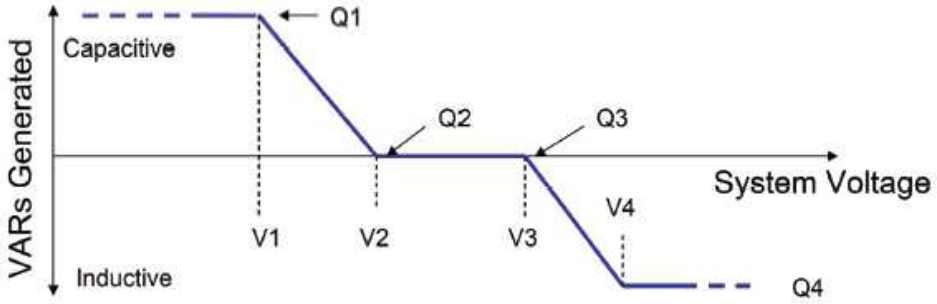
Evolution of Performance Standards

- Options for feeder-level 'open loop' voltage support
  - May not require communications

Variable power based on PV Output



Volt/Var Droop Characteristic

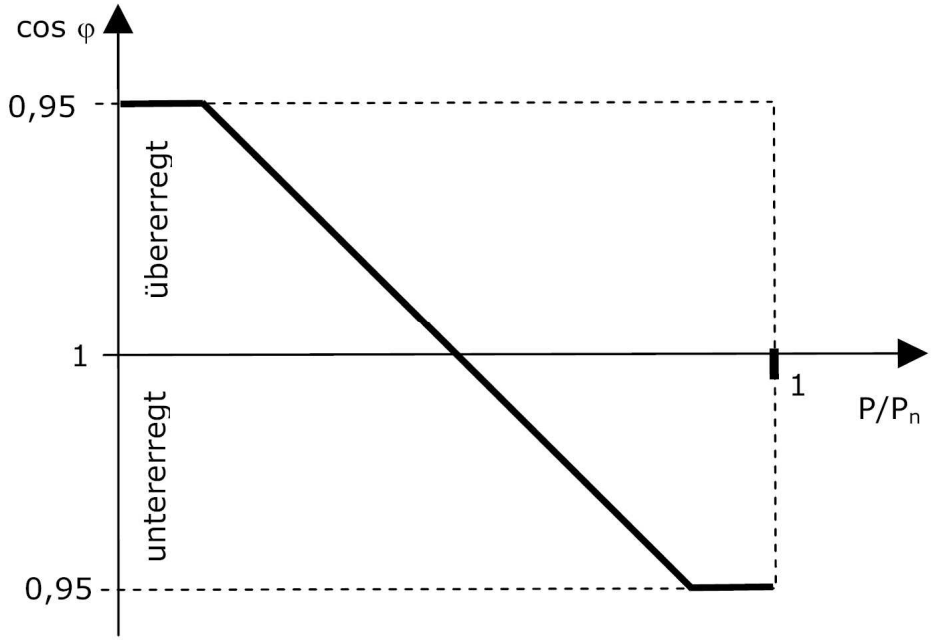


Source: EPRI/Sandia PV Inverter Interoperability Project

DOE RSI study, "Advanced Grid Planning and Operations"

Medium Voltage Standard in Germany (10 kV to 110 kV)

- Static Voltage Support Capability
  - Provide capability of +/- 0.95 pf at full output (impacts equipment rating)
  - Dispatch could be constant pf, constant Var, Var support based on power output (see example below) or Var support based on voltage
  - Applies to PV as of 2010



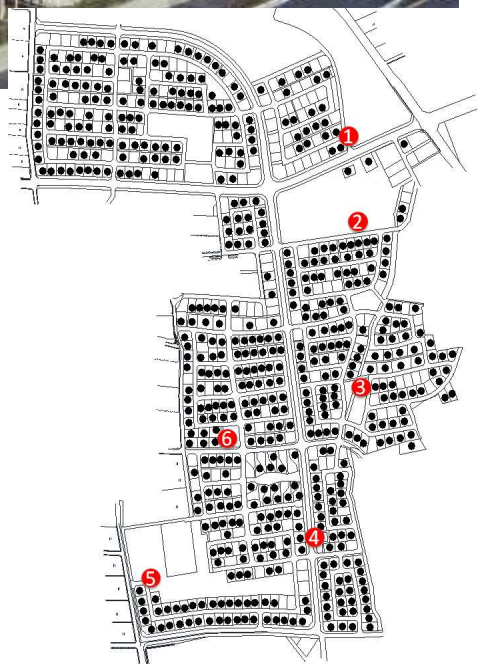
Source: E. Troester, New German Grid Codes for Connecting PV to the Medium Voltage Power Grid, 2nd International Conference on Concentrating Photovoltaic Power plant

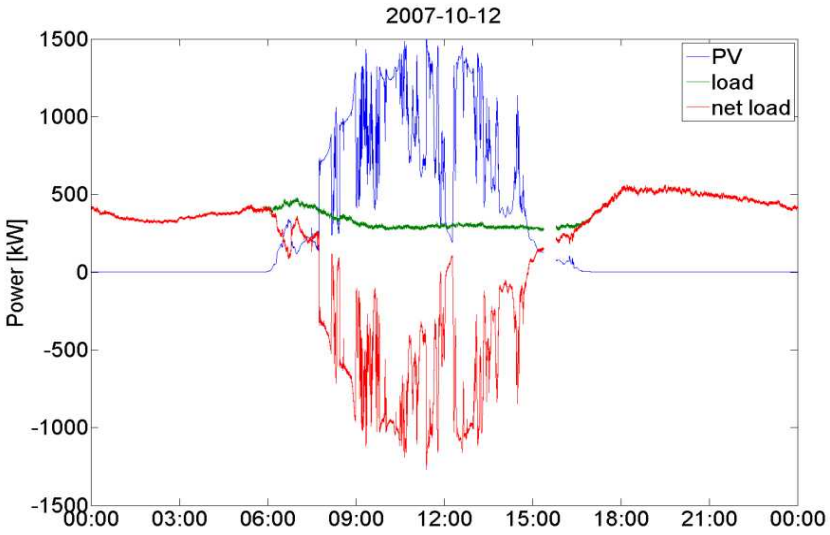
DG Interconnection Standards

- IEEE 1547 and proposed changes
  * VFT and FRT
  * Voltage Control

Need to get DG standards ready for future high PV deployment

- High residential/commercial PV
- Load and generation tightly coupled
- Reverse power
- Limited communications/control (near term)





Interconnection Standards for Distributed Energy Resources

- IEEE 1547 voltage and frequency trip requirements

Voltage Range (% Nominal)	Max. Clearing Time (sec) *
V < 50%	0.16
50% ≤ V < 88%	2.0
110% < V < 120%	1.0
V ≥ 120%	0.16

(*) Maximum clearing times for DER ≤ 30 kW; Default clearing times for DER > 30 kW

Frequency Range (Hz)	Max. Clearing Time (sec)
f > 60.5	0.16
f < 57.0 *	0.16
59.8 < f < 57.0 **	Adjustable (0.16 and 300)

(*) 59.3 Hz if DER ≤ 30 kW

(**) For DER > 30 KW

- Additional disconnection requirements
  - Cease to energize for faults on the Area EPS circuit
  - Cease to energize prior to circuit reclose
  - Detect island condition and cease to energize within 2 seconds of the formation of an island ("**anti-islanding**")

Interconnection Standards for Distributed Energy Resources

- Other applicable codes and standards (not an exhaustive list)

	Requirement
Voltage Regulation	Maintain service voltage within ANSI C84 Range A (+/-5%)
Voltage control	Not permitted (IEEE 1547)
Flicker	Maximum Borderline of Irritation Curve (IEEE 1453)
Harmonics	<5% THD; <4% below 11^{th}; <2% for 11^{th} – 15^{th}, <1.5% for 17^{th} – 21^{st}; 0.6% for 23^{rd} – 33^{rd}; <0.3% for 33^{rd} and up (IEEE 519)
Power Factor	Output power factor 0.85 lead/lag or higher (equipment typically designed for unity power factor)
Direct Current Injection	<0.5% current of full rated RMS output current (IEEE 1547)
Synchronization and Protection	Dedicated protection & synchronization equipment required, except smaller systems with utility-interactive inverters
Safety	NFPA NEC, IEEE NESC

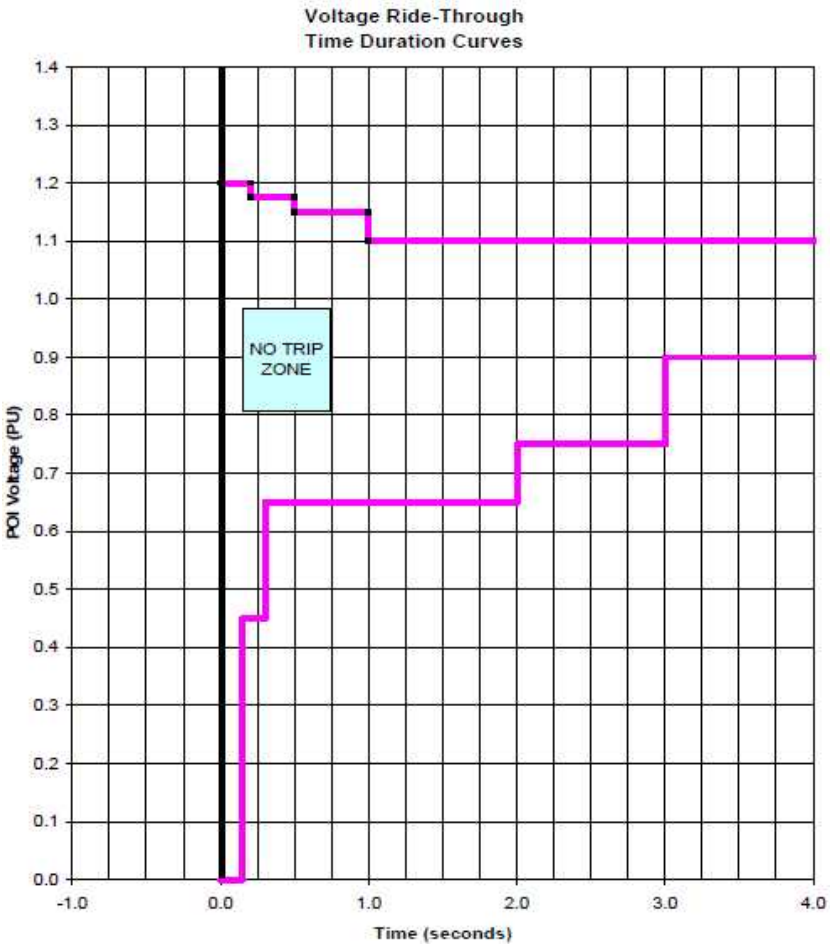
Opposite Points Of View

- Distribution System – IEEE 1547 Domain
  - Bulk generation and voltage support is “infinite” – who cares!
  - Main concern is protection coordination, power quality, and safety during and after distribution system events
  - **DG must trip** outside specified voltage vs. time and frequency vs. time envelope
- Bulk Power System – NERC Domain
  - Distributed generation capacity is too small – who cares!
  - Main concern is maintaining frequency and local voltage (grid security) during and after transmission system events
  - **Generators must not trip** inside specified voltage vs. time and frequency vs. time envelope

As DG penetration increases, these opposing points of view must be reconciled.

Proposed NERC PRC-024 Standard

- Proposed voltage tolerance standard
  - Would apply to all generators > 20 MVA and multiple generator facilities >75 MVA
  - Can all generators do this?



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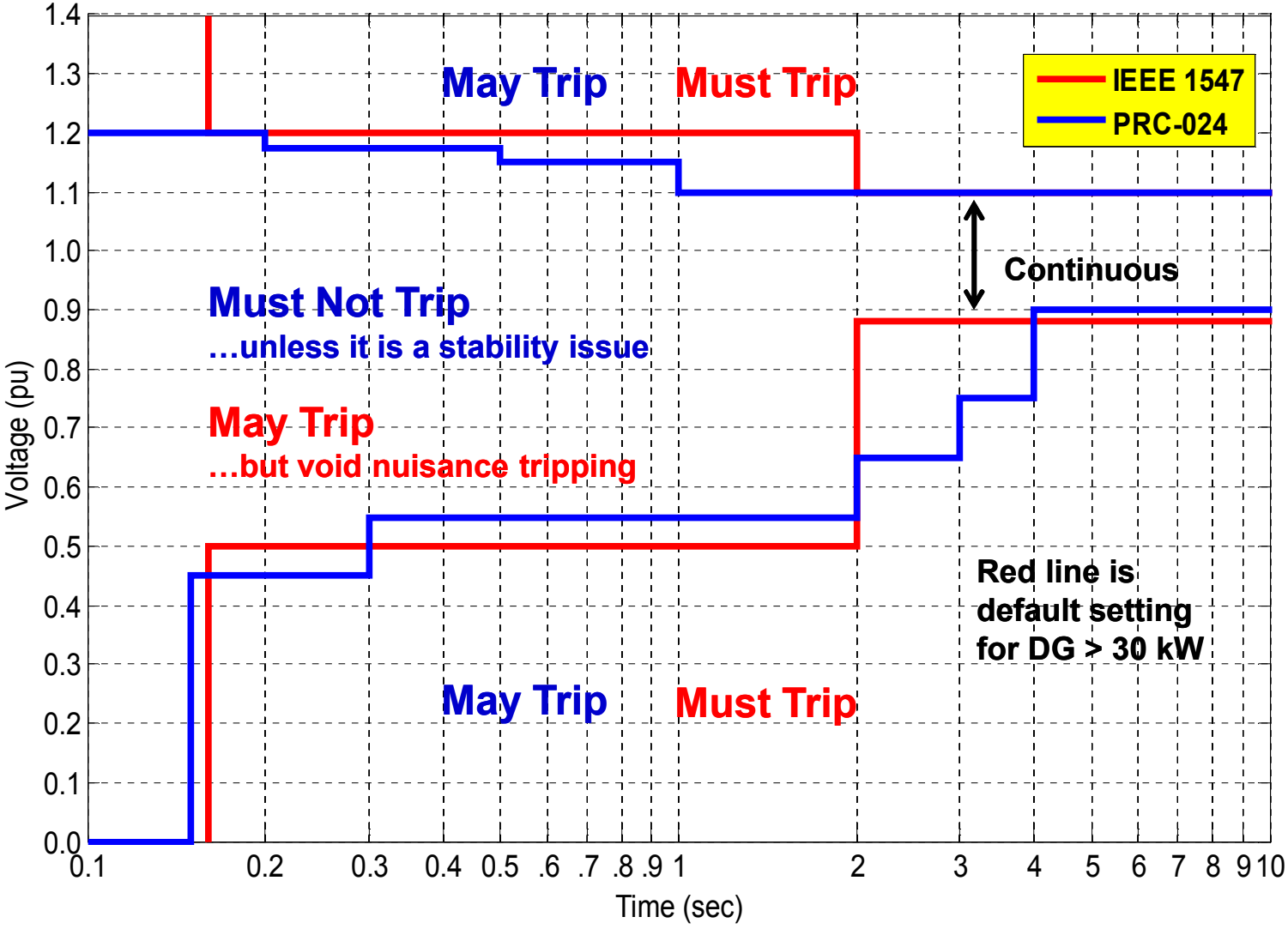
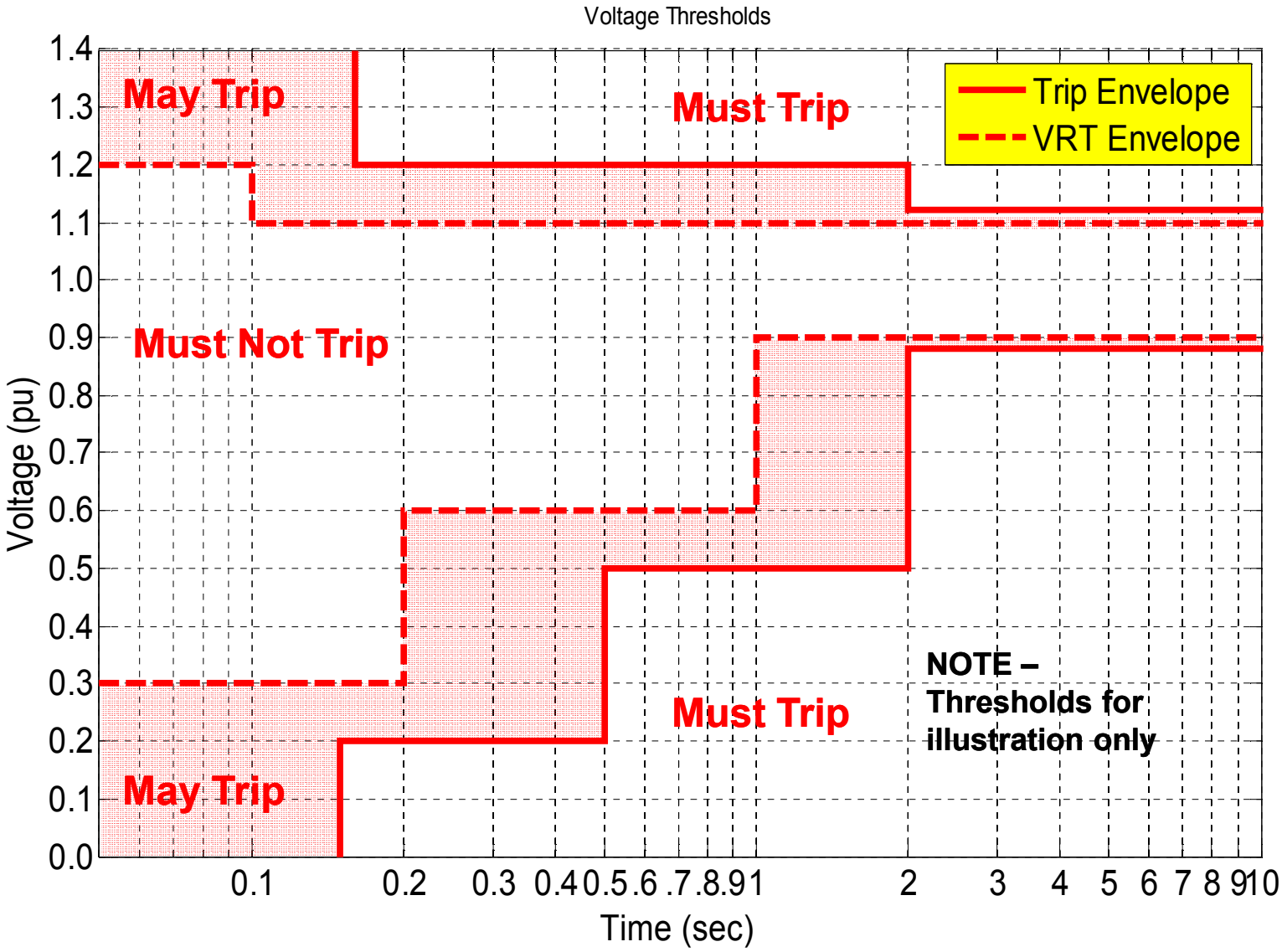
IEEE 1547 Vs. NERC PRC-024



Some IVGTF 1.7 Ideas (unofficial)

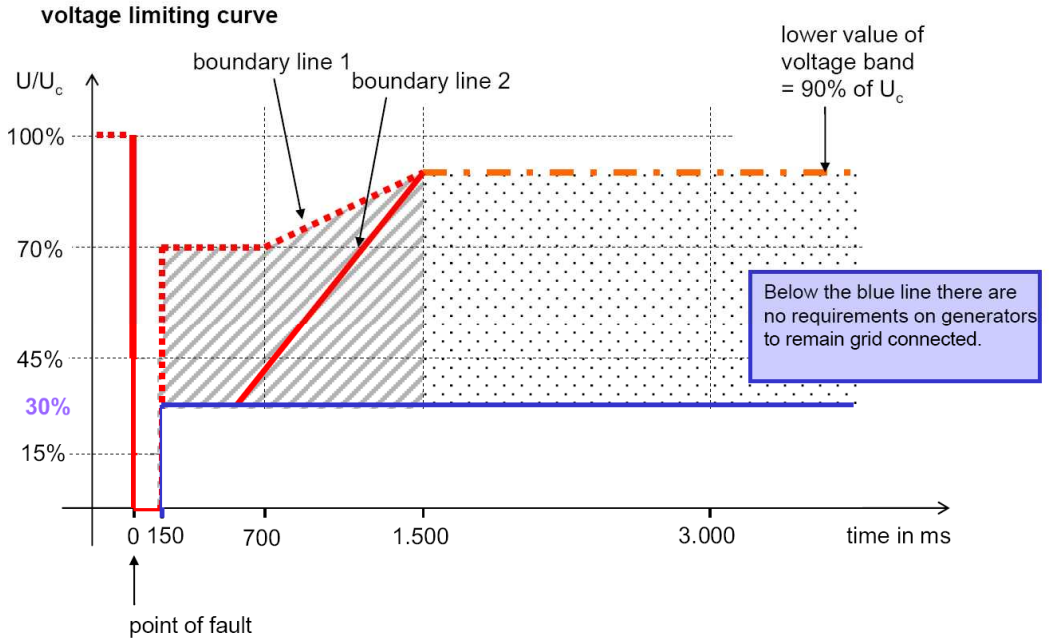
- A measure of VRT/FRT capability is needed for DG
  - No need for Zero-VRT considering DG density
  - High frequency droop response instead of trip
- May need to keep a Must Trip curve as well
  - Voltage/frequency thresholds used in anti-islanding
  - Could be existing IEEE 1547, with some adjustments
    - Relaxing low voltage threshold (for fault tolerance)
    - Consider relaxing continuous high voltage threshold (to address inverter nuisance tripping)
- Need a reasonable “buffer” between VRT and Must Trip envelopes (both time and voltage dimensions)

Some IVGTF 1.7 Ideas (unofficial)



Medium Voltage Standard in Germany (10 kV to 110 kV)

- Fault <u>Tolerance</u>
  - Inverters must comply with boundary line 2
  - Must provide reactive support during fault (voltage control)
  - Applies to PV as of 2011



Source: E. Troester, New German Grid Codes for Connecting PV to the Medium Voltage Power Grid, 2nd International Conference on Concentrating Photovoltaic Power plant

Frequency Tolerance Standards

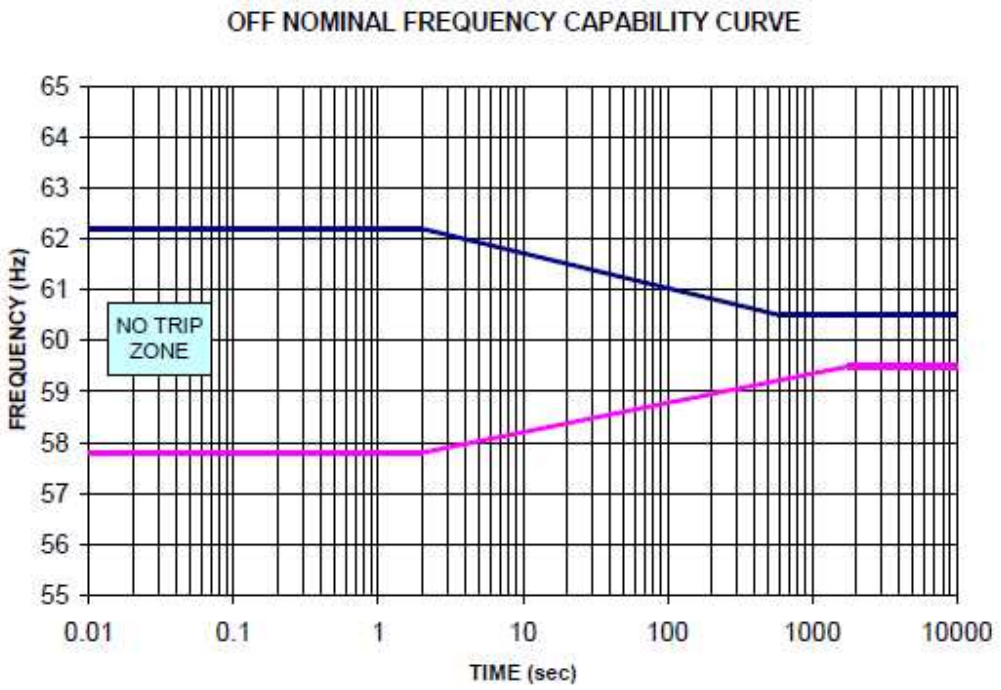
- Prevent excessive loss of generation during a severe frequency disturbance
  - E.g., interconnection breakup
- Current situation in the US
  - Not addressed in FERC Order 661-A
  - Regional Entities establish their own frequency tolerance criteria
    - For example, WECC Off- Nominal Frequency (ONF) standard, applicable to “all generators”
  - For DG, standard is “must trip”, per IEEE 1547
  - NERC efforts underway

WECC Off-Nominal Frequency Tolerance

Frequency Range (Hz)	Min Clearing Time
59.4 – 60.5	N/A
59.4 – 58.5 or 60.6 – 61.5	3 min
58.4 – 57.9 or 61.6 – 61.7	30 sec
57.8 – 57.4	7.5 sec
57.3 – 56.9	45 cycles
56.8 – 56.5	7.2 cycles
< 56.4 or >61.7	instantaneous

Proposed NERC PRC-024 Standard

- Proposed frequency tolerance standard
  - Would apply to all generators > 20 MVA and multiple generator facilities >75 MVA



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Comments and Questions?

References

CPUC Rule 21:

http://www.cpuc.ca.gov/PUC/energy/Procurement/LTPP/rule21.htm

Proposed revision to RULE 21:

http://docs.cpuc.ca.gov/EFILE/MOTION/162852.PDF

FERC SGIP/SGIA:

http://www.ferc.gov/industries/electric/indus-act/gi/small-gen.asp

Technical conference on FERC proposed rule making to address changes to SGIP:

http://www.ferc.gov/EventCalendar/Files/20120703152852-AD12-17-000TC.pdf

Suggested Guidelines for Anti-Islanding Screening:

http://prod.sandia.gov/techlib/access-control.cgi/2012/121365.pdf

Updating Interconnection Screens for PV System Integration:

http://energy.sandia.gov/wp/wp-content/gallery/uploads/Updating_Interconnection_PV_Systems_Integration.pdf

Hawaii PUC decision and order on new Rule 14H:

http://www.irecusa.org/wp-content/uploads/2012/01/2010-1.0015.DO30027.12.20.11.pdf