



# Distributed PV Impacts on the Electric System



**Barry Mather, Ph.D.**  
**Senior Electrical Engineer**  
**Power Sys. Engineering Center**  
**[barry.mather@nrel.gov](mailto:barry.mather@nrel.gov)**

# Outline

---

- Distribution is like real estate – location, location, location...
- Transmission matters too – reliability is still paramount
- Smart inverters for all! – for impact mitigation and bulk system support

# Dev. of Adv. PV Interconnection Screens



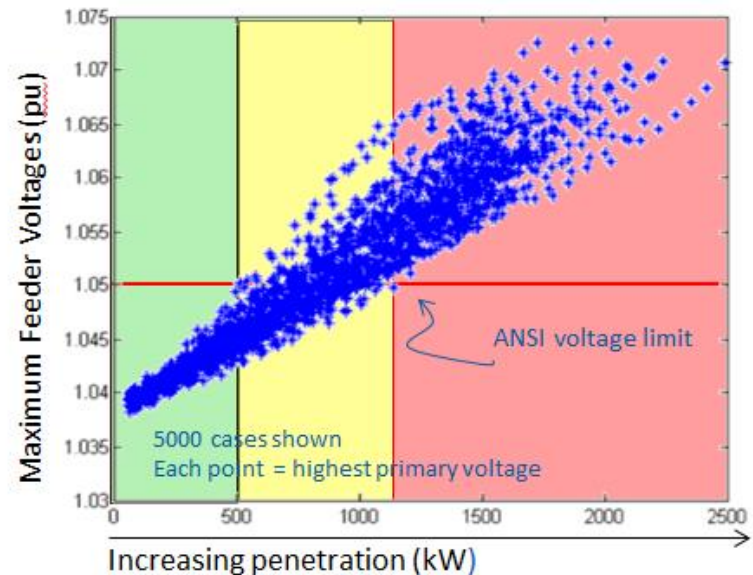
Energy Efficiency &  
Renewable Energy



ELECTRIC POWER  
RESEARCH INSTITUTE

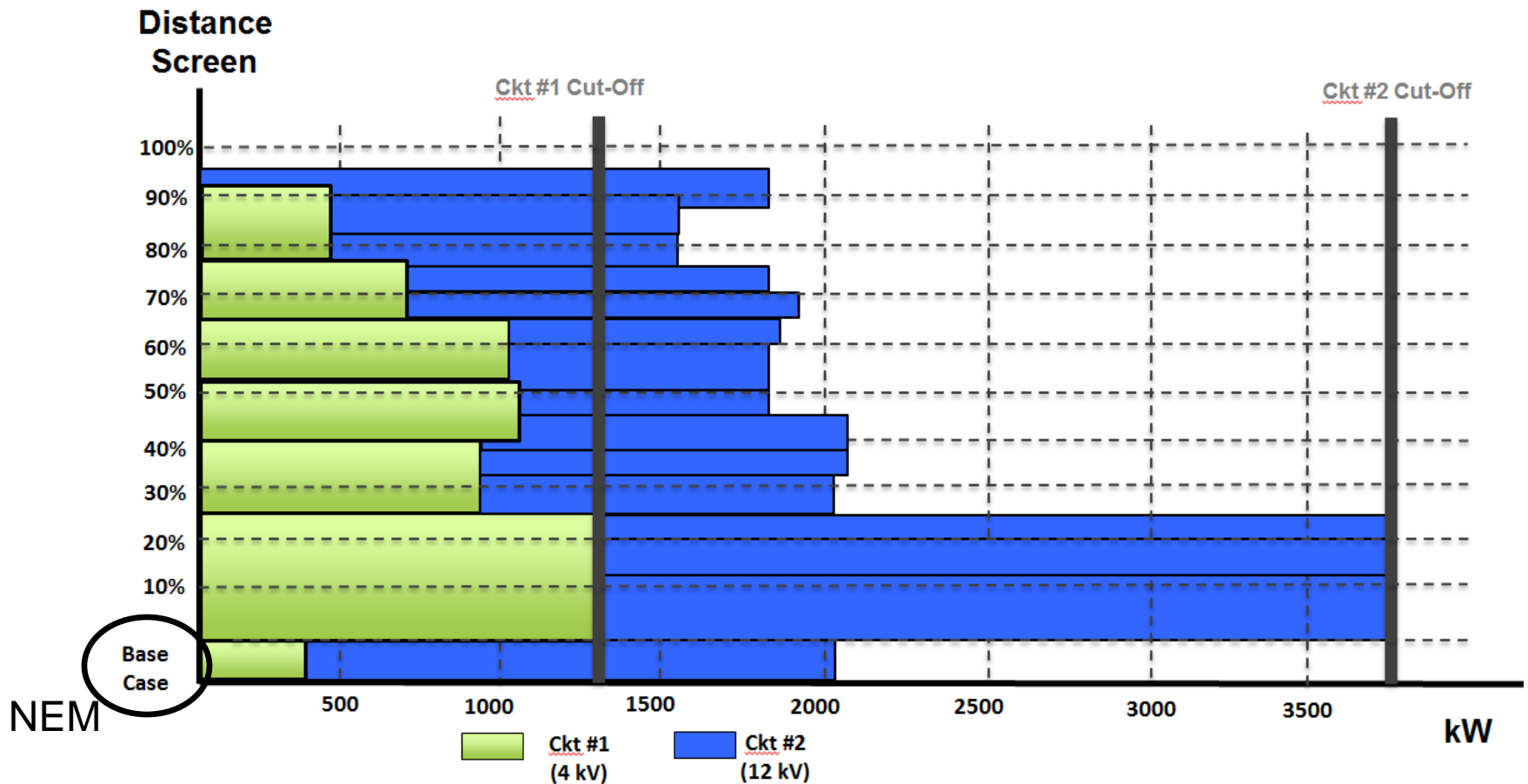


- Collaborative project with EPRI, NREL, SNL and CA utilities to develop advanced screening methods for distributed PV grid interconnection
- Advanced screens will inform CA Rule 21 and will allow more PV to be interconnected quickly when those systems will not adversely effect the interconnected system and will reduce utility interconnection queue



# PV Interconnection Screening (Distance)

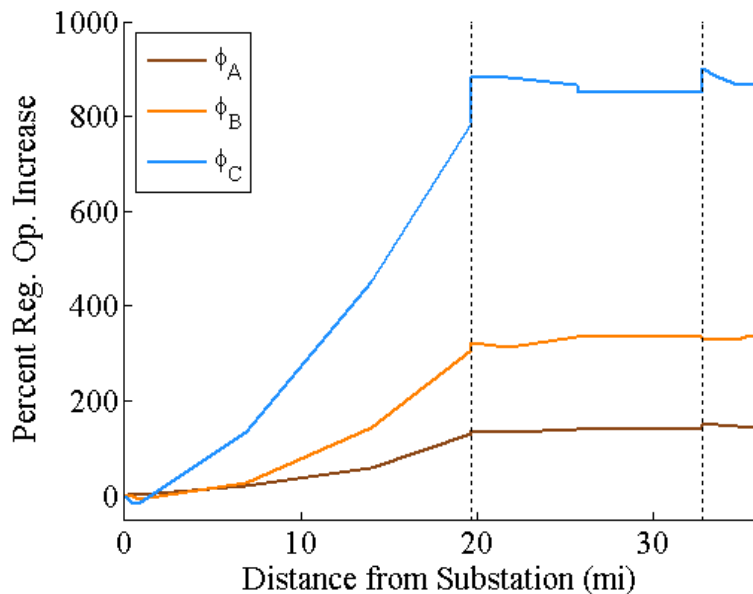
Amount of PV that can be added before a voltage deviation violation occurs (for many various deployment scenarios satisfying the PV interconnection screening metric)



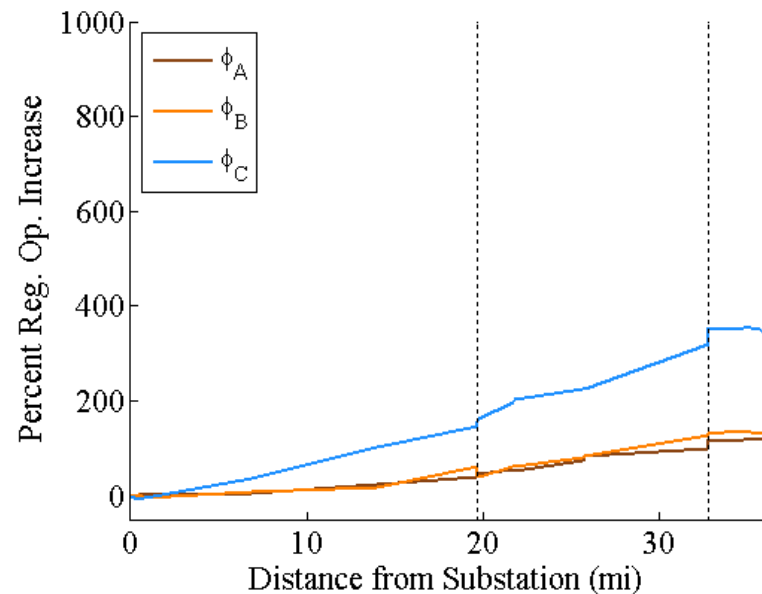
# Increased Regulator Operation (1MW PV)

1MW PV Interconnected at Any Single Point Along Circuit

## Regulator #1



## Regulator #2



- The impact on regulators (and capacitors) is dependent on the location of the installed PV system – utility scale system in this case.

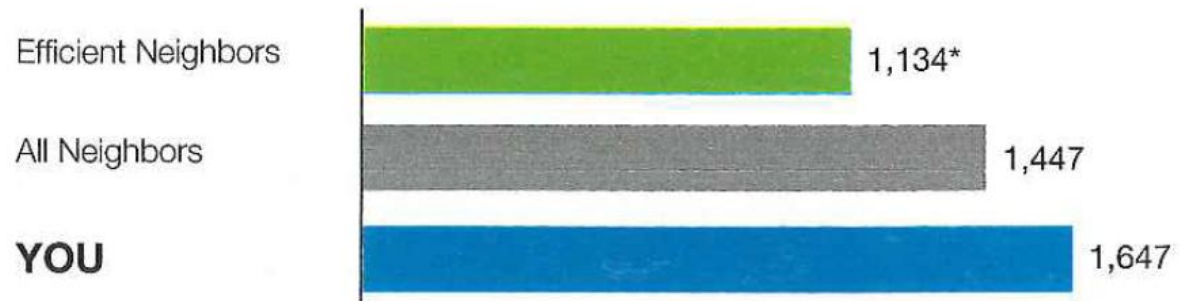
# Other Issues with Distributed PV

- Everything causes an impact – How much impact is too much? Who decides?
- Distributed PV “curtailment” is typically due to overvoltage – PV systems near the end of the line have higher financial risk.
- NEM systems are getting a free pass from a technical perspective – As PV penetration increases all systems will have to participate in mitigation and bulk system support (50.1 Hz-like retrofit?)
- There is no guarantee that a system will operate when needed – Value of equipment deferral is shaky at best.
- Reactive power on distribution is about 3x more sensitive to locational impact metric – Stacked value of DG-based reactive power is shaky at best.

# Distribution LMPs – Just My Opinion

- What level of customer participation is reasonably expected?

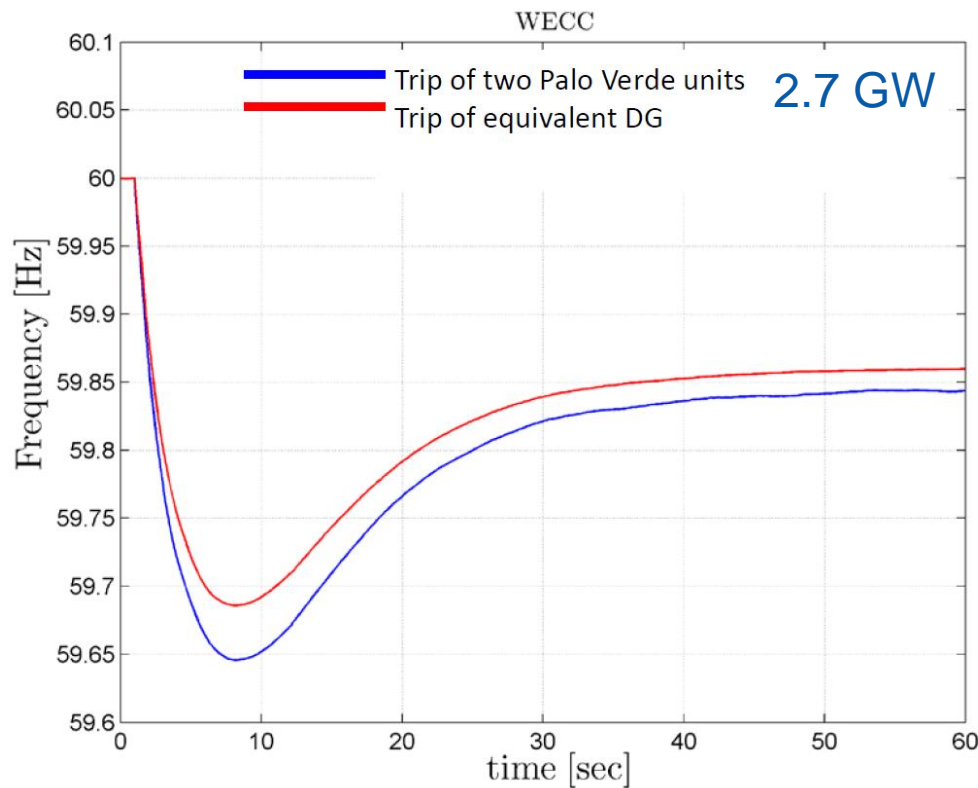
Currently...



- My utility suggested the following:
  - Unplug electronics when not in use
  - Program your thermostat
  - Get a home energy assessment
- They did not suggest I install a PV system!

The bottom line: current interactions/participation are not sophisticated, why should we assume different in the future?

# Transmission Impacts from Dist. PV



From: N. W. Miller, et al.,  
Western Wind and Solar  
Integration Study Phase  
3 – Frequency Response  
and Transient Stability,  
NREL Report, Dec.,  
2014.

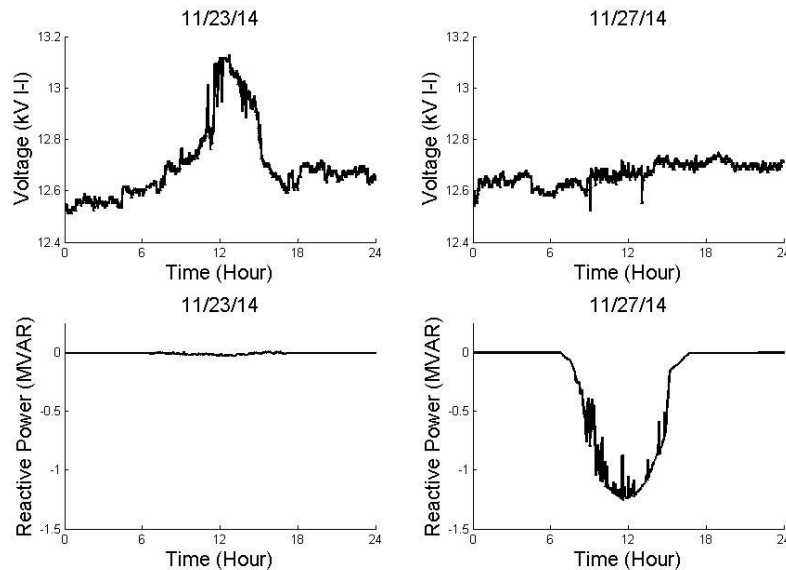
- Most extreme loss of generation may (soon) be due to loss of DG (mostly PV) – through a (n-2) coordinating loss/fault
- Impacts overall system reliability – how does an ISO know how much DG is operating and how will it respond?



# Smart Inverters: Oft Discussed, Seldom Used

Should they be required?

YES! – all PV systems should be required to implement some advanced PV inverter functionality (minimum of bulk system support) but should be used to offset their impact.



- A recent field demonstration showed off-unity power factor operation successfully reduced voltage related impacts
- Requires a marginal increase in PV inverter rating (price)

The real question: What functions and settings should be used?

Warning – requiring mitigation necessitating energy storage will probably result in defection.

# Thank you for your attention

Contact:

Barry Mather Ph.D.  
National Renewable Energy Laboratory  
barry.mather@nrel.gov  
(303)-275-4378