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Managing High PV Deployment on the EPS: Overview of Key Challenges and Mitigation Options.

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Distributed Generation Interconnection

Applicable rules for DG interconnection depend on jurisdiction:

- FERC jurisdictional (utility-side generation)
  - Must follow FERC Order 2006 – SGIP for systems < 20 MVA
- State Jurisdictional (customer-side generation)
  - 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
    - Existing CPUC Rule 21 does not specify a size, soon to change.

DG often qualifies for expedited interconnection: "Fast Track Process" screens applicable to DG < 2 MW

- No system upgrades are required
- Safety and reliability are not materially affected
- Makes sense to avoid unnecessary study cost & processing time

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Grid Integration Challenge

- Are High PV Deployment scenarios technically feasible?
- What are the impacts and mitigation? What is the cost?
- How should we plan the grid to enable High PV Deployment ?

Definition of Variable Generation (VG) Deployment Level

- From the distribution system point of view
  - VG Capacity / Peak Load of line section or feeder*
  - VG Capacity / Minimum Load
  - VG Capacity / Feeder, Transformer or Station Rating
- From the bulk system point of view
  - Annual VG Energy / Annual Load Energy*
  - VG Capacity / Peak Load or Minimum Load

* Definition most commonly used

- Often used in policy and procedures
  - Deployment level by energy-used in State RPS targets
  - Deployment level by capacity-used in the context of interconnection procedures (screening)

Definition of VG Deployment Level

- Example for distribution system

	Peak / Min (MW)	Deployment level for 1 MW PV
Feeder Load	3 / 0.9 [1]	33% / 111%
Station Load	10 / 3 [1]	10% / 33%
Station Rating	20 MVA	5%

[1] Minimum Load may be in the range of 20% to 40% of Peak Load

- Example for bulk system

	Load		Deployment level for 1 GW PV	
	Peak/Min (GW)	Energy (GWh)	By Capacity	By Energy [3]
Utility (LSE)	5 /2 [1]	24,000 [1]	20% / 50%	6%
Balancing Area	50 / 20 [2]	240,000 [2]	2% / 5%	0.6%

[1] e.g., SDGE, 2009 [2] e.g., CAISO, 2009 [3] Assumes 16% annual capacity factor

What is High PV deployment?

- It depends!
  - With respect to what part of the system?
    - Feeder or Local Grid?   >50% by capacity?
    - BA/Market?   Interconnection?   >5% by energy?
  - Assuming Business-As-Usual or Best Practices?
    - Technology, Standards, Procedures, Market, Regulatory…

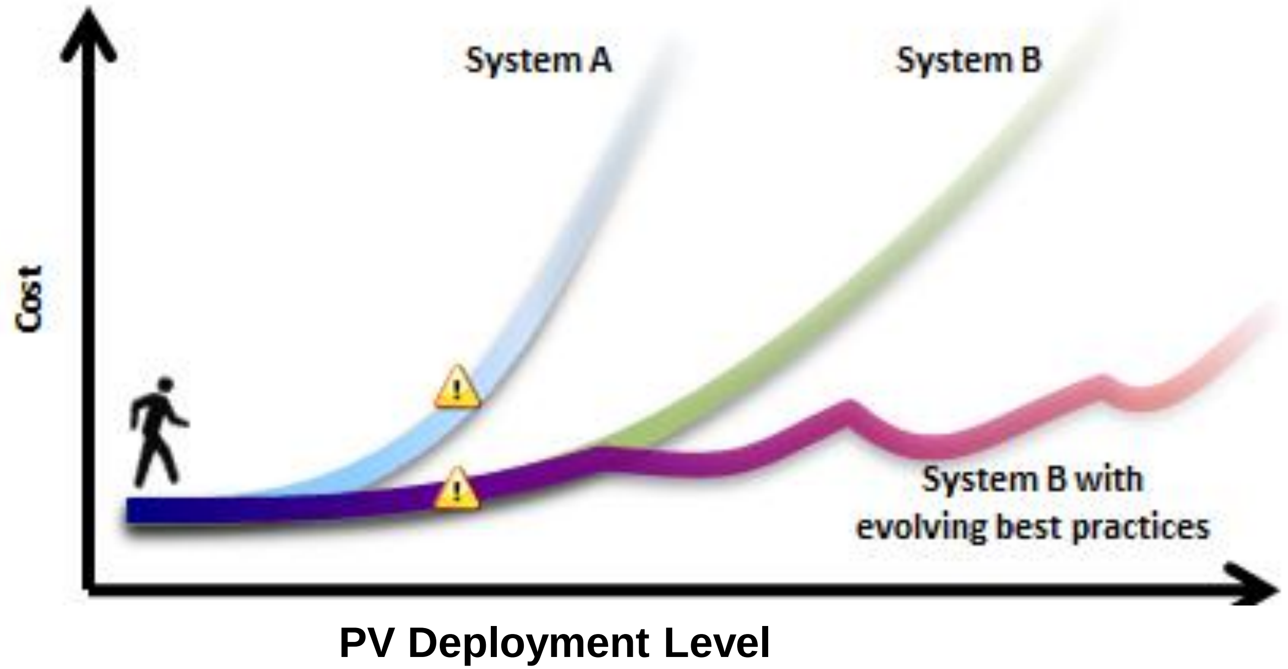
- High PV deployment is a concern when…
  - Performance & reliability would be materially impacted

    AND

  - Cost of mitigation and cost allocation are objectionable or unacceptable to stakeholders

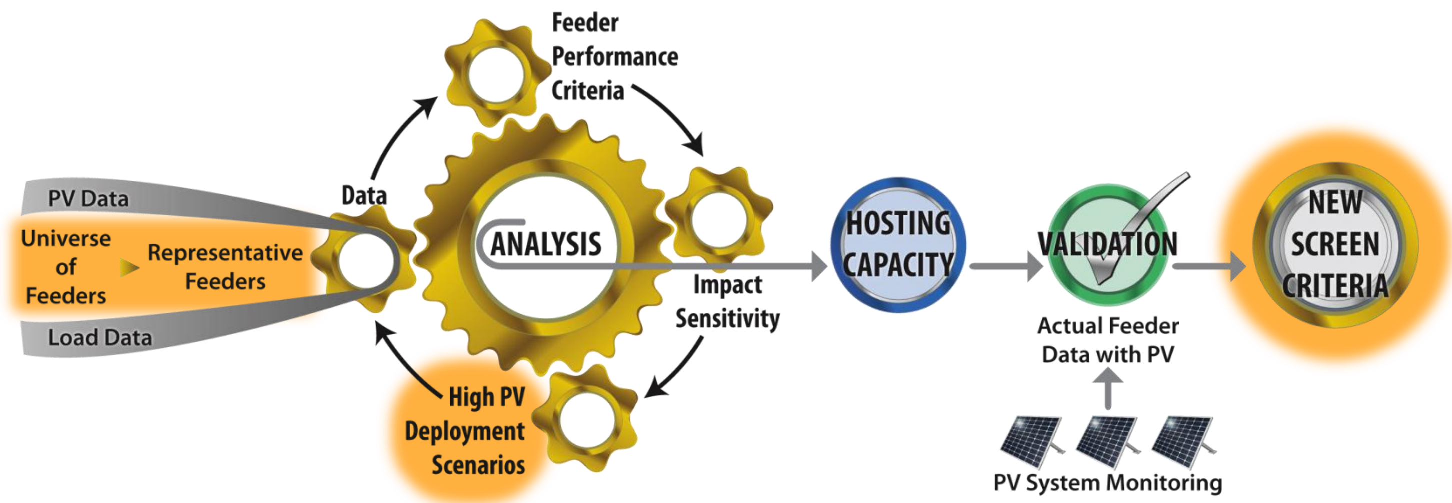
Are There Deployment Level Limits?

There are no **absolute** technical limits to the PV Deployment Level
– Cost is the issue, and this is system-specific



Screening the Distribution System

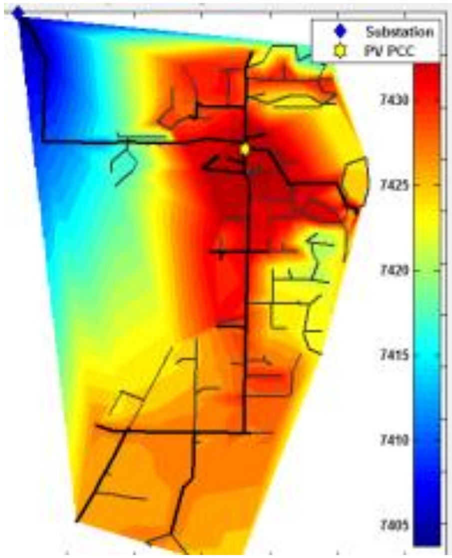
The DOE sponsored Sandia role in the EPRI/CSI project is focused on a two-year goal to develop new screens with a strong technical foundation based on analyzing representative feeders and studying the effect of high PV deployment scenarios on the hosting capacity of the feeder.



Successful outcomes:

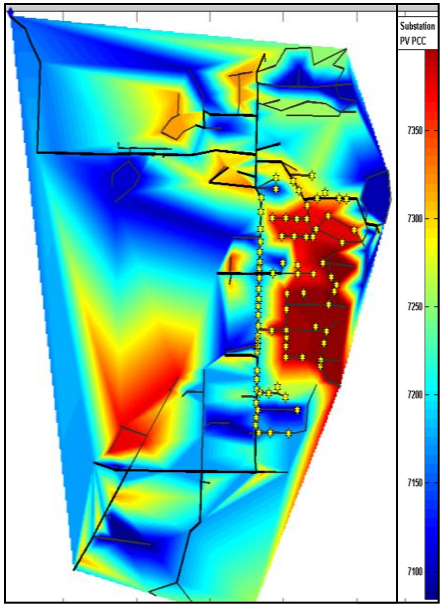
- **New screens with sound technical criteria will accurately determine high risk potential impacts.**
- **Faster and more accurate screens will expedite the interconnection of a greater number of PV systems and lower overall interconnection costs by avoiding unnecessary and expensive impact studies.**

Modeling and Analysis of high PV deployment scenarios



Current Technical challenges:

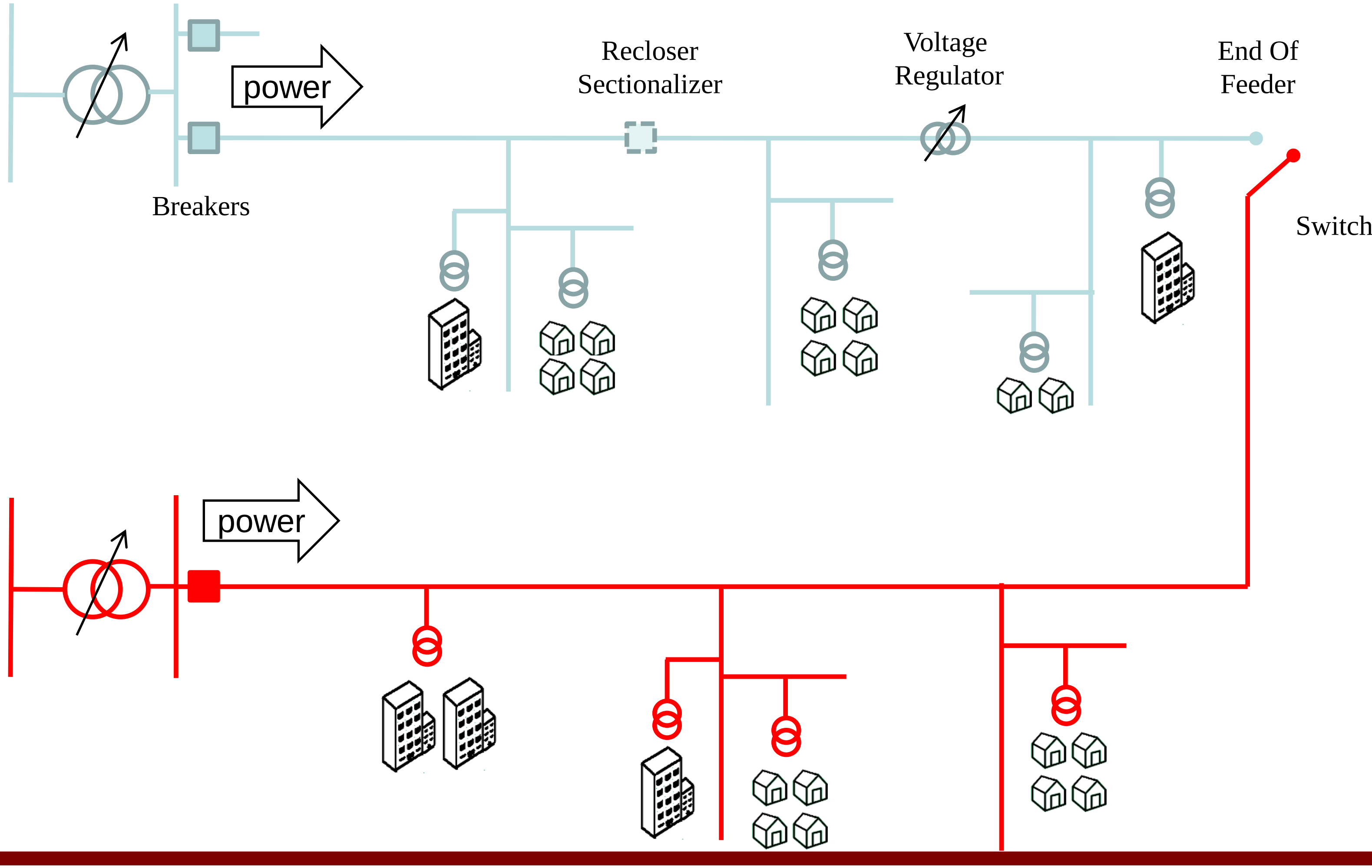
- Modeling and Analysis of high PV deployment scenarios requires **new tools and methods** to determine system impacts.
- The number and size of PV systems interconnecting to distribution systems is **accelerating** and the **complexity of the impact analysis is compounded** by the large variation in the type of PV systems being installed- centralized and highly distributed.
- Utility tools and planning models have limited capability to perform interconnection analysis for high PV deployment scenarios. The result is "worst case" snapshot analysis that does not reflect the actual hosting capability of the circuit.



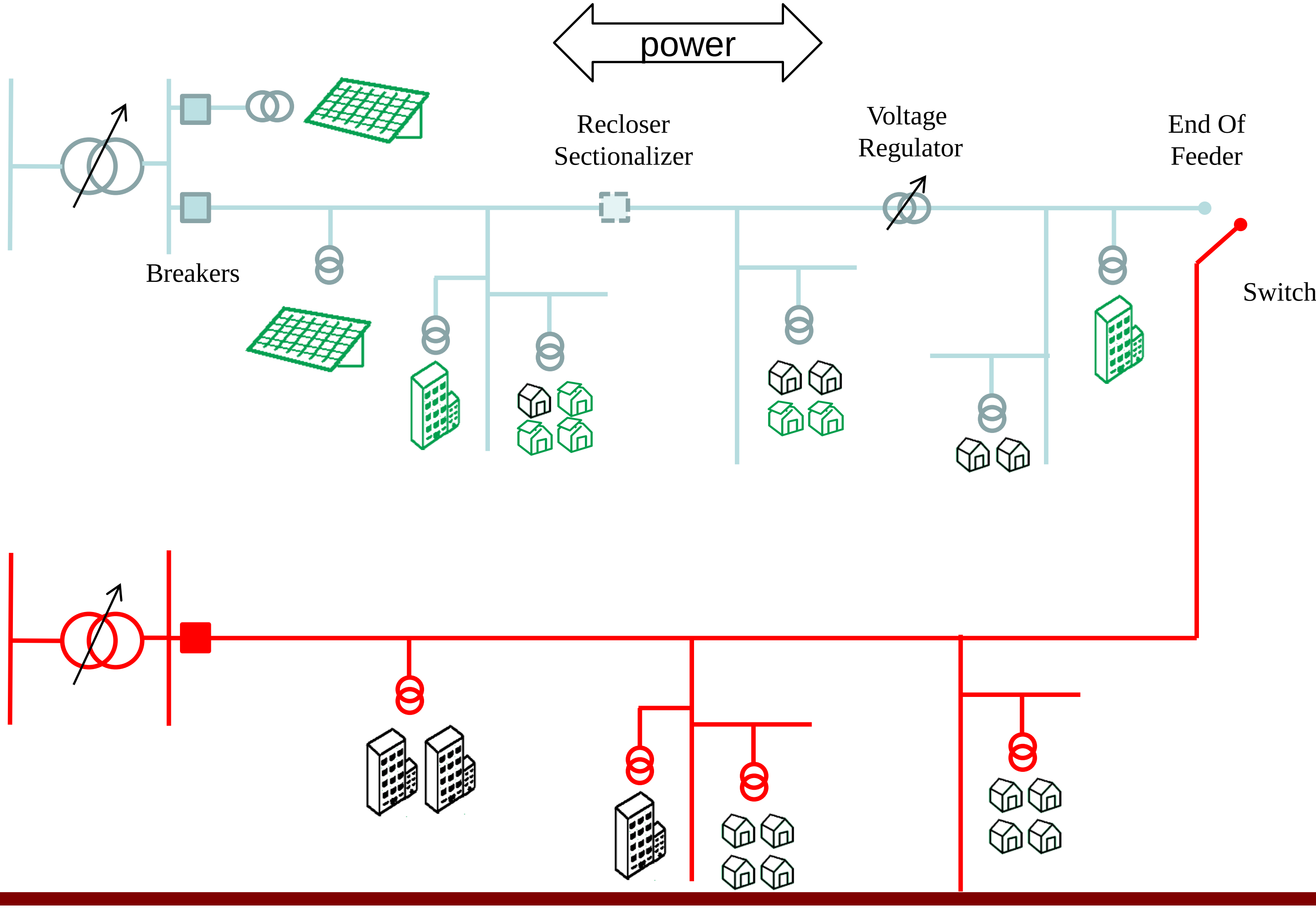
Approach

- Determine by detailed simulation the impacts of achieving high PV deployments on the distribution system.
- The analysis methods must account for the effect of solar variability and develop techniques and processes to generate high-resolution solar output data for interconnection studies on distribution systems.

Distribution System



Distribution System with High PV deployment

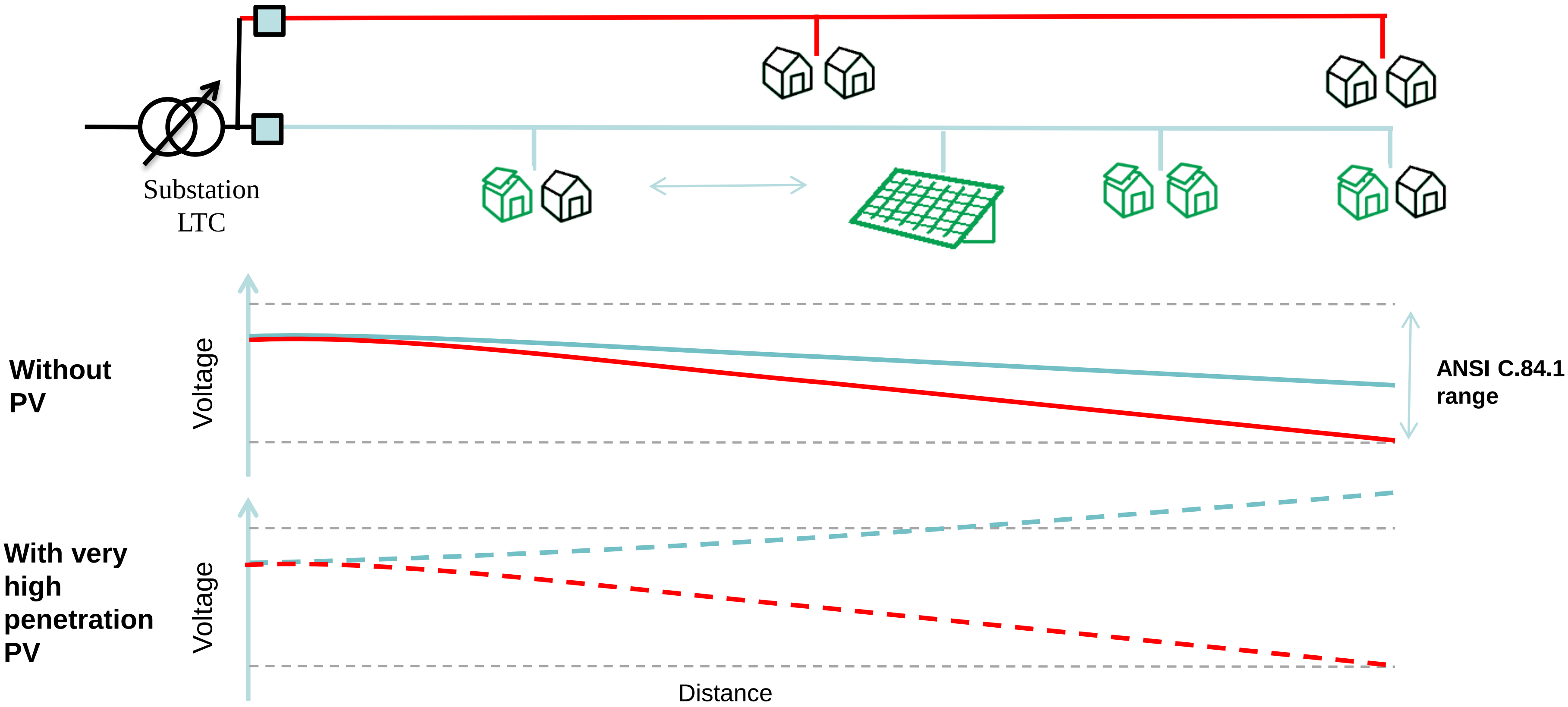


Distribution System Integration

- Voltage Regulation
  - Ability to maintain customer voltage within range
  - Wear-and-tear on voltage control equipment (e.g., tap operations) due to variable output
- Power Quality
  - Flicker, harmonics
- Protection
  - Performance of relays and other protection equipment
  - Risk of unintentional islanding
- System planning and operations
  - Feeder load switching, maintenance, outage management
  - Controllability and visibility of distributed resources
  - Possible impact on bulk system

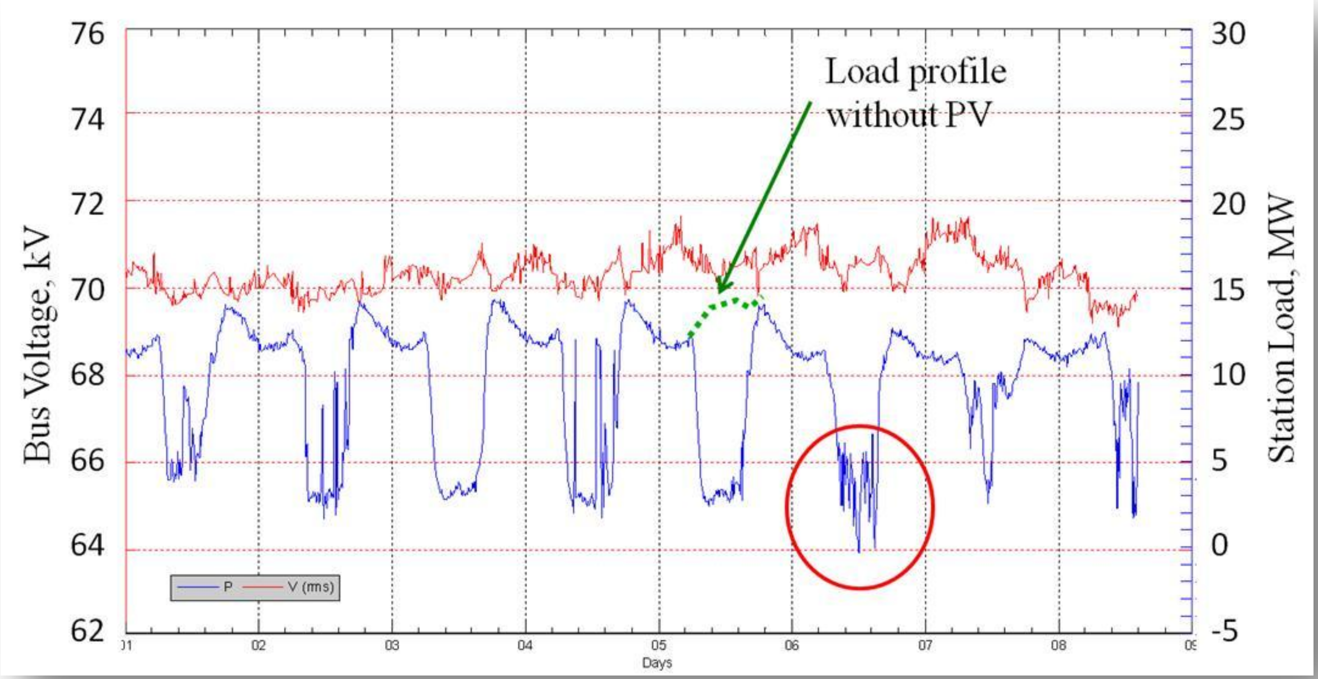
Voltage Regulation Issue

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



Voltage Regulation Issue

- High penetration does not always lead to voltage issues
  - Short urban feeder
  - PV connected to the feeder head close to the substation
- Example below: PV is connected next to strong urban feeder head, station voltage does not change



Impact Mitigation- Now and in the Future

- Examples of lower cost mitigation measures:
  - Change Voltage regulation equipment control set points to minimize PV variability impact on LTC operations.
  - Rethink the feeder voltage control scheme to maximize voltage support benefit of PV while minimizing regulation equipment operations.
  - Upgrade fixed capacitor banks to voltage controlled switched banks for upper limit ANSI range A violations.
  - System upgrades to handle feeder configurations under N-1 contingency cases may be avoided by ***cost effective*** curtailment provisions in the interconnection agreement.
  - Implement distribution planning best practices to optimize feeder performance: phase balancing of loads, advanced capacitor controls, load balancing, etc.

Impact Mitigation- Now and in the Future

- Examples of higher cost mitigation measures:
  - Advanced Inverter Functionality-PV inverter power factor set to offset voltage rise/fall. Set point, Schedule, Plant level control.
  - Capacitors and Voltage regulation equipment added/removed from the distribution circuit
  - Reconductor feeder backbone, upgrade transformer, dedicated feeder. Etc.

- ***Future:*** Allow PV smart inverters to manage the voltage at the point of interconnect. Not easy to do and established standards would need to be changed.

Conclusions

- There are many examples of high PV deployment levels in the USA and elsewhere, where impacts have been minor. However, high PV deployment in some distribution circuits could cause problems.

- As greater deployment levels of PV occur in specific locations, a robust screening and system impact study process will identify which PV systems cause grid impacts and determine the mitigation measures and associated costs to interconnect.

Questions?

Studies on the System Benefits of PV

- Transmission and Distribution (T&D) deferral.
- Integration of PV and demand response programs

PV Benefits-Transmission and Distribution (T&D) Deferral

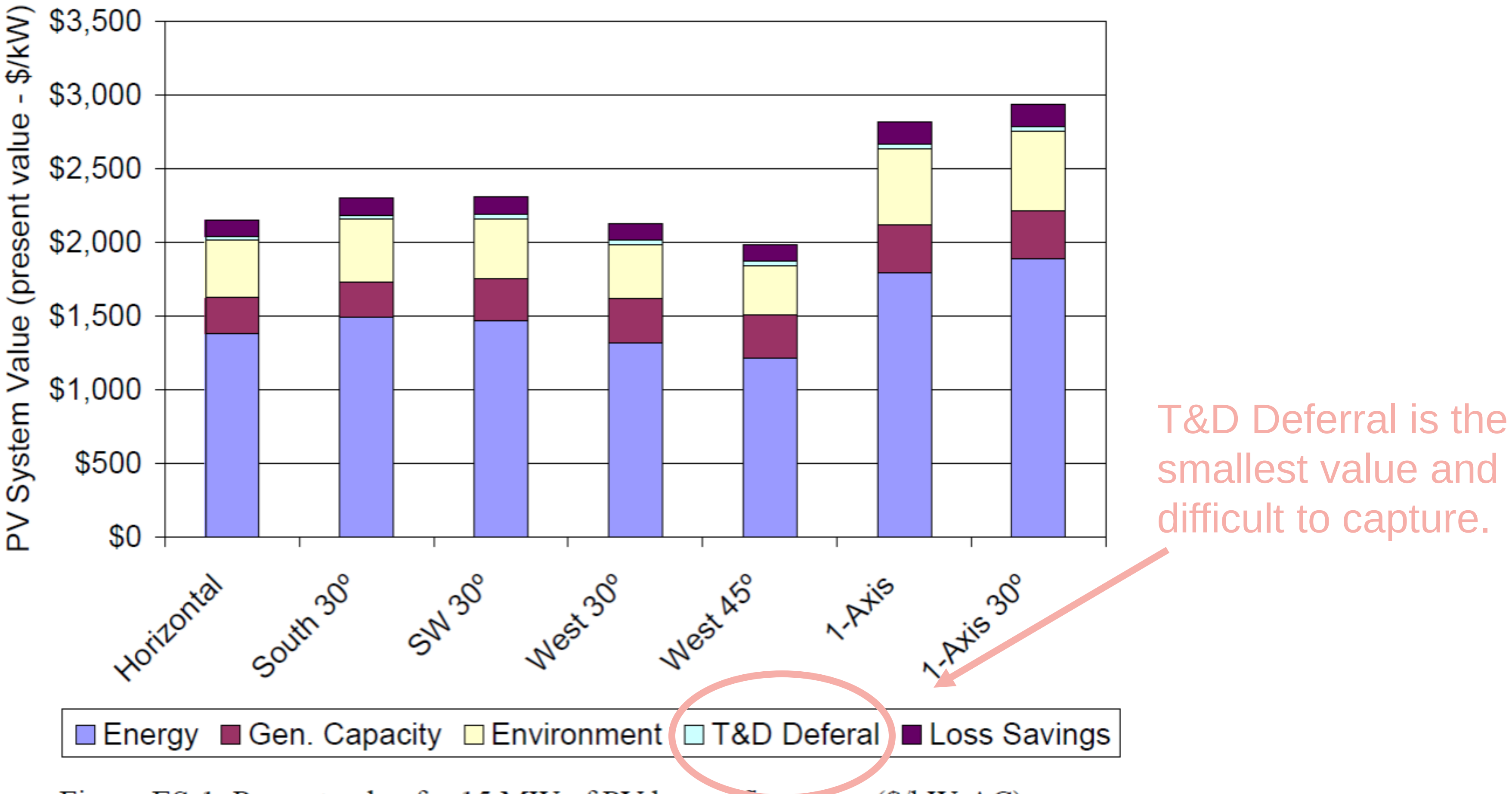
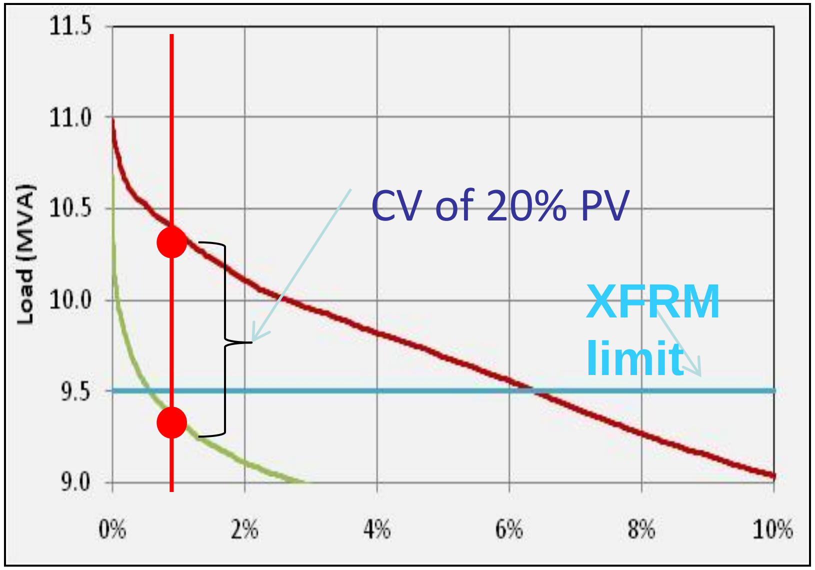


Figure ES-1. Present value for 15 MW of PV by configuration ($/kW-AC).

Source: The Value of Distributed Photovoltaics to Austin Energy and the City of Austin. Prepared by Clean Power Research, L.L.C. March 17, 2006

Deferal value of PV



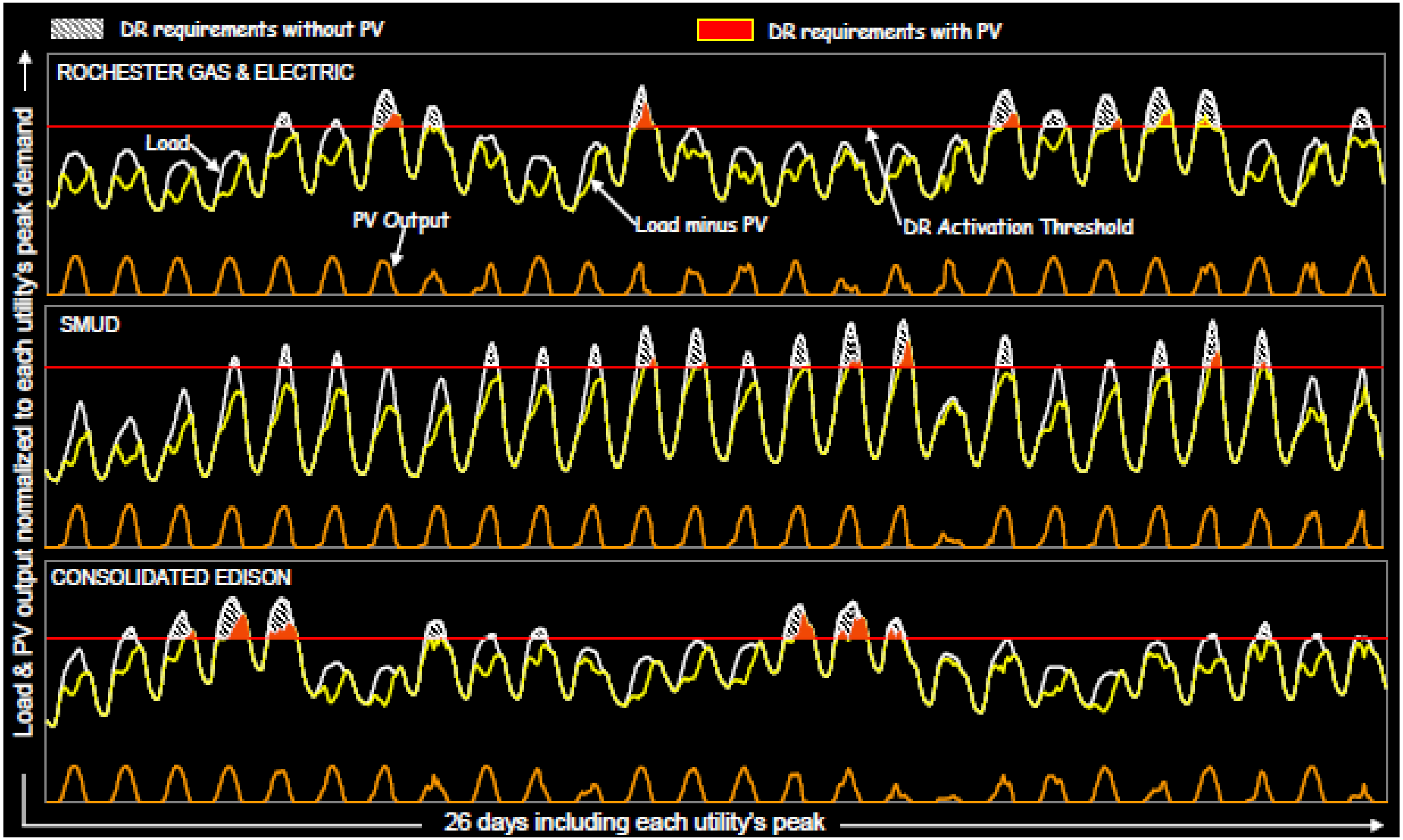
Load Duration Curve

The method for estimating the deferral value involves analysis of a full year of load data. The red curve in the figure above shows when the load on the substation transformer is projected to exceed the transformer rating.

The green curve shows the net substation load with 20% penetration of PV. The Capacity Value (CV) of the PV can be seen from the downward shift in the load duration curve of the substation with PV.

The number of hours of exposure is much less!

Integration of PV and demand response programs



Source: Integration of PV into Demand Response Programs.
Richard Perez, et al. Under NREL subcontract AEK-5-55057-01