



UCE Exhibit 1.4D

Docket No. 11-035-200

Exploration of PV and Energy Storage for Substation Upgrade Deferral in SLC, Utah

Second Progress Report for Rocky Mountain Power and Utah Clean Energy

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Project Overview

- **Project Scope**
 - Explore potential application of PV and energy storage for station/feeder upgrade deferral
 - Explore effect of azimuth and tilt angle optimization
 - Provide energy storage sizing example/methodology
 - Show how PV could impact sizing or effectiveness of energy storage
 - Discuss attributes of energy storage technology options
 - Discuss other added benefits of energy storage and PV at the distribution level, including voltage support and losses
 - Discuss other alternatives, including load transfer, demand response (rate incentives and direct control)
- **Emphasize methodology, build analytical tool**
 - Use actual data to illustrate

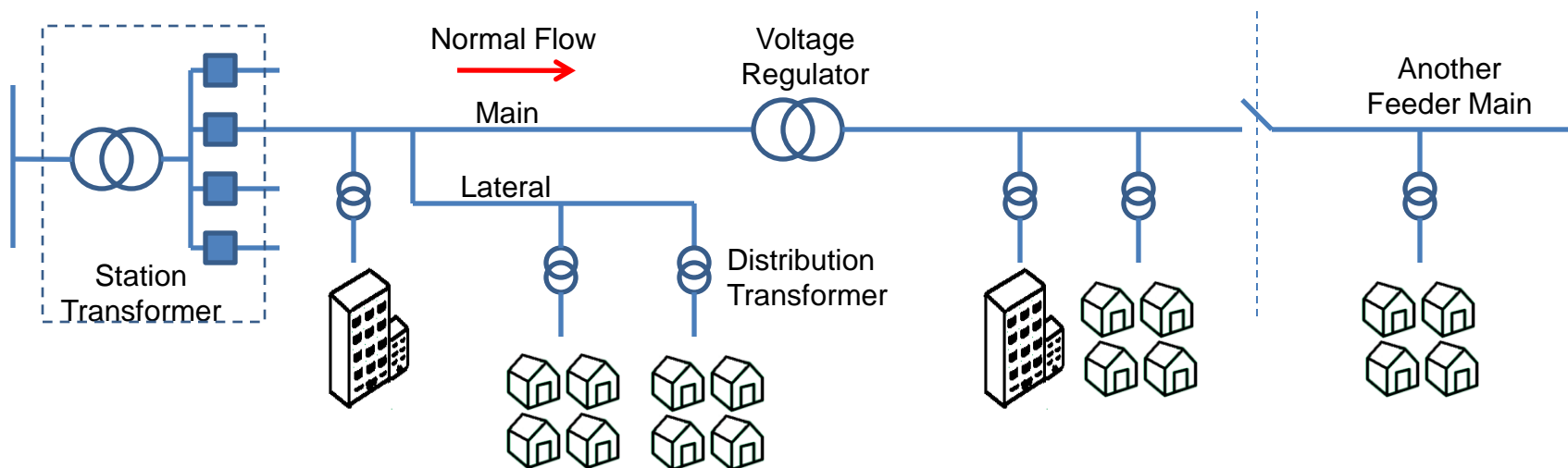


Progress Thus Far

- Analysis of load profiles for selected stations
 - Residential, Commercial
- Development of time-synchronized PV output data
 - Same location, same period
 - Different tilt (inclination), azimuth (orientation)
- Analysis “T&D capacity value” of 10% and 20% PV
 - Metric is reduction in exposure to overload
- Analysis of energy storage application
- EXEL Analysis Tool (internal)
- Finalizing SAND Report

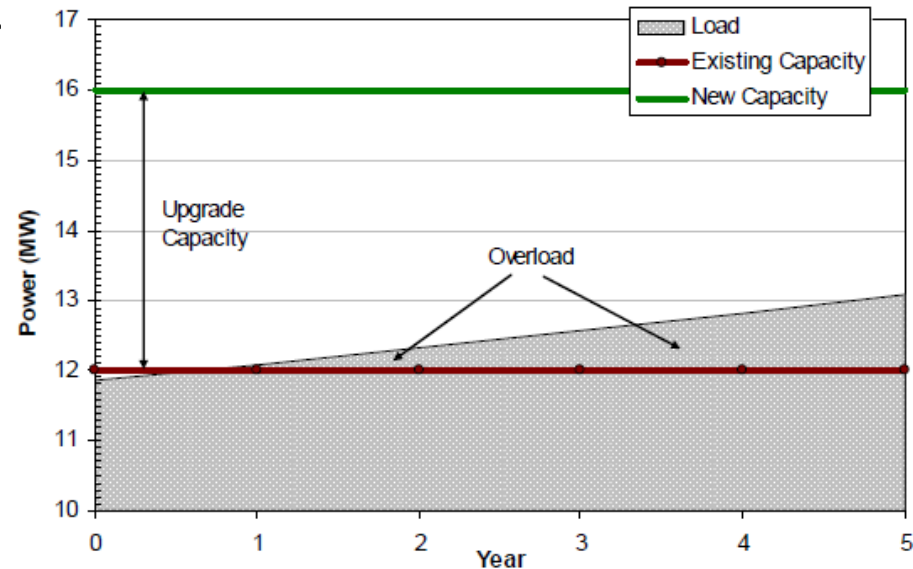
Distribution System Load Limits

- Distribution transformer
- Feeder main/lateral
- Voltage regulator (if present)
- **Station transformer**
- Sub-transmission and transmission



Deferral Value

- Utilities earn a rate of return to cover the cost of equipment in service
 - Annual revenue requirement ranges from 8% to 15%
 - Reflects principal, interest, dividend, taxes, insurance
- Deferral value is equivalent to the *annual revenue requirement* \times *upgrade cost*



Source: Energy Storage for the Electricity Grid, Benefits and Market Potential Assessment Guide SAND2010-0815



Deferral Value

- Example

- A 12 MVA station transformer is upgraded with a new 16 MVA unit for a cost of \$1,200,000. Assume that the annual fixed charge rate is 11%, and that there is no residual value.
- The annual cost to own the new transformer is
 $0.11 \times \$1,200,000 = \$132,000$
- The *deferral value* for 1 year is also \$132,000
- In this case, the *marginal cost* of the T&D upgrade is
 $\$1,200,000 / 4 \text{ MVA} = \$300,000 \text{ per MVA}$



Deferral Value

- Marginal Cost of system upgrades is a useful measure of the deferral value, and how alternatives compare

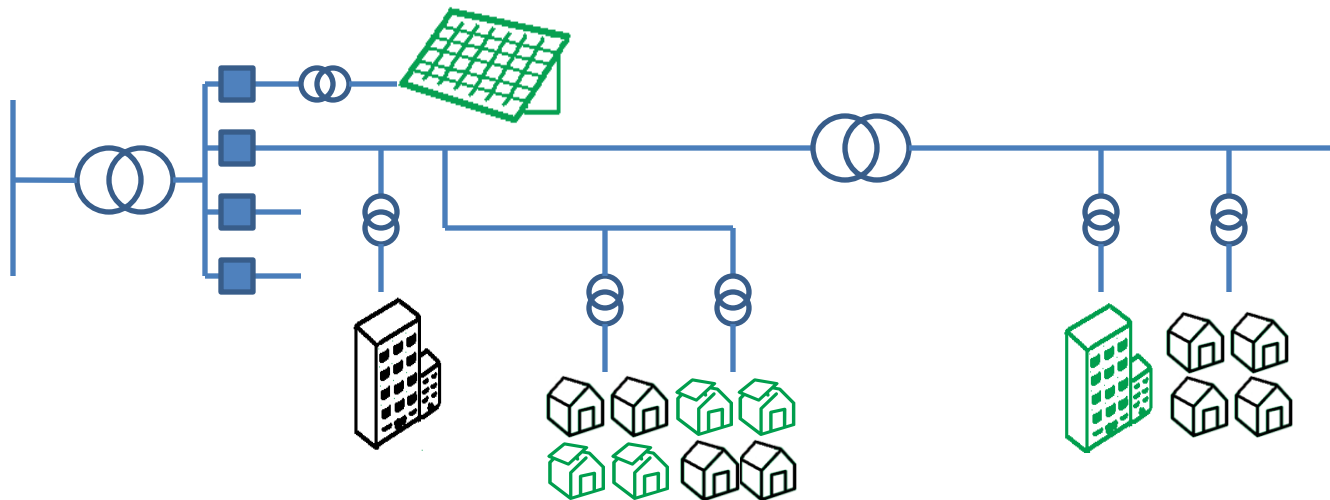
Marginal cost of
utility equipment
Source: ORNL

FERC Form1 Account	Marginal Cost (\$/MVA)		Average Cost (\$/MVA)	
	National 1989 to 1998	PJM 1989 to 1998	National 1998	PJM 1998
Dist Land (360)	2,639	5,653	1,501	2,978
Dist Structures (361)	2,481	5,538	1,219	3,408
Dist Station Equip (362)	32,869	57,248	16,925	25,820
Dist Battery Storage (363)	2	0	0	0
Dist Poles & Towers (364)	50,390	50,746	22,403	24,457
Dist Overhead Conduct (365)	52,059	63,363	22,246	28,366
Dist Undgr Conduit (366)	13,815	23,739	6,428	12,376
Dist Undgr Conduit (367)	44,226	65,121	18,043	26,885
Dist Transformers (368)	40,787	39,757	23,656	24,715
Dist Services (369)	26,553	34,494	11,888	16,433
Dist Meters (370)	13,625	14,045	7,655	8,989
Dist Installations (371)	2,854	4,858	1,133	1,327
Dist Leased Property (372)	-131	1	42	6
Dist Street Lights (373)	8,034	10,175	4,438	4,610
Dist Total	290,203	374,737	137,576	180,369
Trans Total	80,650	64,876	52,229	48,681
Total Dist and Transmission	370,853	439,613	189,805	229,050

Source: The data is from 105 utilities selected from the intersection of utilities for these accounts in both 1989 and 1998 included in the POWERdat database (Resource Data International, Inc.). This data was originally from data collected in FERC Form 1.

T&D Value of PV Generation

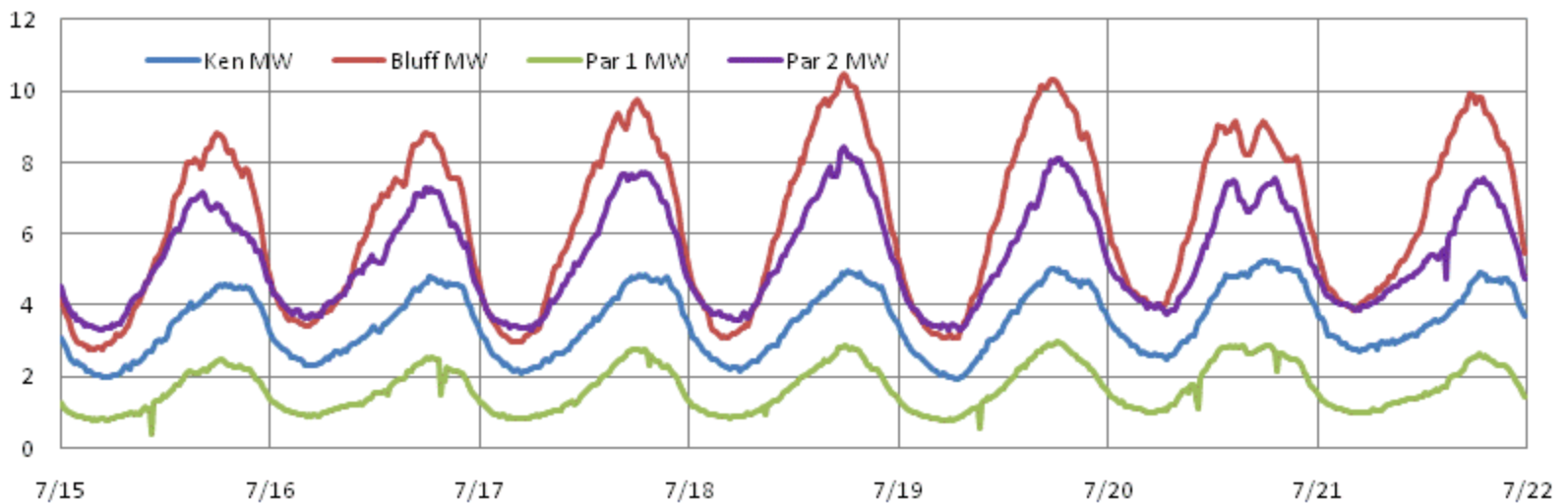
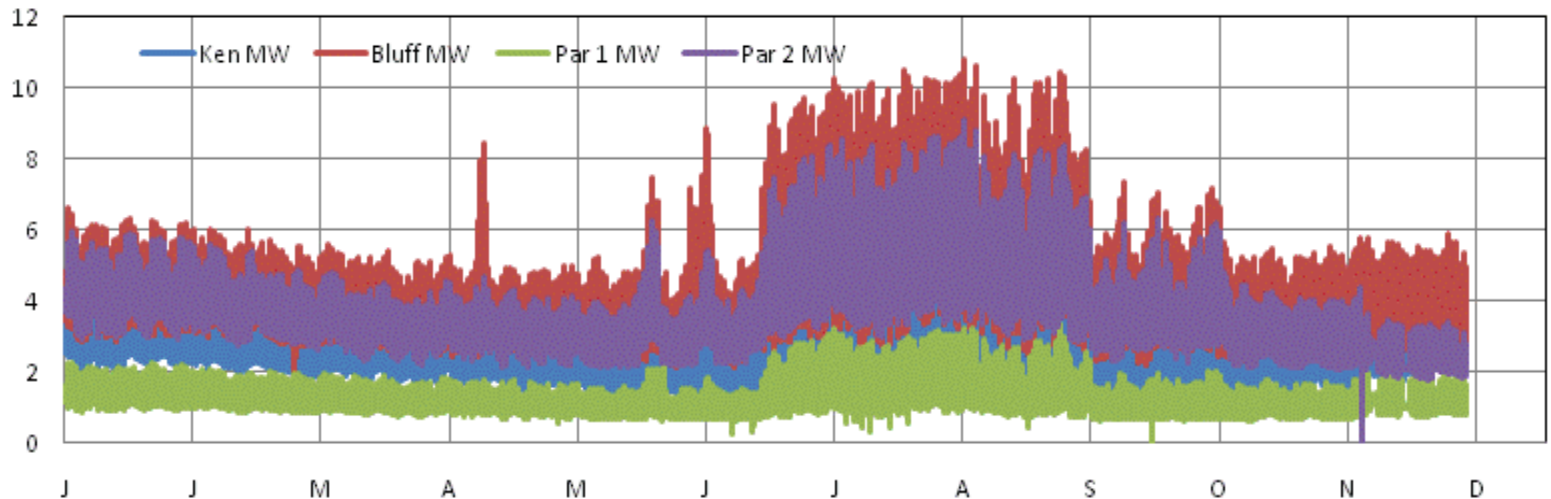
- Reduces emissions and system losses
- Reduces feeder/transformer load
 - Possible opportunity for deferment of transformer/station replacement or upgrade
 - Benefit is specific to the situation
 - Need to study actual data to evaluate





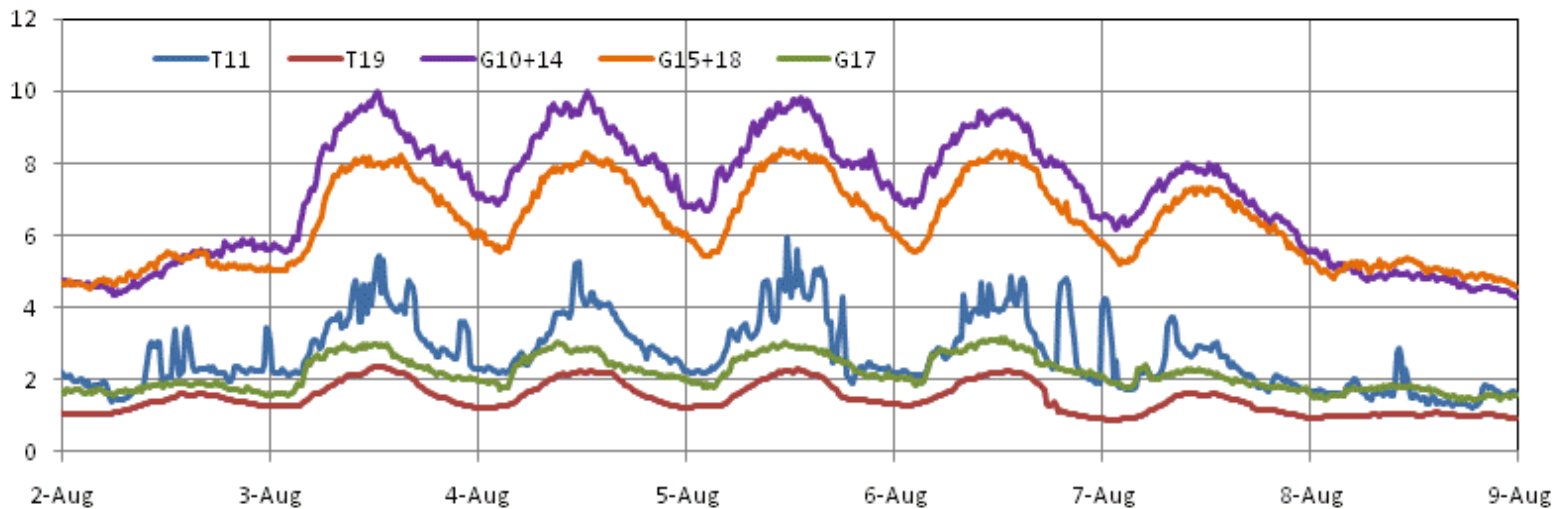
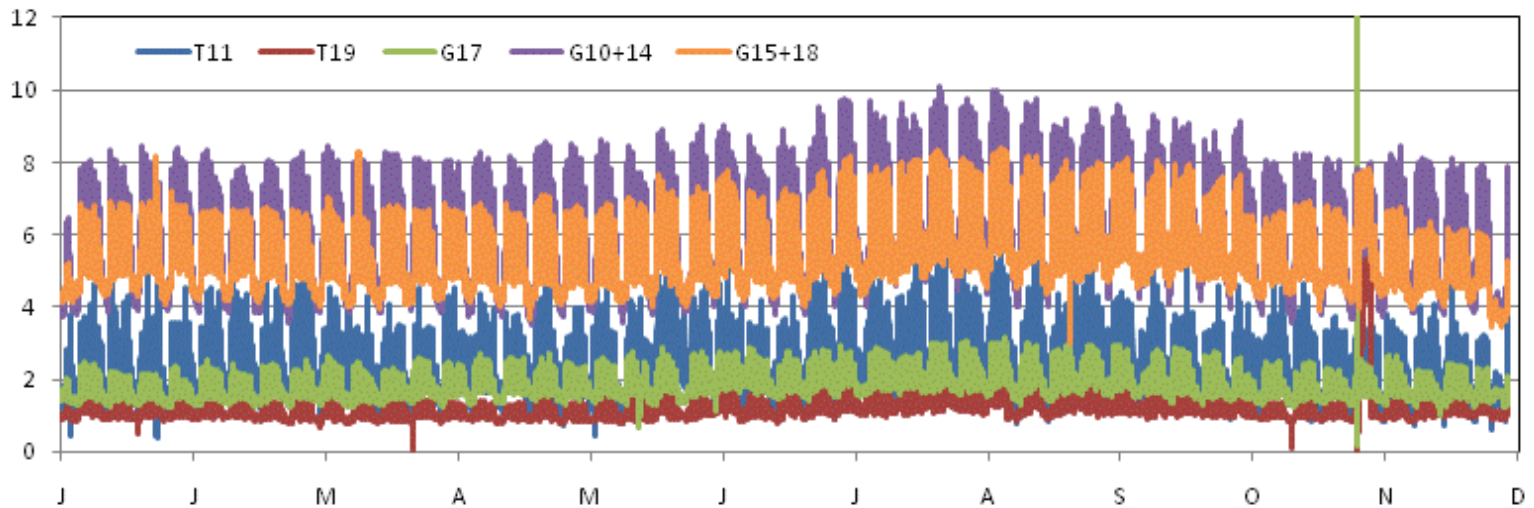
Analysis of SLC Residential and Commercial Load Characteristics

Sample of SLC Residential Load





Sample of SLC Commercial Load





Load/Station Characteristics

Station Name	Feeder Type	Transformer Rating (MVA)	Peak Load (MVA)	Growth rate AVG % per year	Utilization Factor	Load Factor
Kensington	Residential	6.25	6.01	2.6%	96%	46%
Bluffdale	Residential	14.0	11.2	6.1%	81%	40%
Parleys 1	Residential	6.25	3.5	8.3%	56%	39%
Parleys 2	Residential	9.75	9.61	1.0%	99%	42%
Draper 1	Residential	14.0	11.1	1.0%	79%	
Draper 2	Residential	16.0	9.4	3.2%	59%	
Terminal 11	Commercial	14.0	6.7 ¹		48%	36%
Terminal 19	Commercial	30.0	2.4		8%	51%
Grow 10, 14	Commercial	28.0	10.1		36%	62%
Grow 15, 18	Commercial	30.0 ³	8.4	4.0%	28%	66%
Grow 17	Commercial	16.0	3.2 ²		20%	60%

¹ Adjusted from 10/28 07:00 to 20/29 13:30 which contained a peak load of 7.9 MVA (load transfer?)

² Adjusted from 10/26 08:00 to 10/26 13:00 which contained a peak load of 14.4 MVA (load transfer?)

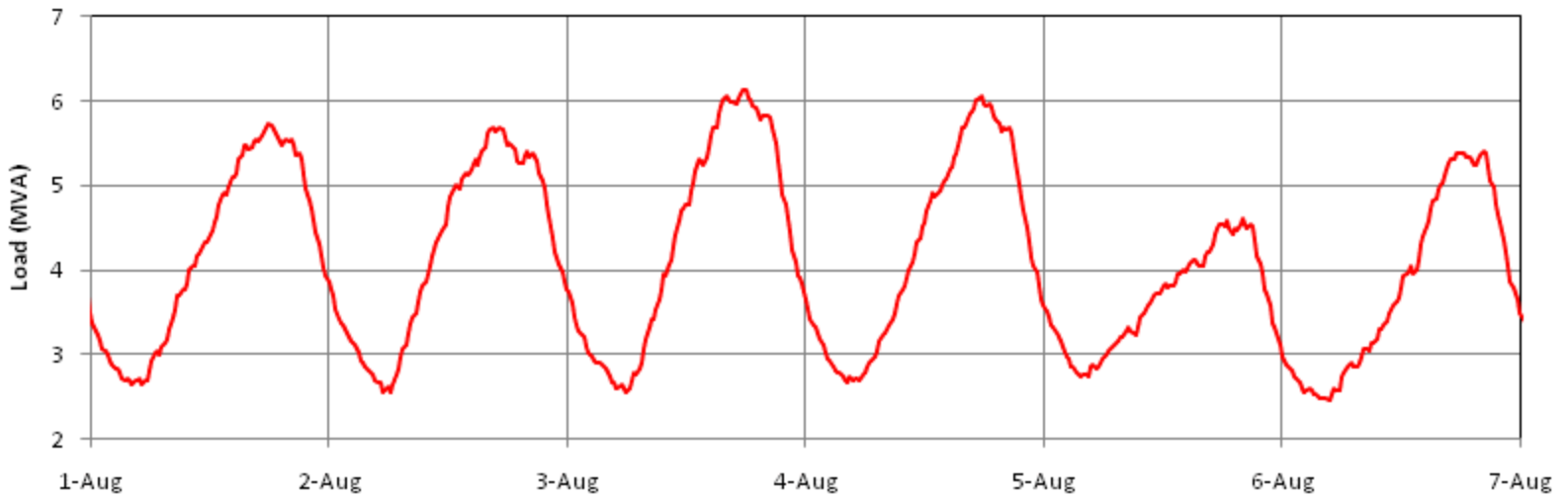
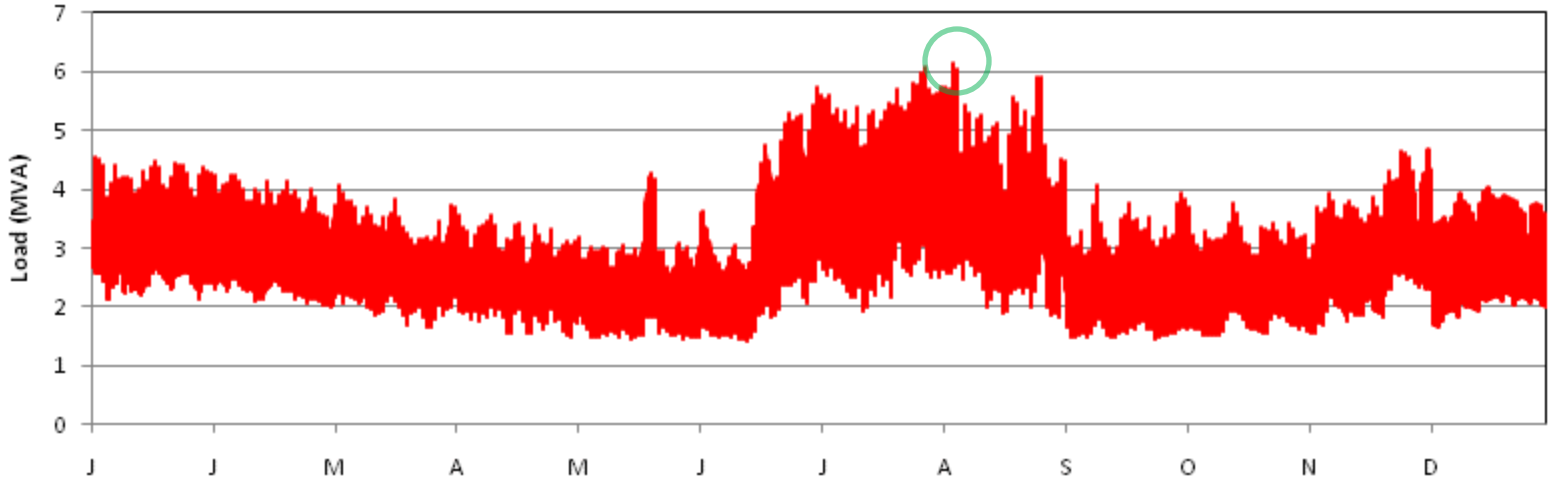
³ Assumed rating of 9.5 MVA for illustration purposes

Data for residential load is calendar year 2008; data for commercial load is calendar year 2009

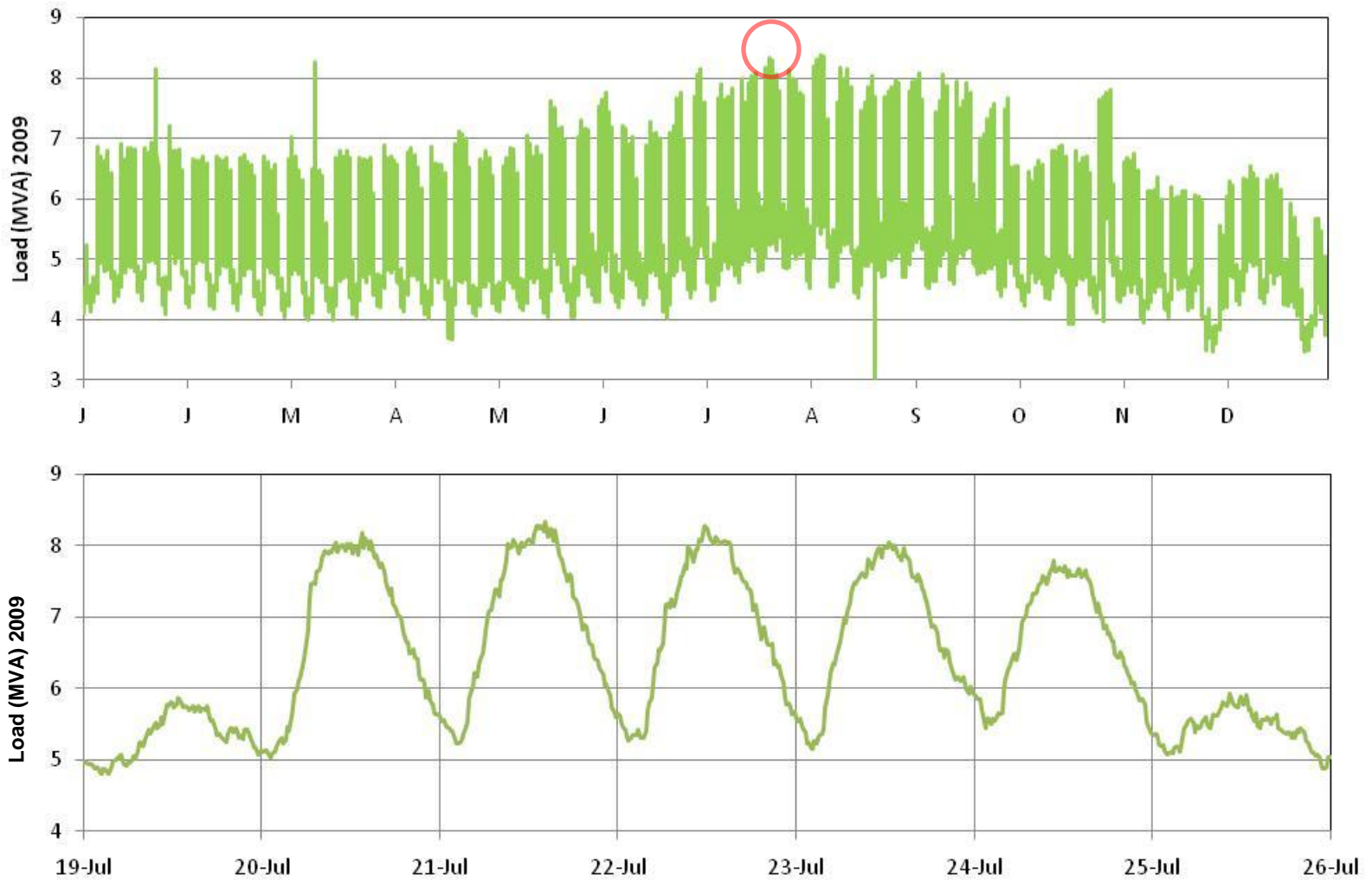
$$Utilization\ Factor = \frac{Peak\ Load}{Transformer\ Rating}$$

$$Load\ Factor = \frac{Peak\ Load}{Average\ Load}$$

Residential Load (Kensington)



Commercial Load (Grow 15/18)





Solar Data and Simulation of PV Output Data

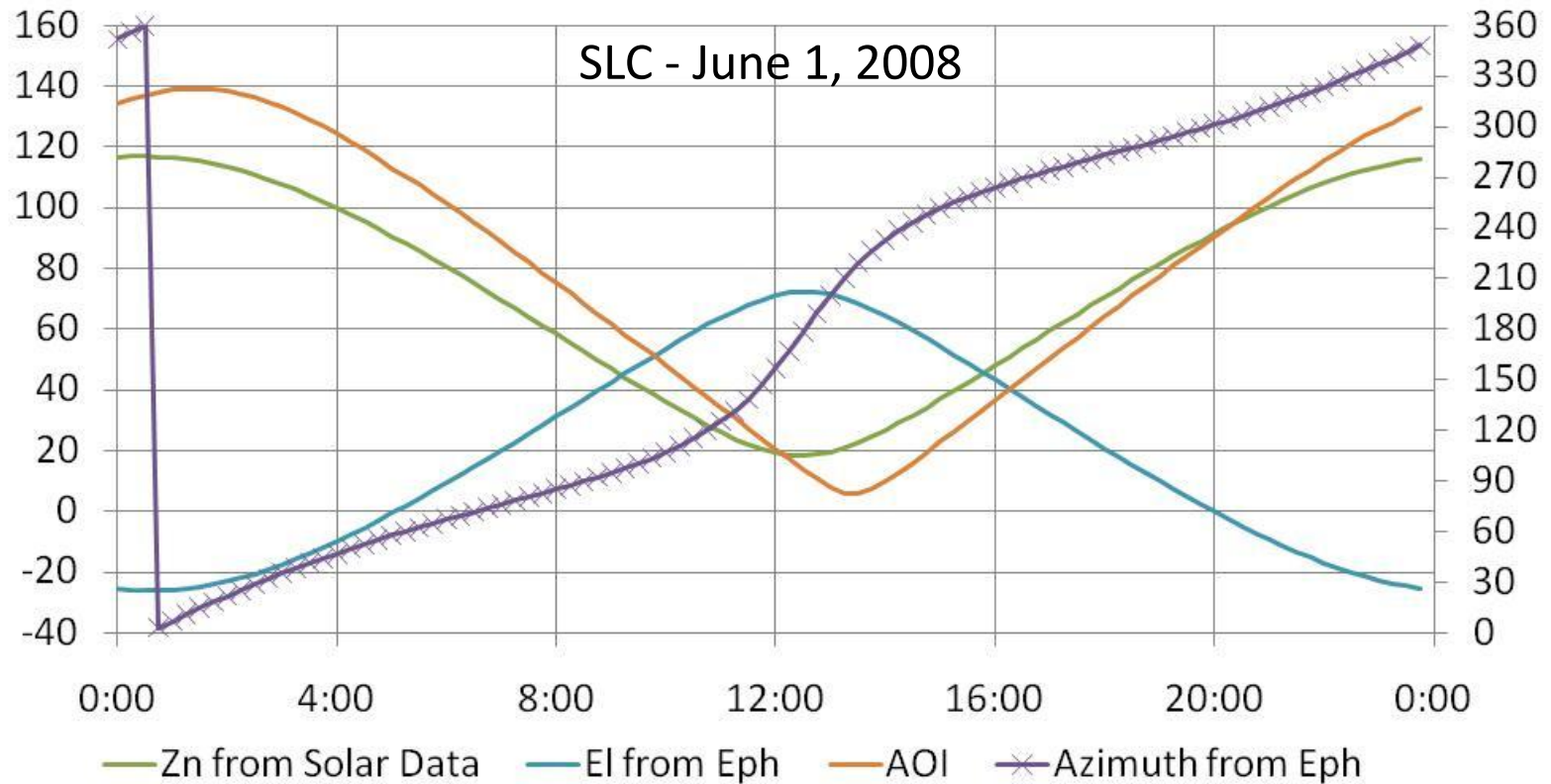


Solar Radiation Data

- Ground Sensors (NOAA-ISIS)
 - Integrated Surface Irradiance Study Network
 - The ISIS station in Salt Lake City
 - Located at National Weather Service site near airport
 - Data available from 2002 through 2009.
 - Data collected every 3 minutes.
 - <http://www.srrb.noaa.gov/isis/>
 - Needs conversion to Plane-of-Array (POA)
- Satellite-based estimates data
 - http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005

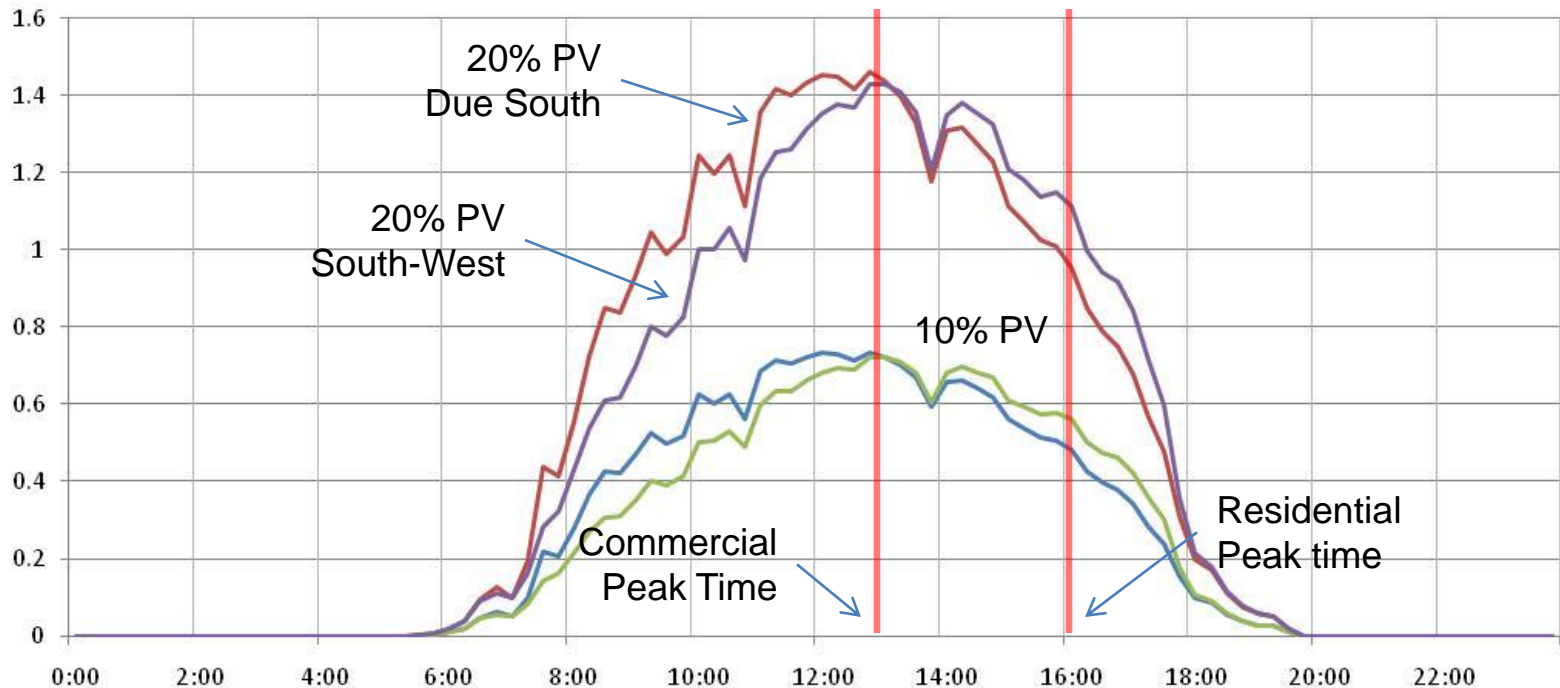
Modeling Solar Data

- Global horizontal (GH) irradiance is given
- Need to calculate irradiance on the plane of array (POI) for the desired array tilt and orientation



Solar Data

- Effect of PV array fixed orientation
 - Due South (maximum energy) and South-West
 - Shift is noticeable, but net effect on net load is very small
 - Chart below is for latitude tilt, residential case (6.25 MVA)





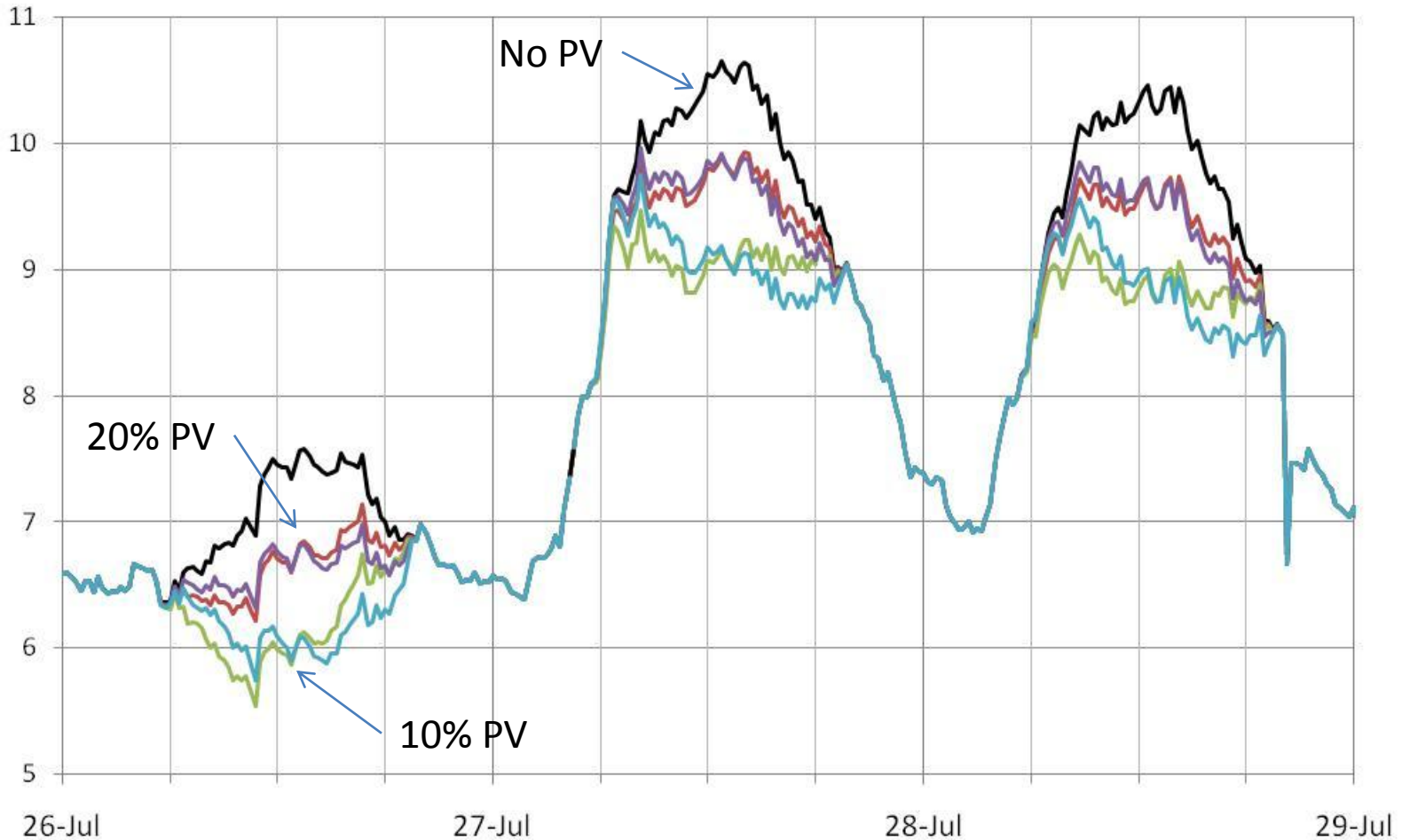
T&D Deferral Value of PV (Distribution Station Overload)



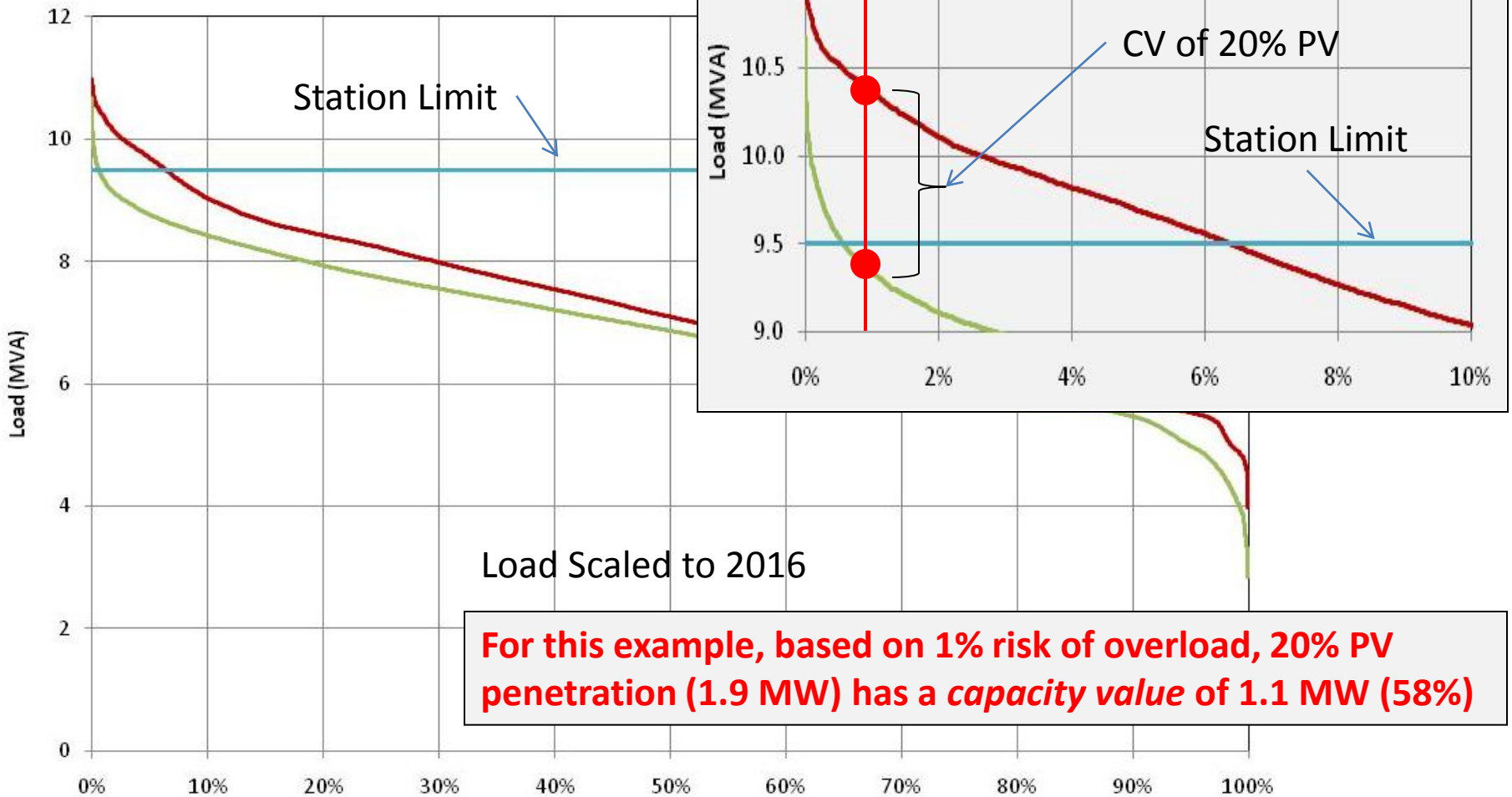
Analysis of Deferral Value of PV

- Procedure
 - Obtain time-and-location-coincident load and solar data
 - Analyze scenarios of interest
 - Load year(s)
 - PV penetration level (No PV, 10% & 20% PV penetration)
 - Establish “capacity value” (CV) of PV
 - Based on peak load, or...
 - ...better yet, based on some acceptable risk of overload (e.g., 1%)
 - See discussion of transformer rating/loading at the end of presentation
 - Estimate deferral value
 - This is based on avoided cost of capital upgrade only
 - Does not attempt to compare cost-effectiveness of alternatives

Results for Commercial Load



Results for Commercial Load





Results for Commercial Load

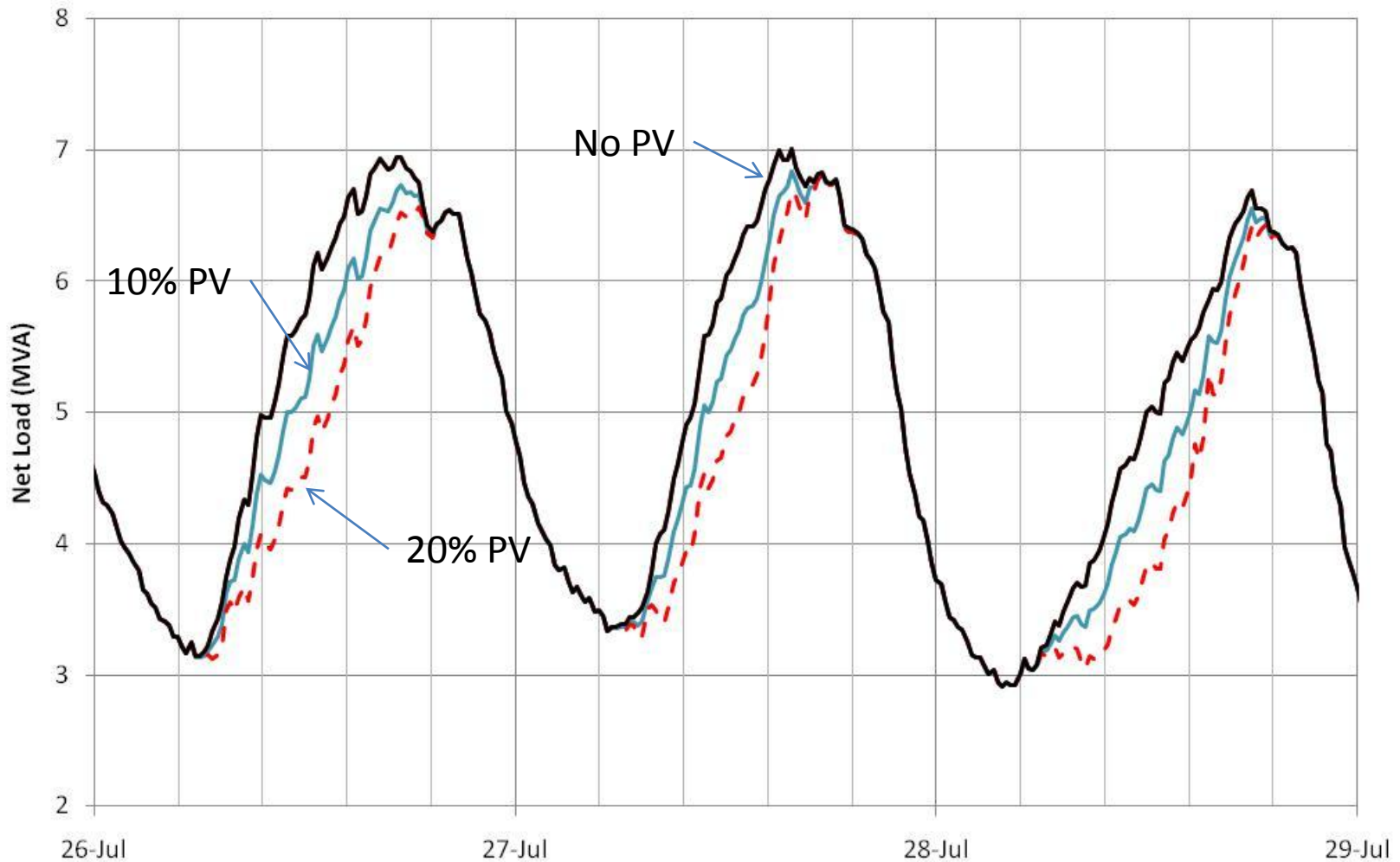
- Assumptions

- Station limit: 9.5 MVA (assumed for illustration)
- Annual load growth: 4% (assumed for illustration)

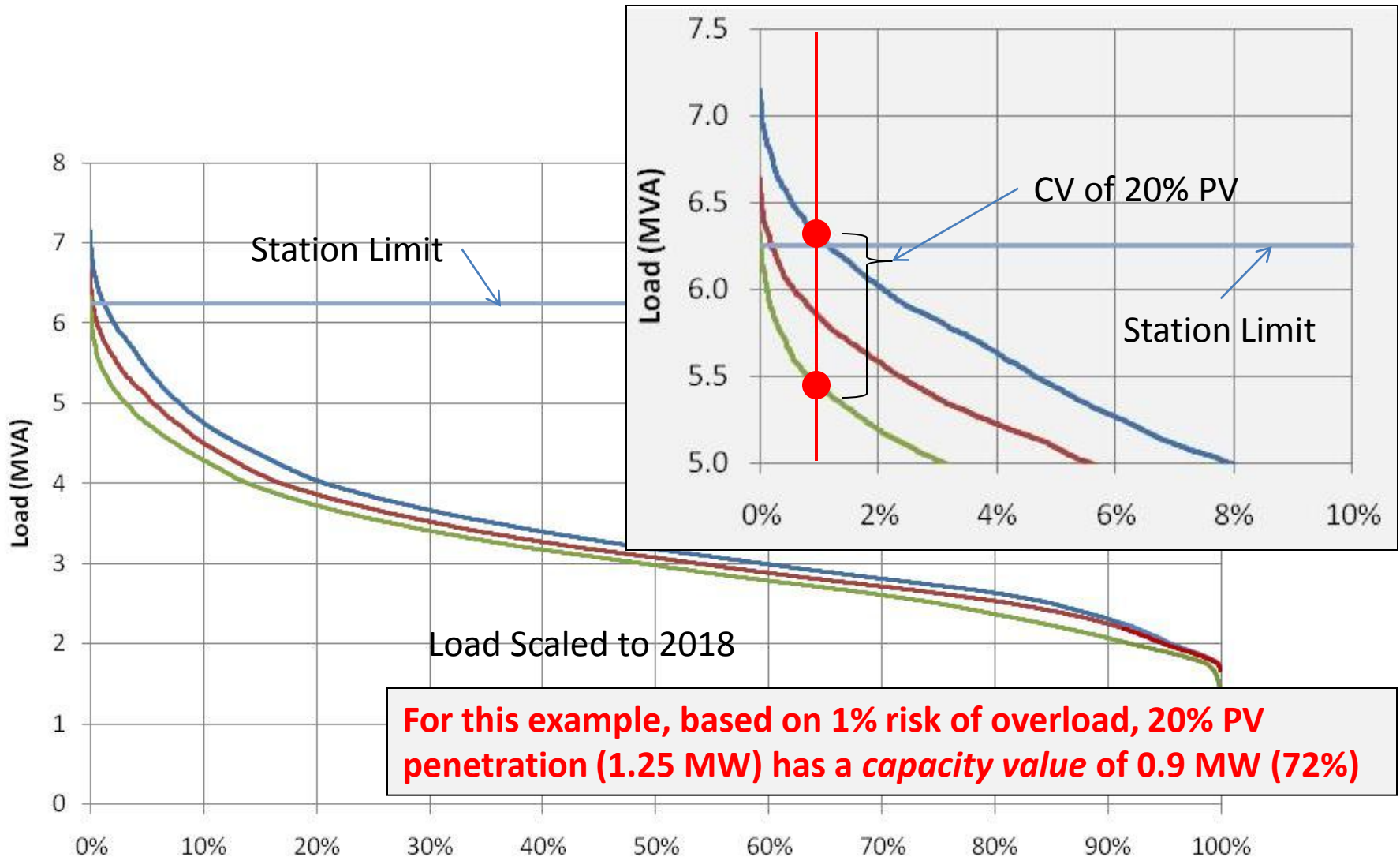
Year	Scaling Factor	No PV		10% PV		20% PV	
		Hrs > Rating	Peak Load	Hrs > Rating	Peak Load	Hrs > Rating	Peak Load
2009	1.00	0.0		0.0		0.0	
2010	1.04	0.0		0.0		0.0	
2011	1.08	0.0		0.0		0.0	
2012	1.12	0.0		0.0		0.0	
2013	1.17	17.5		0.0		0.0	
2014	1.22	135.0		3.8		0.3	
2015	1.27	332.3		61.0		7.5	
2016	1.30	510.8		179.5		34.8	

- In this example, 10% and 20% PV penetration could defer the station upgrade by 1-2 years and 3-4 years, respectively.

Results for Residential Load



Results for Residential Load





Results for Residential Load

- Assumptions
 - Station limit: 6.25 MVA
 - Annual load growth: 2.5%

Year	Scaling Factor	No PV		10% PV		20% PV	
		Hrs > Rating	Peak Load	Hrs > Rating	Peak Load	Hrs > Rating	Peak Load
2008	1.00	0.0		0.0		0.0	
2009	1.02	0.0		0.0		0.0	
2010	1.05	0.0		0.0		0.0	
2011	1.08	0.0		0.0		0.0	
2012	1.10	0.0		0.0		0.0	
2013	1.13	2.8		0.0		0.0	
2014	1.16	11.0		2.0		1.0	
2015	1.18	23.0		11.3		7.0	
2016	1.21	43.3		21.5		14.0	
2017	1.24	66.5		43.3		29.0	
2018	1.3	100.8		72.5		54.8	




Estimating Deferral Value

- Example based on Commercial case
 - The current plan to upgrade the 9.5 MVA station transformer would cost \$2,000,000. The new transformer would have a rating of 14 MVA. The annual fixed charge of 11%, and there would be no residual value for replaced station equipment.
 - Based on analysis, it is determined that 950 kW of PV (10% penetration) would defer the need for upgrade by 1 to 2 years
 - The *deferral value* for 1 year is
$$0.11 \times \$2,000,000 = \$220,000$$
 - In this case, the *marginal cost* of the T&D upgrade is
$$\$2,000,000 / 5.5 \text{ MVA} = \$364,000 \text{ per MVA}$$



T&D Deferral with Energy Storage and PV (Distribution Station Overload)



Deferral Value of PV & Storage

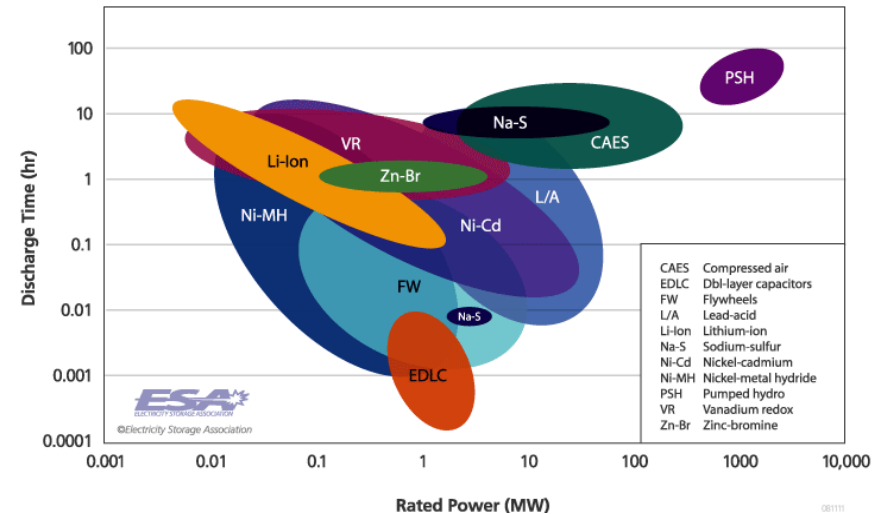
- Procedure
 - Obtain pertinent data
 - Analyze scenarios of interest to determine reasonable battery size
 - Evaluation of deferral value or cost-effectiveness
 - This is based on avoided cost of capital upgrade only
 - Energy storage is likely to be a utility-owned asset; thus, it could be treated as an option among other alternatives
 - Other value opportunities should be considered in a full evaluation (voltage support, etc)

Technical Considerations

- Sizing
 - Capacity (kW interface)
 - Energy (kWh useful storage)
- Technology
- Portability
- Other

System Ratings

Installed systems as of November 2008



Energy Storage (kWh)



PCS (kW)

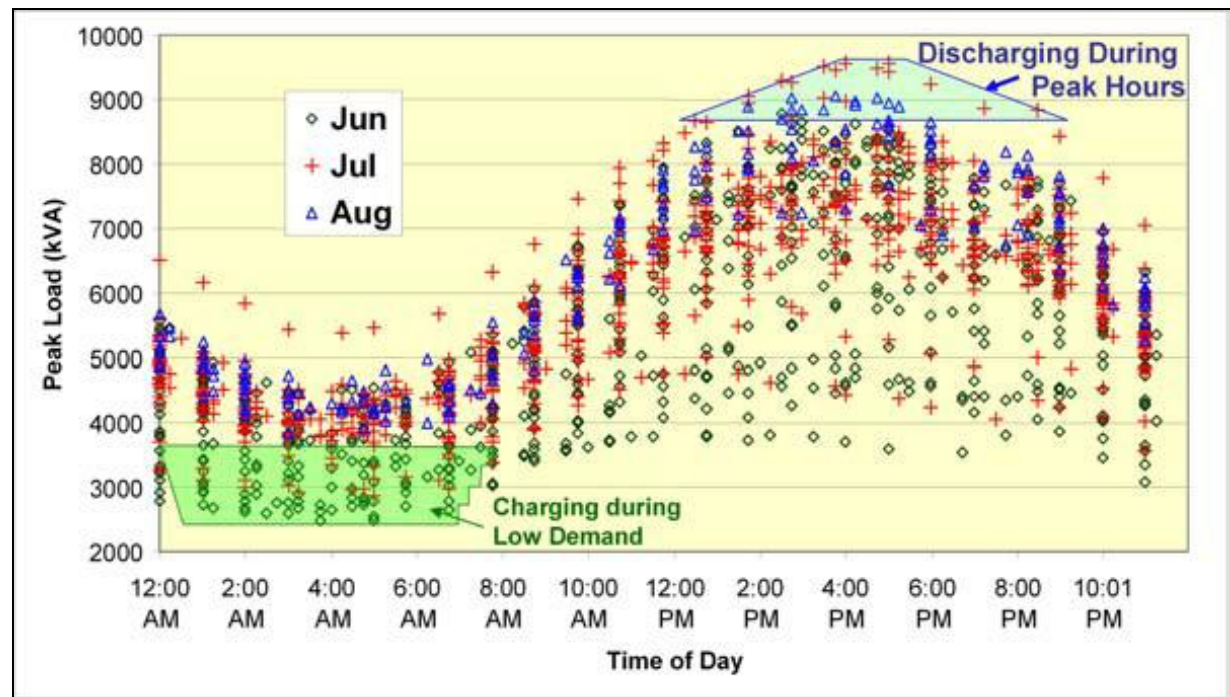


Grid



Technical Considerations

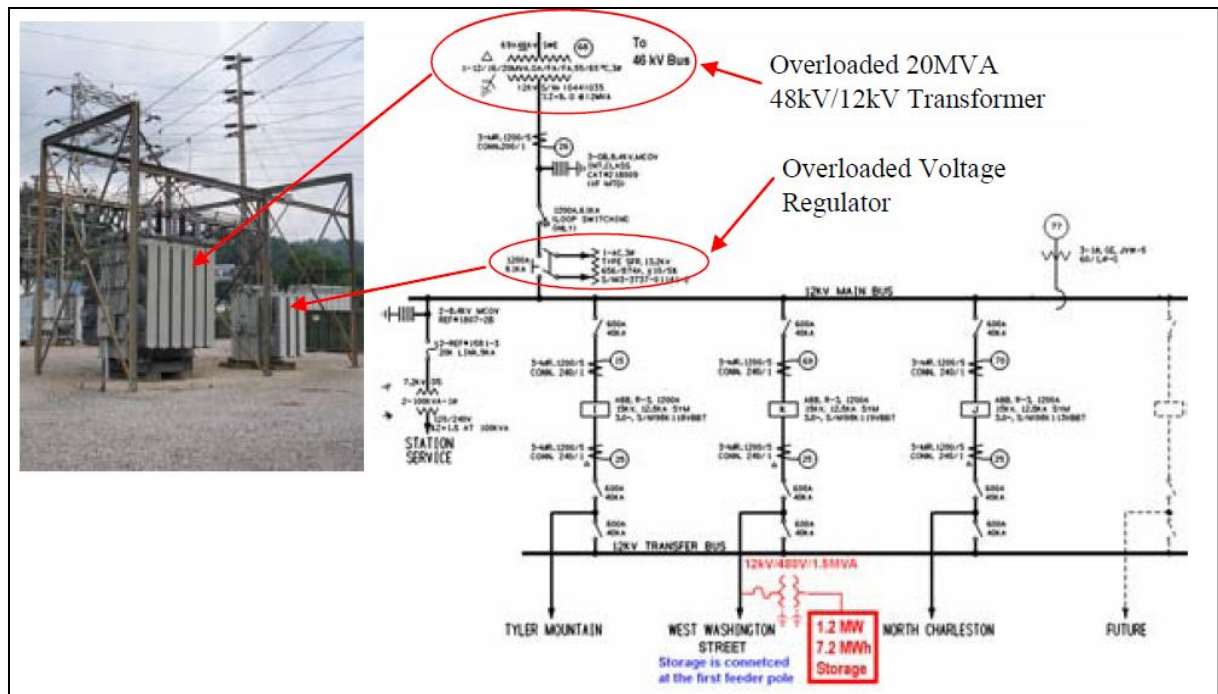
- Operating strategy
 - Discharge on peak, charge off peak
 - Details are site/situation/technology specific



Source: Installation of first Distributed Energy Storage System at American Electric Power (AEP) SAND2007-3580

Technical Considerations

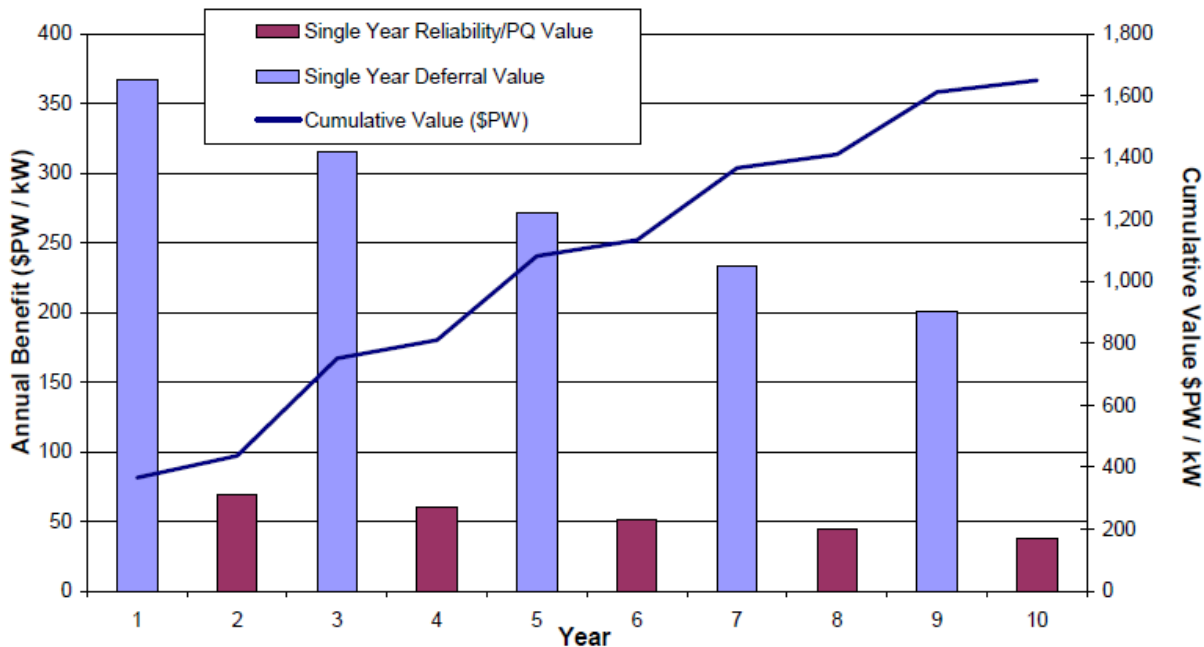
- Location of Energy Storage
 - Downstream from system constraint
 - Substation (easiest) or elsewhere on the feeder



Source: Installation of
first Distributed Energy
Storage System at
American Electric Power
(AEP) SAND2007-3580

Deferral Horizon

- Value proposition is optimal for a 1-2 year deferral horizon
 - Avoids the need for underutilized capacity
 - This makes a strong case for mobile storage



Source: Energy Storage for the Electricity Grid, Benefits and Market Potential Assessment Guide SAND2010-0815

Technical Considerations

- Stationary Vs. Mobil

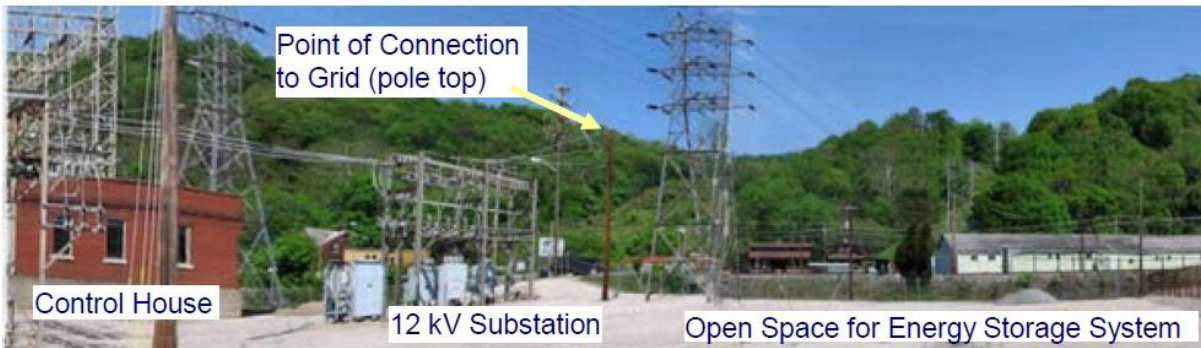


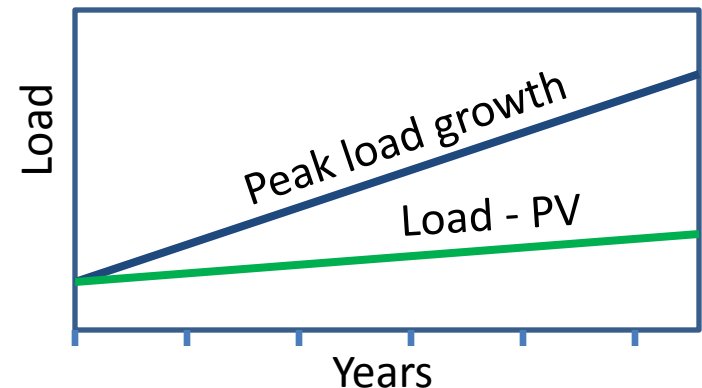
Photo courtesy of AEP



Source:
<http://www.premiumpower.com/product/transflow2000.php>

Effect of PV Deployment

- PV reduces energy storage requirement
 - Discharge time (energy)
 - PCS size requirement (if it lowers peak load)
- Ideal synergy takes place when PV deployment offsets load growth
 - Energy storage could cost-effectively defer upgrade over multiple years

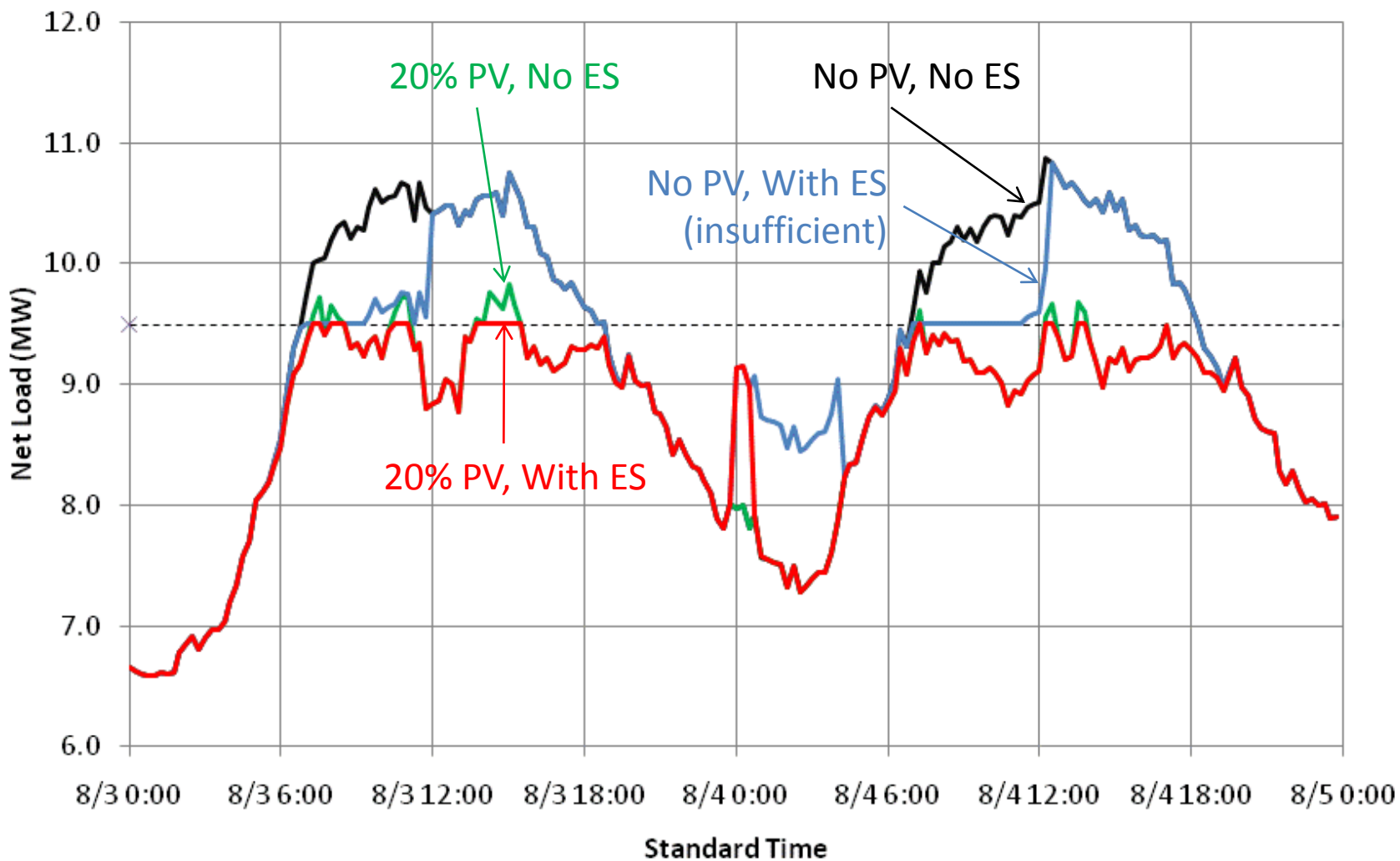




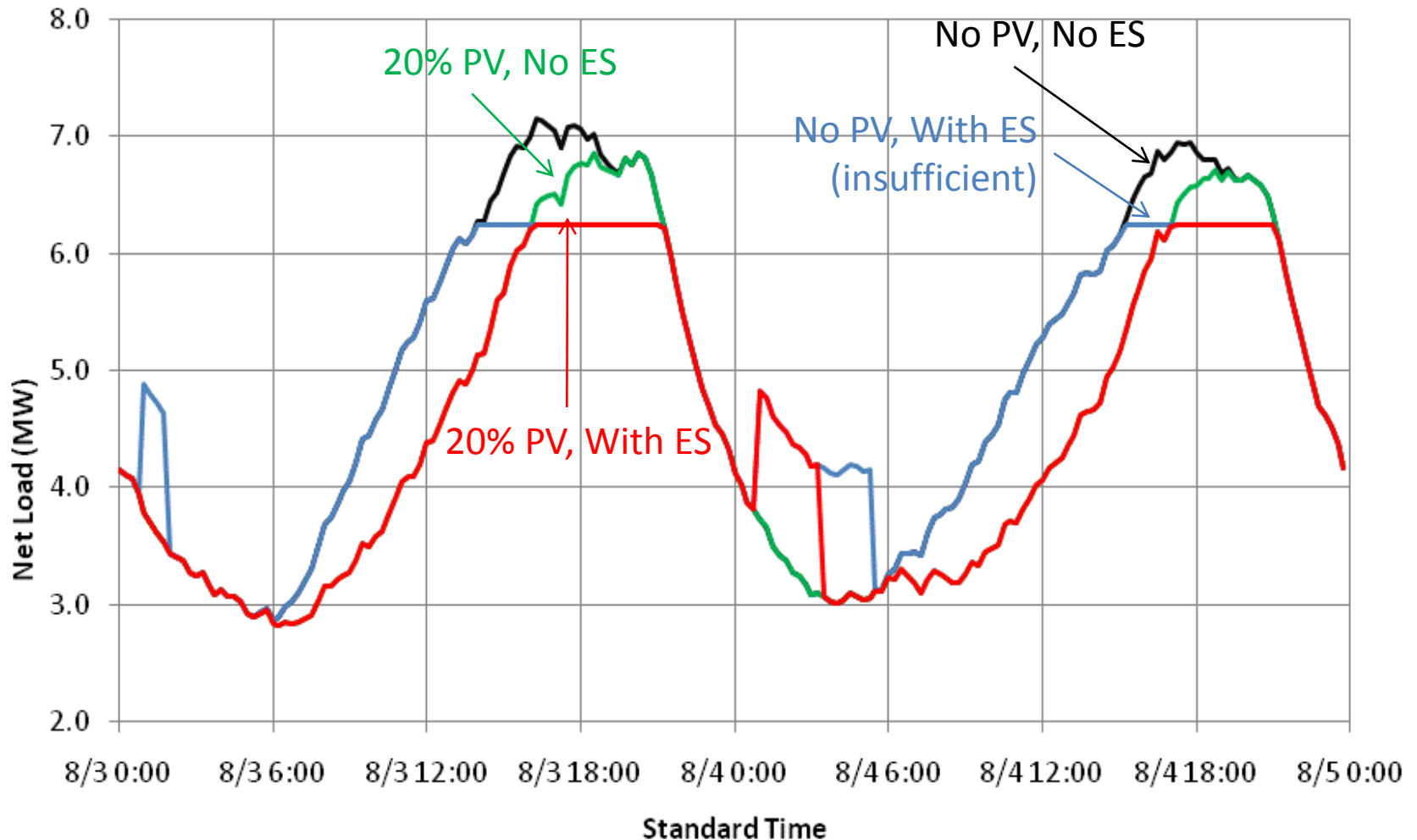
Storage Considerations

- Inputs
 - Battery Capacity MWh
 - Inverter Rating kW (maximum discharge rate)
 - Depth of Discharge – DOD
 - Lead Acid Batteries
 - Discharge Start Time
 - Discharge Stop Time
 - Charge Start Time
 - Charge Rate (% of inverter rating)

Example With Commercial Load



Example With Residential Load





Energy Storage and PV

- Based on the sample data analyzed, PV deployment in the 10-20% range greatly improves value proposition for station deferral using energy storage
 - Both battery capacity and PCS rating are greatly reduced

Case	Energy (MW-h)*		PCS Rating (MW) **	
	No PV	20% PV	No PV	20% PV
Commercial	12.0	2.0	1.2	0.3
Residential	4.5	2.5	1.0	0.8

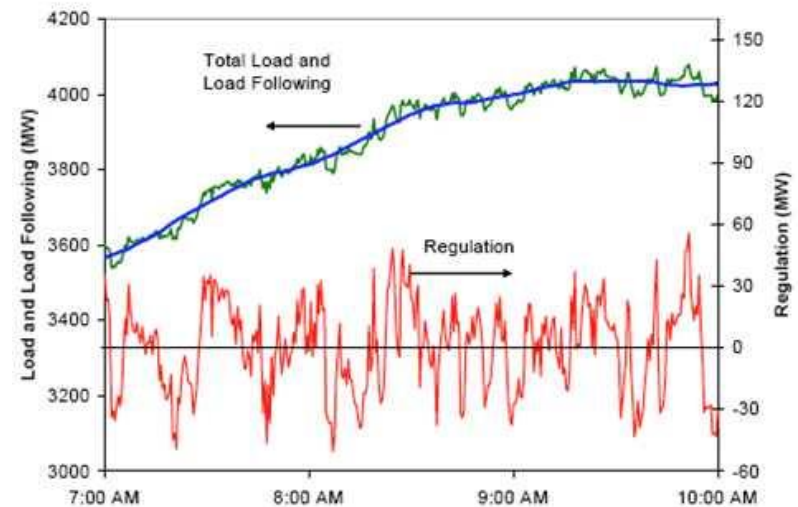
* Energy requirements shown are for a one-year deferral. Actual size of battery depends on allowable depth of discharge (DOD) and deferral years

** PCS rating is based on peak load for the study year

- Storage provides multiple other values (besides deferral)

Additional Energy Storage Benefits

- Utility/System operator
 - T&D deferral (distribution)
 - Voltage support
 - Power quality
 - Transmission congestion
 - Regulation, load following
- Customers
 - DSM (TOU, etc)
 - Power quality
 - Service Reliability (UPS)





Conclusions

- The value of PV with respect to T&D deferral is situation-specific
- Energy storage could be a cost-effective alternative to manage station overloads
 - Value proposition is best for a 1-2 year deferral
 - PV deployment (10% to 20% penetration) can greatly improve the value proposition for deferral
- Analysis shows methodology & basic concepts
- SAND Report forthcoming



Discussion of Transformer Rating and Loadability (If we have time)



Transformer Rating and Loading

- Transformer Loading

- Rating MVA is the continuous load that results in the following temperature limits:

Standard limits for transformer temperature raise	
Average winding temperature raise	65°C
Winding “hot spot” temperature raise	80°C

- Assumes ambient average ambient temperature of 30°C (86 F) and maximum temperature of 40°C (104 F)
 - Transformers can typically be loaded well above their rating without impacting operating life (30 to 50 years)
 - Load is cyclical
 - Ambient conditions vary

Transformer Rating and Loading

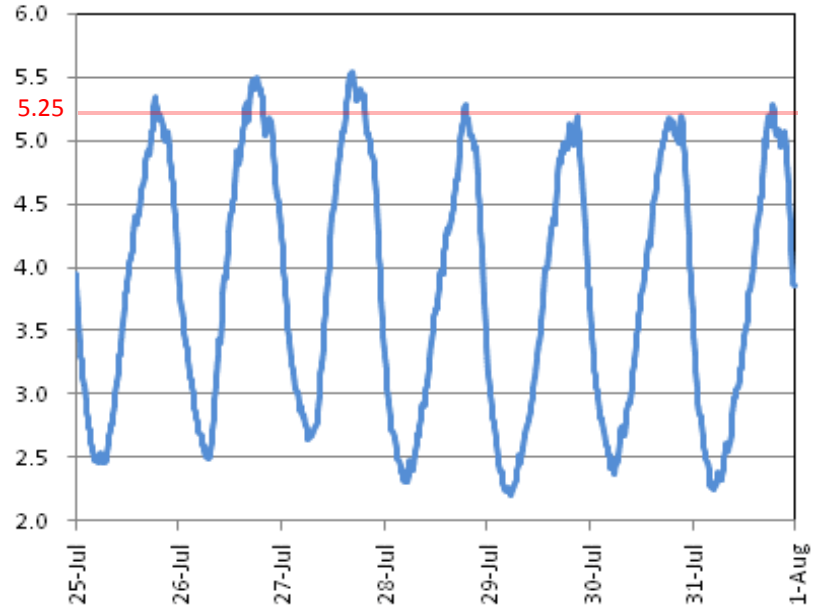
- Reasonable adjustment based on load capacity factor
 - A transformer can be loaded 0.4% to 0.5% percent above its nameplate rating for each percent by which capacity factor (load/transformer rating) averaged over any 24 hr period is below 100%, up to a maximum adjustment of 25%





Transformer Rating and Loading

- Example:
 - A transformer has nameplate rating of 5.25 MVA, load as shown on the right
 - By 5 PM on July 26, the load reached 5.25 MVA, rising
 - Capacity factor is 78% over the previous 24 hrs
 - The operator could allow up to 5.75 MVA loading (9% above nameplate rating) without loss of life

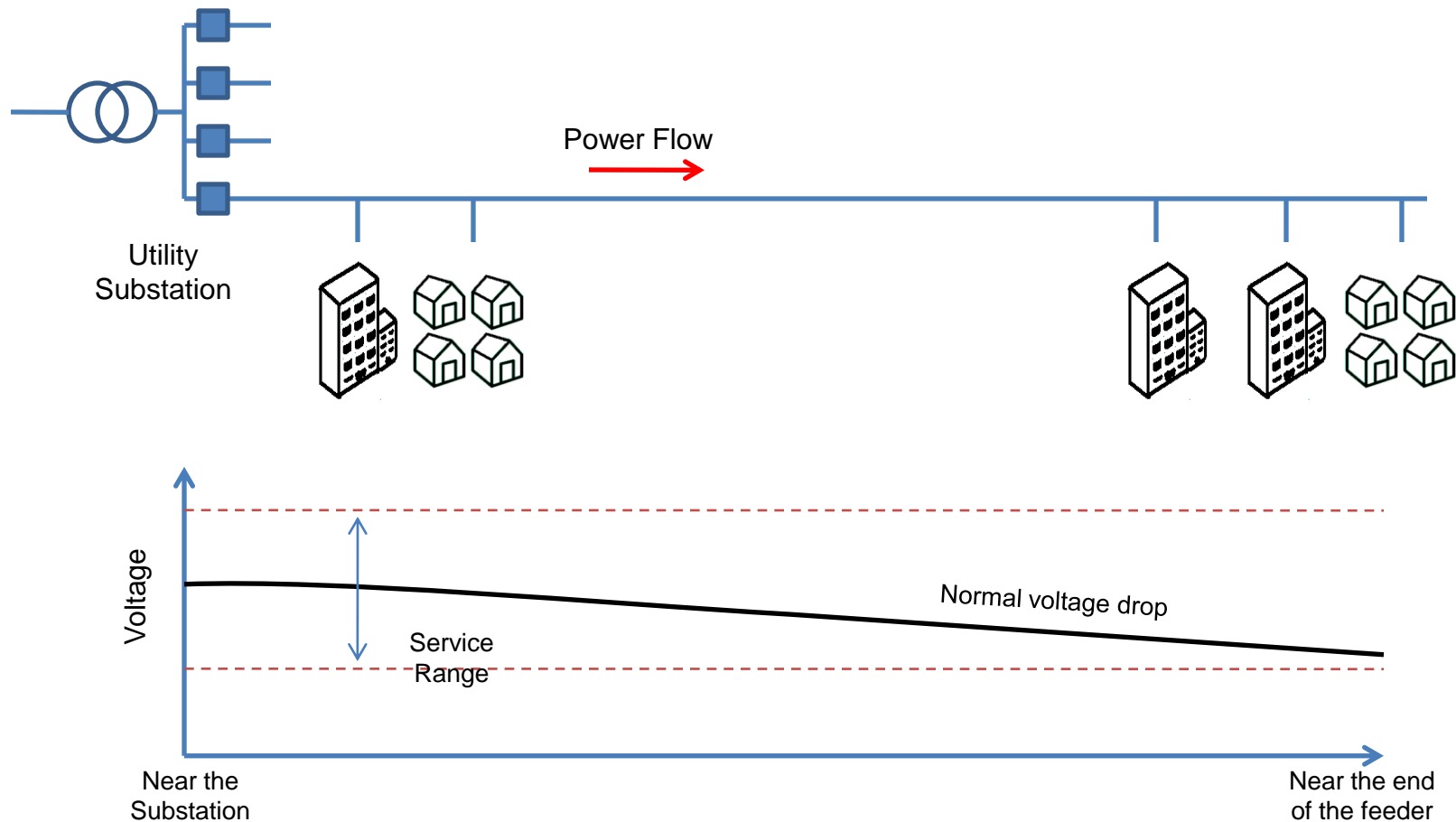




Discussion Voltage Regulation with High Penetration PV (If we have time)

Voltage Raise Issue

- Voltage along the feeder must be maintained within service limits (standards)



Voltage Raise Issue

- High amounts of PV generation (or other DG) can cause voltage to raise above service limits

