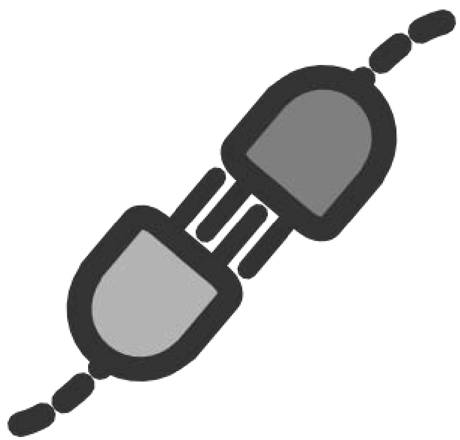
PV Impact on the Electric Grid



March 19, 2012
PJM NEMSTF

Pepco Holdings, Inc

Overview

- Three Critical Areas for Higher Penetration Solutions
- Typical Feeder with Automatic Line Equipment
- PV Issues with Different Size Systems and Potential Solutions
  - Large PV (Greater than 3 MWs)
  - Medium PV (250 kW – 3 MW)
  - Small PV (less than 250 kW)
- Utility Efforts to Accommodate PV

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3 states and Washington DC in mid-Atlantic US

pepco
A PHI Company

648 sq mi (*575 in MD)*

782,000 cust (*528,000 in MD)*

4 and 13kV distribution

delmarva power
A PHI Company

5,400 sq mi (*3,500 in MD)*

498,000 cust (*199,000 in MD)*

4, 12, 25 and 34kV distribution

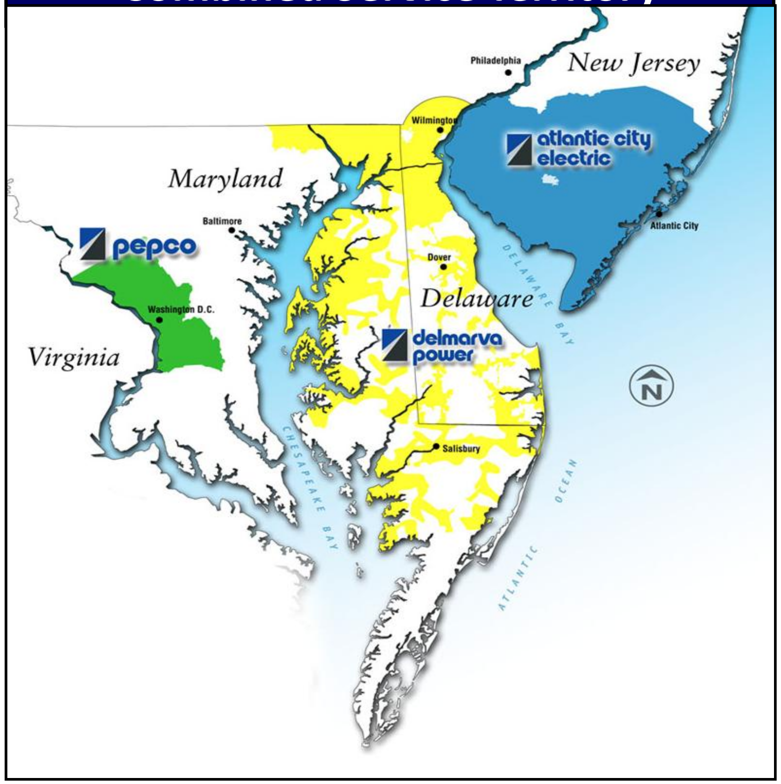
atlantic city electric
A PHI Company

2,700 sq mi

546,000 cust

4, 12, 23, and 34kV distribution

Combined Service Territory

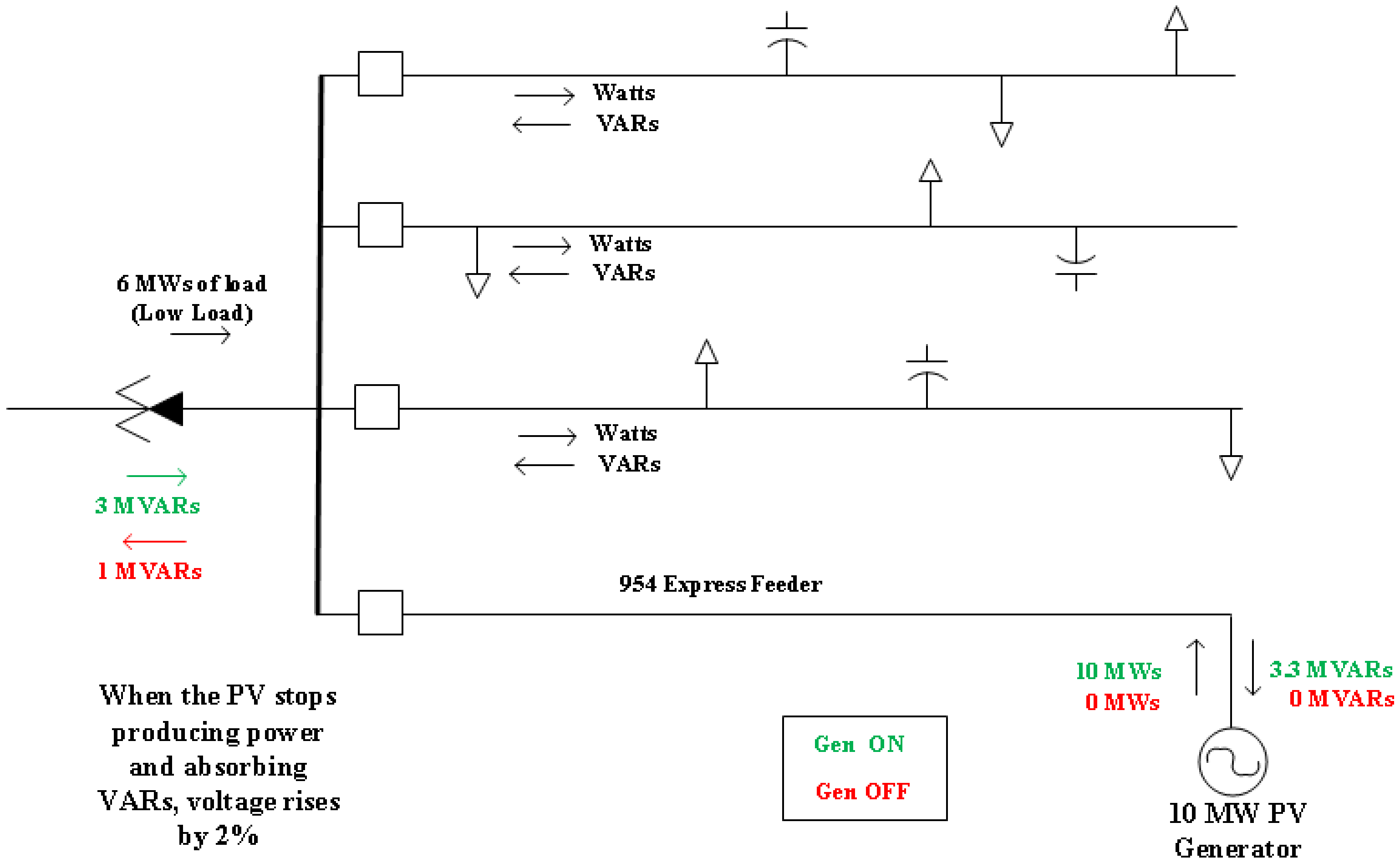


Large Solar – 3 MW to 20 MW

Potential Voltage Rise and Fluctuations

- Simulated Voltage Levels for 18 MW PV System (on 120V base)
  - System Off 124.0
  - 0.97 Leading PF 125.9 ← setting
  - Unity PF 126.8
  - 0.97 Lagging PF 127.4
- Tariff Limit: 115.2 – 124.8 V (+/- 4%)
- Feeder Voltage: 12,470 V phase to phase
- Injection to Substation: 9MWs each on 2 fdrs.
- Substation has 2 other load carrying fdrs.

Low Load Single Line

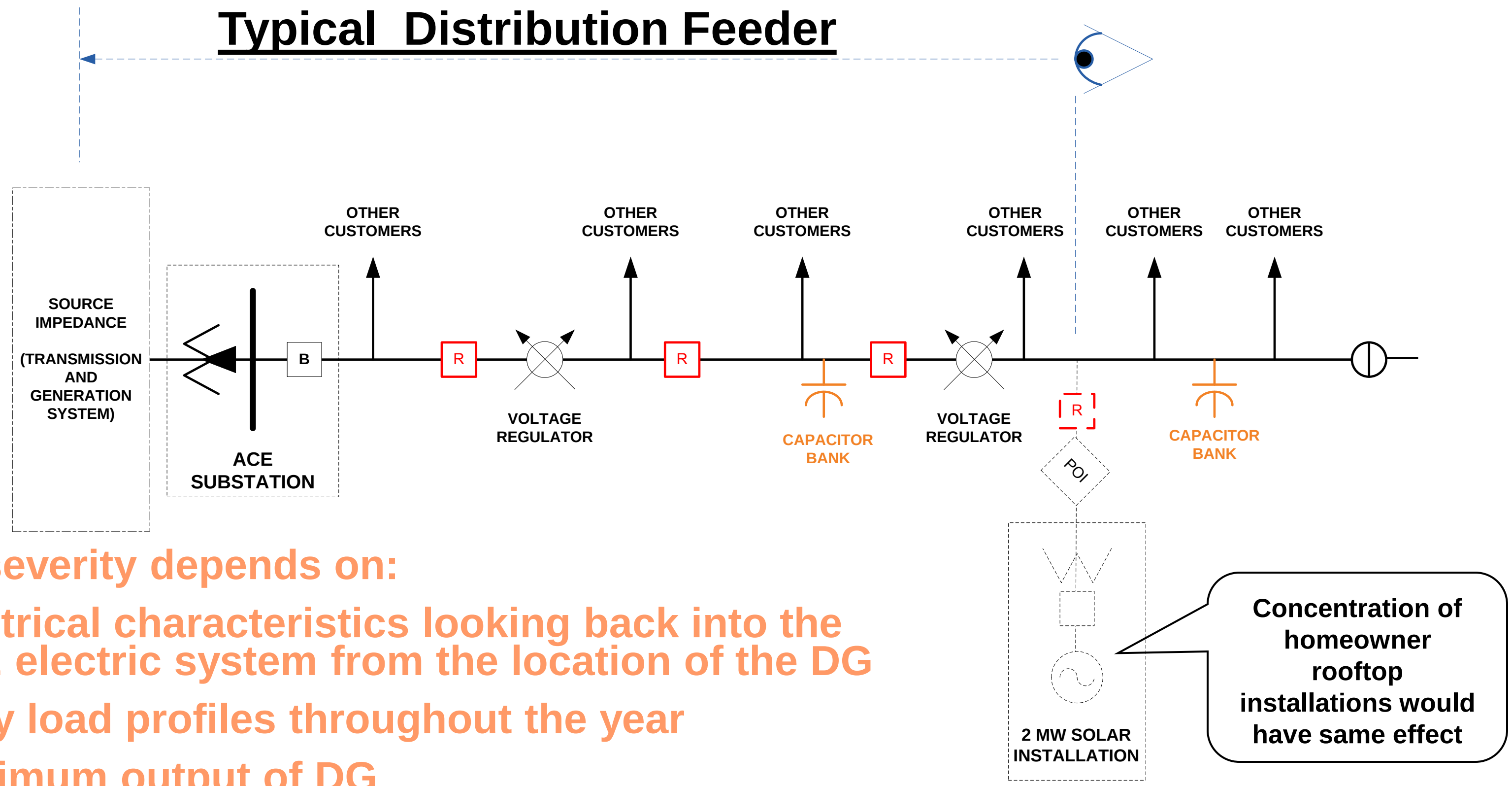


Issues and Solutions for Large Solar

- Voltage Rise or Fluctuation on express feeder - Move interconnection to higher voltage level, PF, future use of dynamic var control, limit ramp rate, curtailment, SCADA
- Voltage regulation for other feeders – smart LTC controls
- Losses – Move to higher voltage level and/or connect load to circuits
- System Stability – Low Voltage Ride Through

Medium Solar – 250 kW - 3 MW

Impacts to a Distribution Feeder

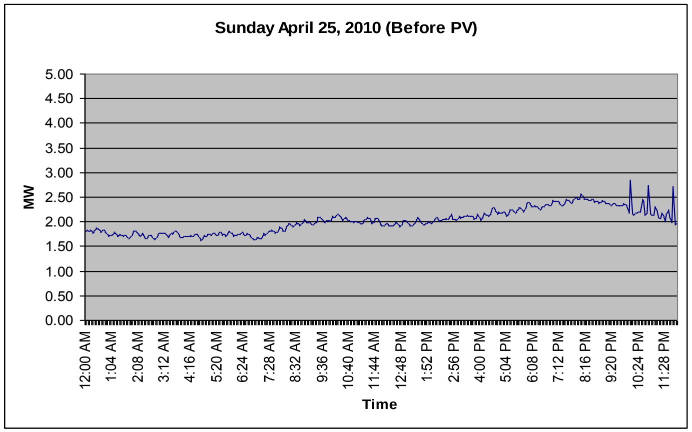


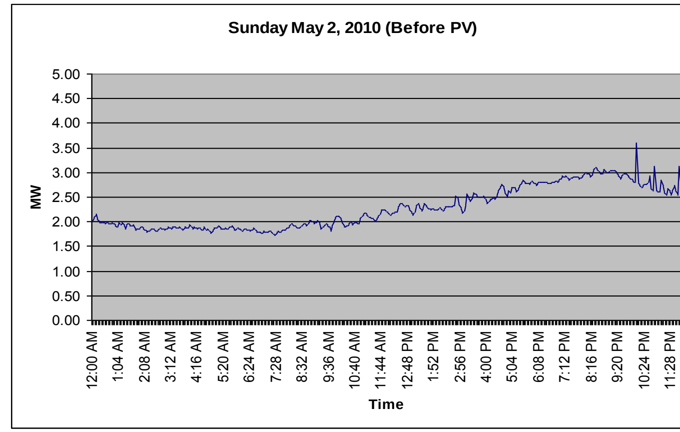
adapted from actual DG customer application

- Impact severity depends on:
  - Electrical characteristics looking back into the ACE electric system from the location of the DG
  - Daily load profiles throughout the year
  - Maximum output of DG
  - Substation transformer settings
  - Location and settings of regulators, capacitors, and reclosers

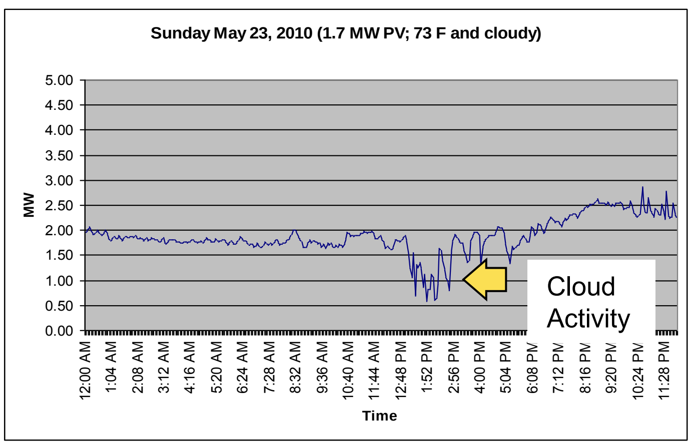
Distribution System Impacts (cont.)

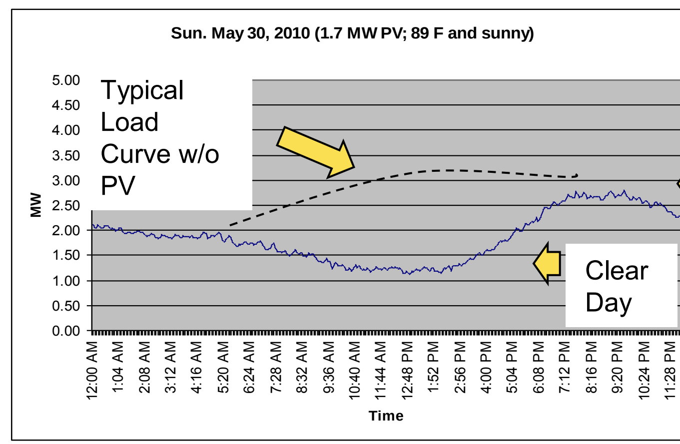
Sunday Load Profile Before and After 1.7 MW PV Installation as seen at Feeder Terminal





Industrial Load Startup

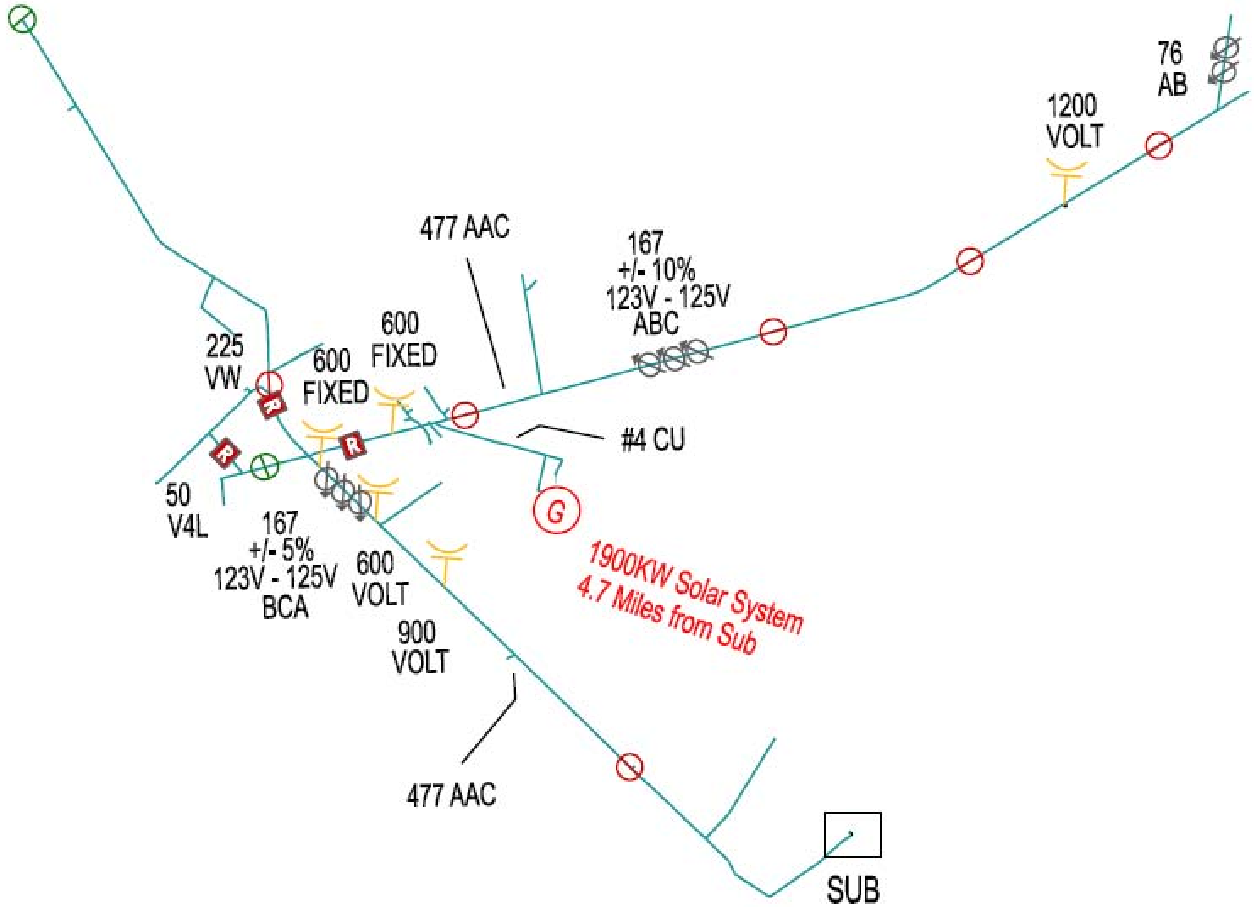




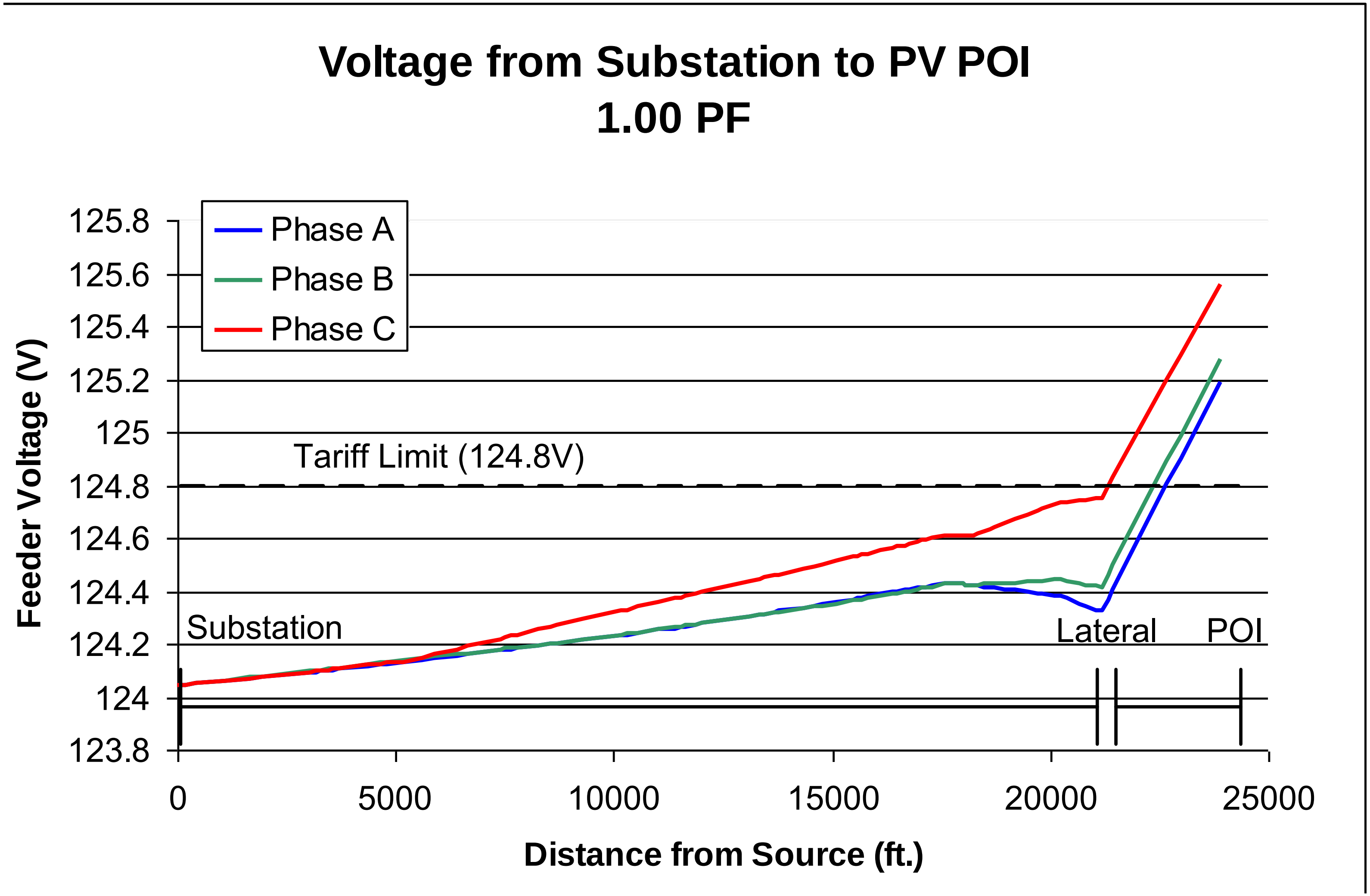
Monday Holiday

No Startup

1.9 MW PV System (Feeder Nominal Voltage: 12,470V)



1.9 MW PV System



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1.9 MW PV System – 3 Options to Mitigate Voltage Issues

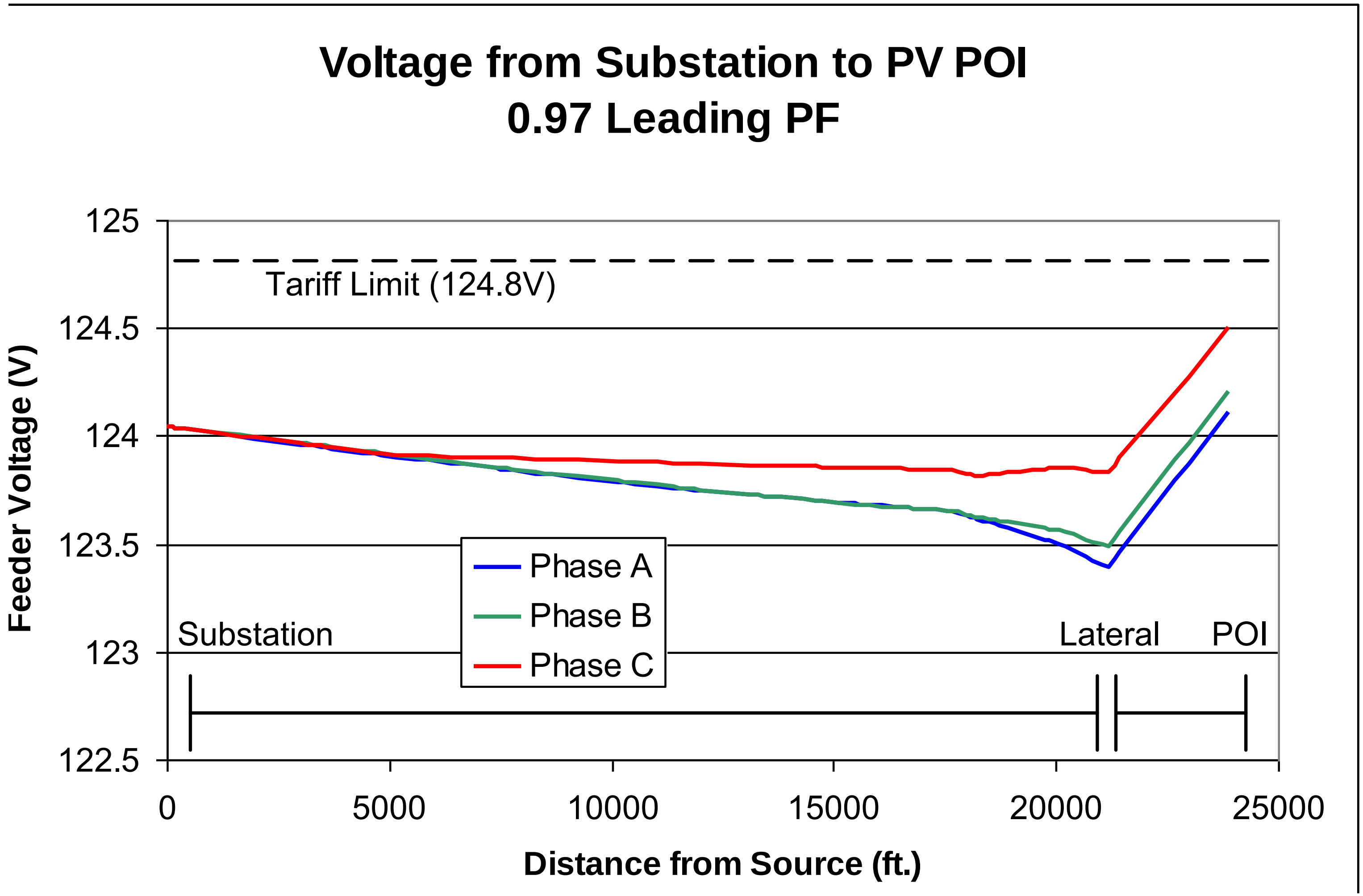
Summary Table				
	*Maximum Steady State Voltage(V)	Maximum Voltage Fluctuation at the PV site(V)	Maximum Voltage Fluctuation at the Upstream Regulator(V)	Cost
Without Mitigation	125.3	2.3	1.0	$0
Absorbing Power Factor Solution**	124.0	1.2	0.2	$2,200
500KVA/1500kWh Battery Solution	125.0	0.5	0.1	$1,115,014
750KVA/3000kWh Battery Solution	124.7	0.0	0.0	$2,189,390
477 AAC Reconductor	124.9	1.3	1.1	$266,000

*All Maximum Steady State Voltages occurred during low load,

**Absorbing Power Factor of .97 was used for this study

***The battery storage solution is unlike the other solutions and may have other operating value streams but also may have maintenance and/or replacement costs over the life of the solar system. These have not been investigated and included in this comparison.

1.9 MW PV System



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Issues and Solutions for Medium Solar

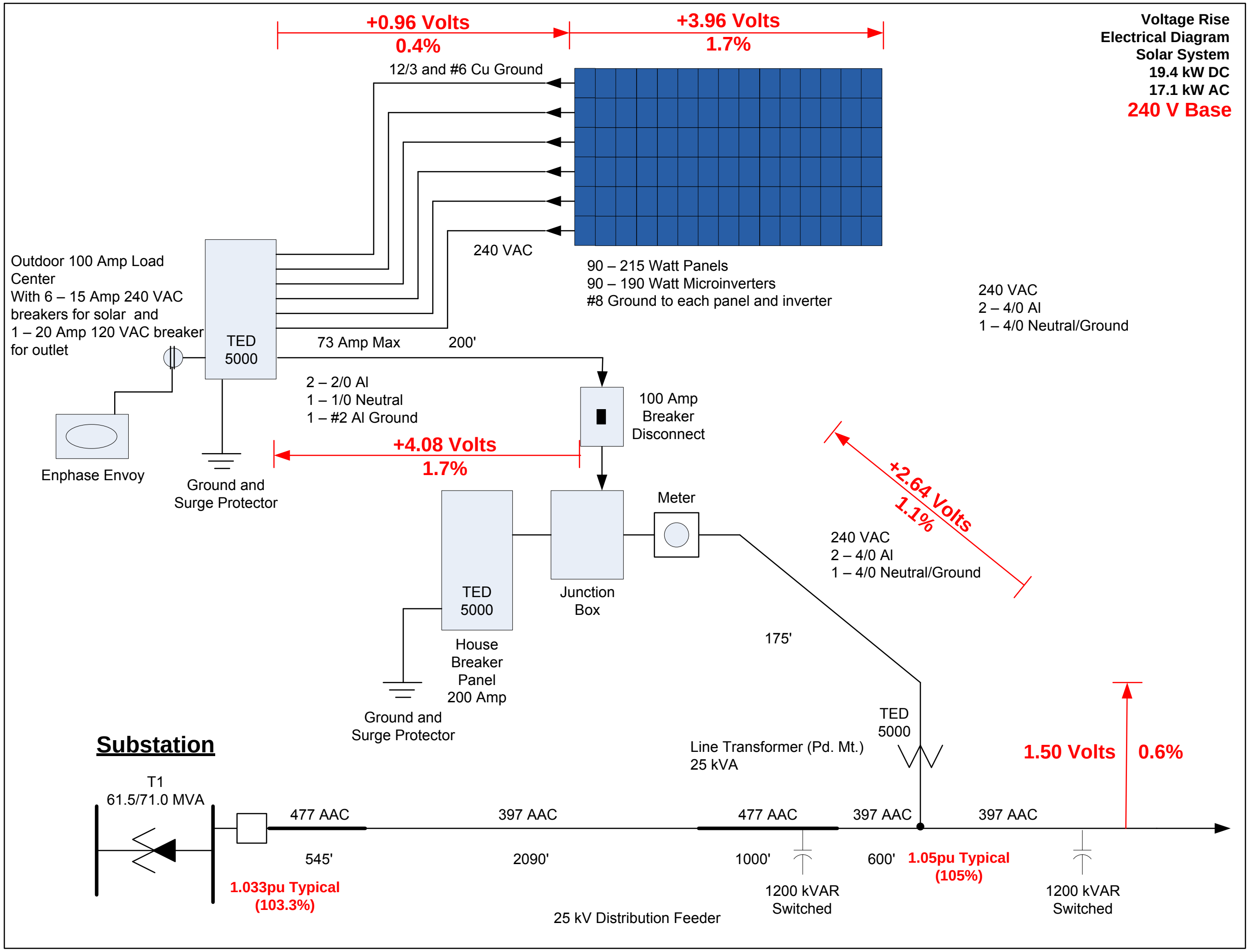
- Voltage Rise and Fluctuation, especially at greater distances from the sub – which can effect automatic line equipment and if high enough cause voltage violations for customers
  - Utilize an absorbing (leading) PF on the inverters (fixed or on a schedule)
  - Move Capacitor or Voltage Regulator further away from POI, adjust settings if necessary

Issues and Solutions for Medium Solar (cont.)

- Utilize battery storage
- Upgrade the conductor size
- Implement Advanced Feeder Management to reduce line voltage during peak solar output
- Utilize flexible load control to increase load at high solar output periods
- Utilize an SVC
- Reduce the size of the PV system

Small Solar – 250 kW or less

Voltage Rise



Voltage Rise Chart
(at max gen and no load)

Nominal Voltages: 120V or 240V

Max Voltage at Meter: 126V or 252V (per ANSI)

Electrical Segment	**Voltage Rise**		
	@ 120V	**@ 240V**	**%**
Microinverter String to End	2.0	4.0	1.7
Connection to PV Breaker Panel	0.5	1.0	0.4
Line to PV Disconnect (2/0 Al)	2.0	4.0	1.7
Sub-total	**4.5**	**9.0**	**3.8**
Service Drop	1.3	2.6	1.1
Line Transformer	0.8	1.6	0.6
Total	**6.6**	**13.2**	**5.5**

Note: The microinverter voltage measurement accuracy is +/- 2.5%

Issues and Solutions for Small Solar

- Voltage Rise - especially with small line transformer, long or small service, and with distance to the inverters – ths can cause inadvertent tripping of inverters and/or high voltage at the premise
  - Contractor or home owner should do careful voltage rise calculation – include potential voltage rise across service and transformer

Issues and Solutions for Small Solar (cont.)

- Contractor or owner review design, using larger conductor, shorter distances, etc.
- Utilize an absorbing (leading) PF on the inverters (not common for single phase inverters)
- Use Home Energy Manager to move flexible loads to high output periods
- Utility adjust settings on closest Capacitor or Voltage Regulator to reduce voltage a little at the customer meter if necessary

Issues and Solutions for Small Solar (cont.)

- Customer can utilize battery system to reduce peak output, take advantage of TOU rates (where available) and have premium power
- Use flexible load control via AMI if available
- Inverter learns and adjusts PF during certain times of day
- Utility provides setting changes via AMI (PF or VARS and active power output)

Utility Efforts to Accommodate PV

- New electric system model of both the T & D system that will run time series analysis with all renewables and other generation represented as well as load – will provide aggregate impact, large system impact studies and higher penetration studies
- Collaborative R & D on new anti-islanding scheme

Utility Efforts to Accommodate PV (cont.)

- Collaborative R & D on dynamic var control, centrally controlled vars
- Collaborative effort on collecting 1 second data from multiple points on a feeder and large PV system output to better understand impact on automatic line equipment and model penetration limit

Utility Efforts to Accommodate PV (cont.)

- Collaborative effort to verify the accuracy of atmospheric data, both historical and predicted
- Effort to utilize AMI to monitor and possibly provide control signals to small size inverters
- Reviewing Cellular SCADA for large size systems

Efforts Underway (Cont.)

- Integrating PV output data into Distributed Automation schemes
- Reviewing feasibility of a completely online and automated way for applying and approving PV systems, reprogramming the meter, then transmitting output data automatically -- for very small/low impact systems in areas with AMI.
- Advanced Volt/VAR Control

Smart Energy

- **SMART GRID**
- ISO (Independent Sys.Operator)
  - Bulk Generation
  - Bulk Transmission
    - Synchrophasors
- LDC (Local Distribution Co.)
  - Transmission
  - Substation
    - Power Transformers
  - Feeders
    - Distributed Automation
    - Conductors, ALE
    - Line Transformers
    - Advanced Fdr Mgmt
- AMI
  - Outage Mgmt
  - Load Profile Info
  - HAN (Home Area Network)
    - Price and other comm.

- **SMART INVERTER**
- Low Voltage Ride Thru
- Ramp Rate Control
- Autonomous & Centralized Control
  - -- VAR/PF Control
    - Fixed/Dynamic
    - Algorithim based
  - Curtailment
  - Remote Trip
- WITH BATTERY
  - Premium Power
  - Voltage Control
  - Frequency Regulation
  - Spinning Reserve
  - Arbitrage (TOU or Real Time Pricing)
  - Demand Side Mgmt
  - Pk Demand Mgmt.

- **SMART PREMISE**
- HEMS (Home Energy Mgmt System)
  - Pricing Signal Response
  - Peak Load Control
- DER (Distributed Energy Resource)
- Smart Thermostat
- Smart Appliances
- Smart HVAC
  - Thermal Storage
- EV
  - Controllable Charging
- Remote Access and Control
- Energy Efficiency Controls
  - Turn off Phantom Loads
  - Vacant space mgmt.
- Direct Use of DC

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Thank You!

Pepco Holdings, Inc