Pepco Holdings Inc

How Distributed Energy Resource Integration is Changing the Power Delivery Business

NARUC, DC PSC, Ukrainian Delegation

June 16, 2014

Topics

- Renewable Energy – A Paradigm Shift
- The Solar industry – a Lifecycle View
- Viability of the Solar Industry
- Current Incentives and Drivers
- Europe and California – the View Ahead
- PHI PV Stats
- PHI Processes for Handling DER Applications
- Technical Impact
  - Distribution System
    - Case Study: 1.7 MW PV system in NJ
  - Transmission System
- Financial Impact
- The Future
  - Difficulties to Overcome
  - Opportunities to Consider
  - Activities Underway
    - Advanced Modeling
    - Collaborative R and D
    - Micro Grid Studies

Renewable Energy – A Paradigm Shift

- **Federal and State**
  - Fighting global warming
  - Reducing dependency on fossil fuels
  - Improving the efficiency of the grid
  - Creating better reliability thru distributed energy resources
- **Utilities**
  - Some have bought out or are installing – NRG, Next Era, PSEG, Constellation, etc.
  - See the challenge intermittency brings
- **Customer**
  - Believes the grid is a two way street -- they can import or export power at will
  - Many do not understand their dependency on the grid, in spite of having a PV system
  - Most now believe they are providing the electric grid a favor for which they should be compensated – at least by continuing the NEM rate

The Solar industry – a Lifecycle View

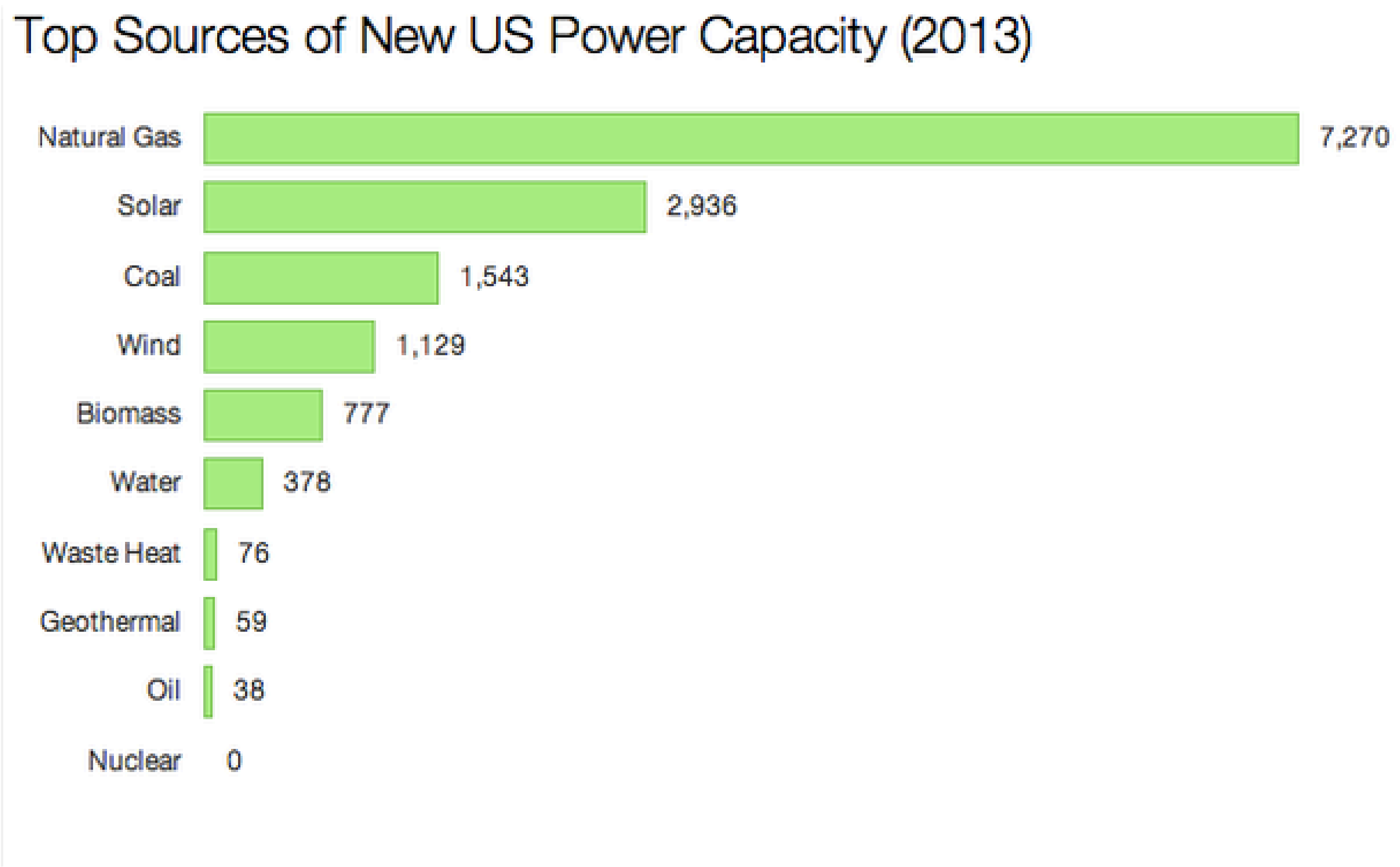
- PV effect discovered in 1876
- Bell Labs made major progress in 1950s, use in space
- It took over 50 years for PV to take off and gain widespread acceptance
- In the beginning of the commercial PV market, many innovators were trying to bring their designs and ideas to market – period starting to come to an end – but look for more bumps
- As sales volume increased and prices dropped, the number of companies decreased
- The big get bigger – First Solar, SMA, Solar City, Sun Edison
- While we saw some very publicized failures in the US, China had over 300 companies fail in the last 24 months
- The projection is for the volume to continue to grow, more vertical integration, continued consolidation of market players and product
- The lifecycle is very similar to the computer or silicon chip industry – small players will be driven out and players like Intel will win and dominate a more stable, predictable market

Viability of the Solar Industry

- The Question is: when does Solar become “Mainstream”?

- **Test 1** – Must be a primary source of new electric capacity: in 2013, Solar was the 2nd largest capacity added. Over 2,900 MWs of solar were added
- **Test 2** – Must become cost competitive w/o dependence of fickle incentives: market is very concentrated in CA, AZ, NJ, NC, MA. There are a number of industry experts predicting grid parity in a few years - -and DOE is determined to make it happen
- **Test 3** – Must be taken seriously by the electric utility industry: EEI published an article indicating that it is a disruptive technology and may be a death spiral for the utility industry. Many others have predicted industry transformation. Battles are going on in 12 states on the NEM Tariff.
- **Test 4** – Must be bankable or have affordable financing. Capital financing has now started - -first securitized packages of solar projects. Solar City has offers to homeowners for free systems.
- By 2027, GTM Research projects 160,000MWs of solar capacity or 15% of installed generation capacity. Right now solar is about 1%.

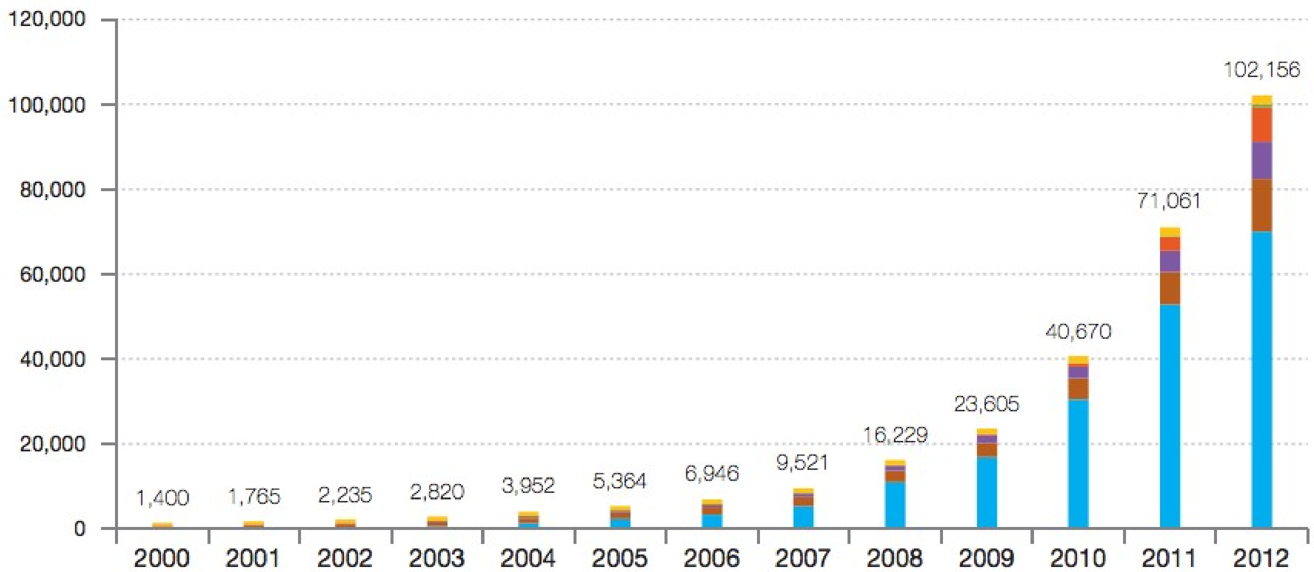
US Generation Addition in 2013



Source: FERC

Growth of Solar Worldwide

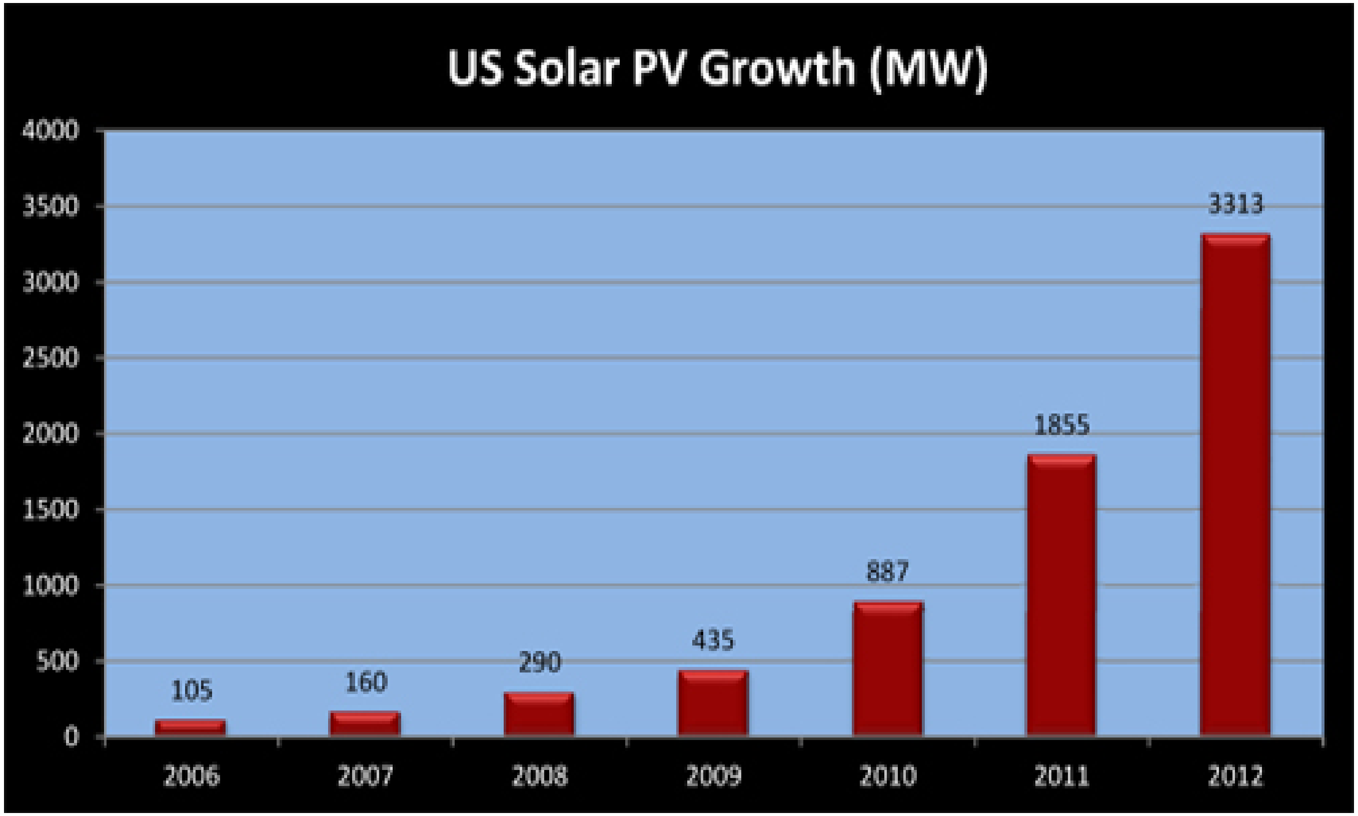
Figure 1 - Evolution of global PV cumulative installed capacity 2000-2012 (MW)



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
ROW	751	807	887	964	993	1,003	1,108	1,150	1,226	1,306	1,590	2,098	2,098
MEA	n/a	n/a	n/a	n/a	1	1	1	2	3	25	71	192	601
China	19	24	42	52	62	70	80	100	140	300	800	3,300	8,300
Americas	146	178	225	290	394	501	650	863	1,209	1,752	2,780	4,959	8,717
APAC	355	495	686	916	1,198	1,500	1,825	2,096	2,631	3,373	4,956	7,628	12,397
Europe	129	262	396	598	1,305	2,289	3,281	5,310	11,020	16,850	30,472	52,884	70,043
Total	**1,400**	**1,765**	**2,235**	**2,820**	**3,952**	**5,364**	**6,946**	**9,521**	**16,229**	**23,605**	**40,670**	**71,061**	**102,156**

ROW: Rest of the World. MEA: Middle East and Africa. APAC: Asia Pacific.

Growth of Solar in US Market

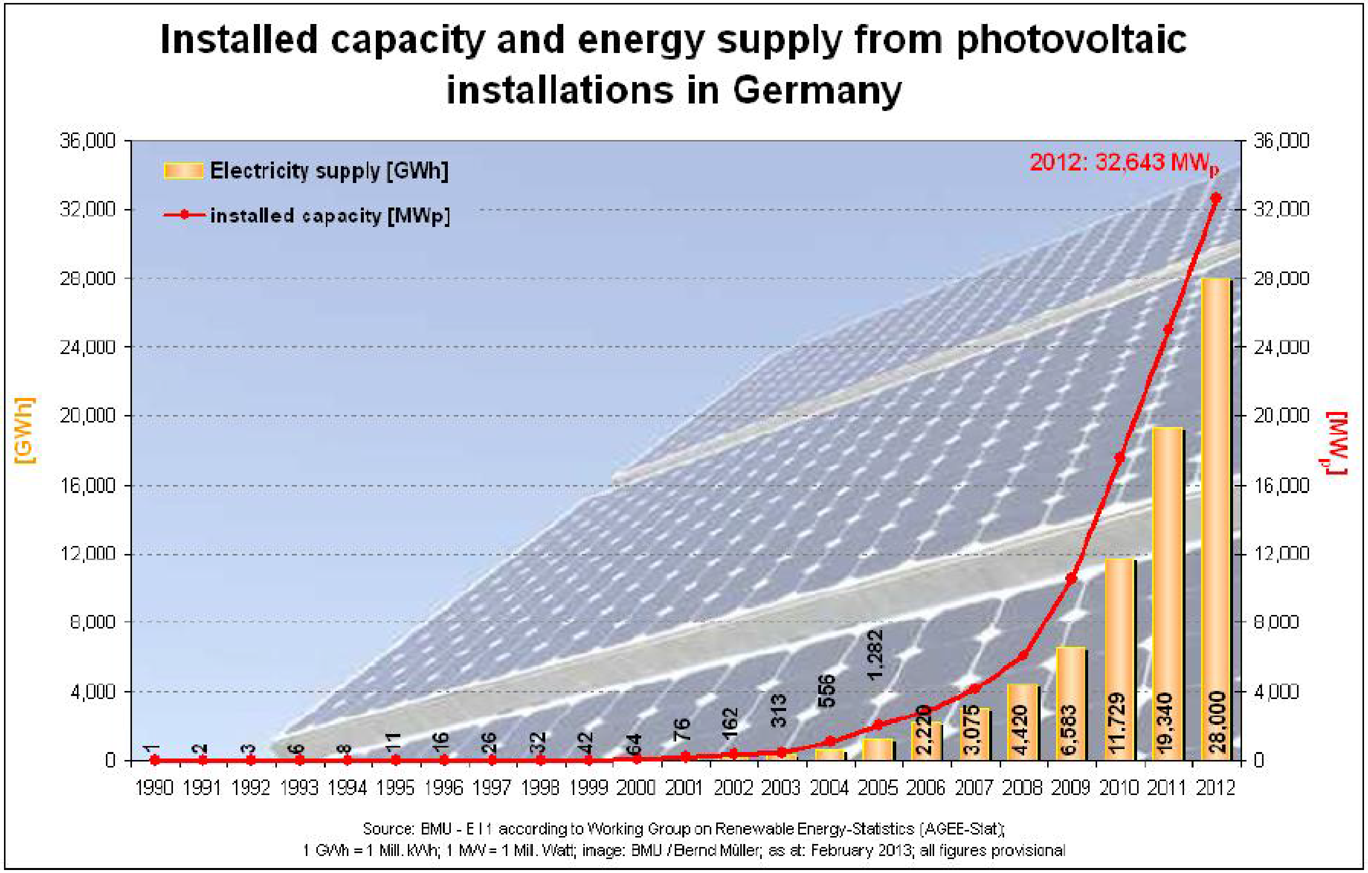


Current Incentives and Drivers

- Federal income tax credit of 30% (2006 – 2016?)
- State Renewable Portfolio Standards where Solar Renewable Energy Credits (SRECs) are offered as production credits. Some places have Feed in Tariffs (FITs).
- State rebates – are going away if not already ended in our states
- NEM Tariff -- displaces delivery revenue and commodity cost, shifts expenses for upgrading and maintaining the grid to non – PV customers

Experience in Germany – Adoption of Solar

Development of Number and Capacity of PV



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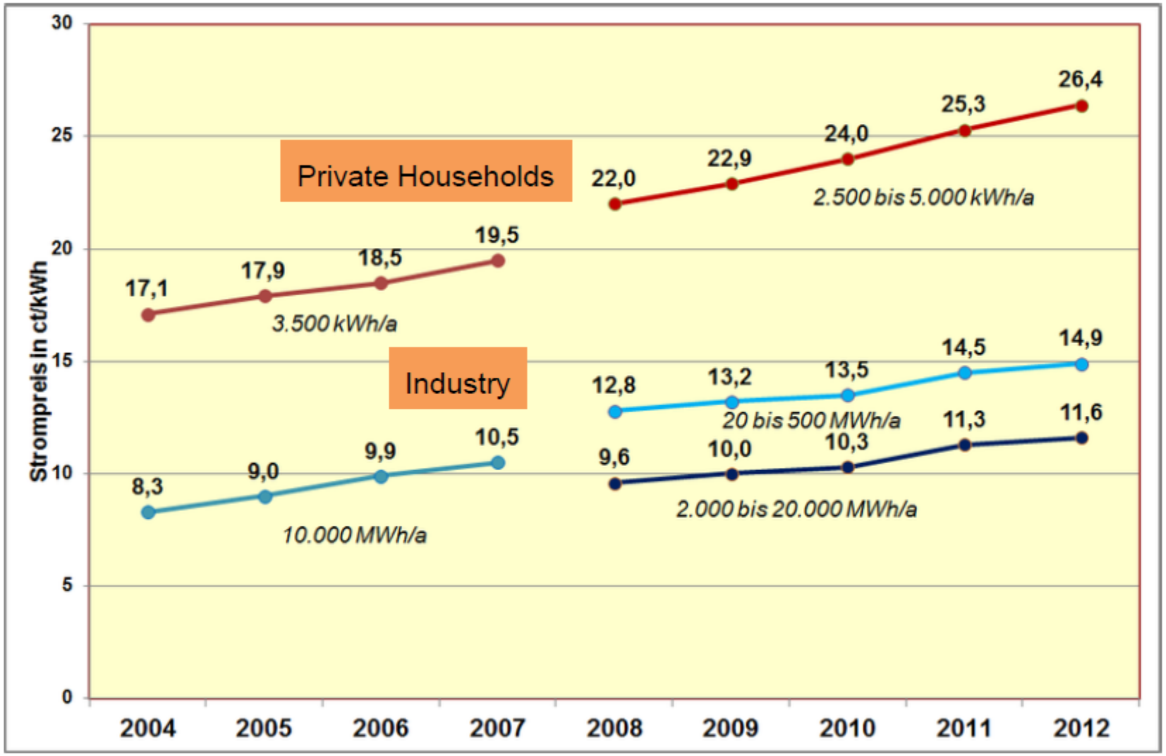
Experience in Germany – Cost of Electricity

Comparison Electricity Price for Households and Industry (ct/kWh)



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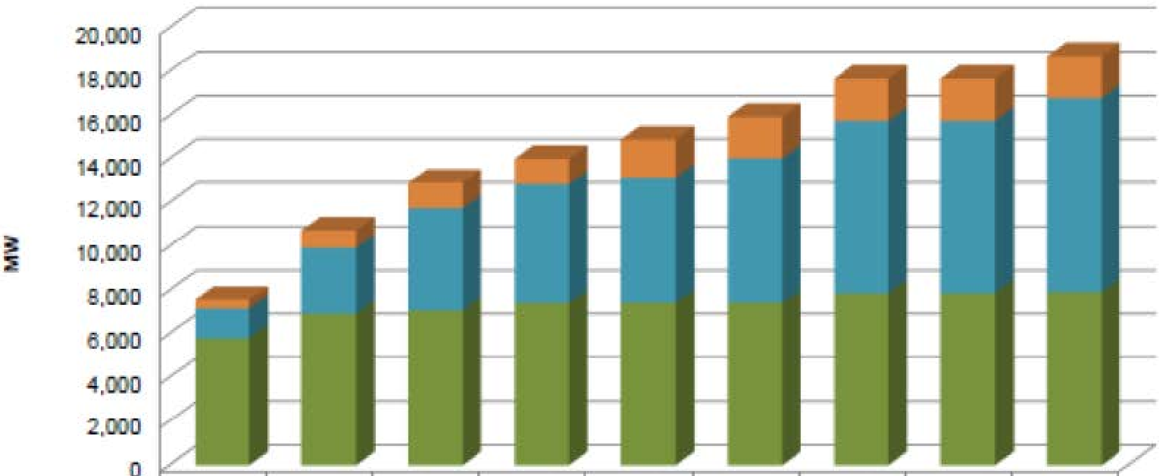
Experience in California – Adoption of Wind and Solar

California System

SDG&E connected
A Sempra Energy utility



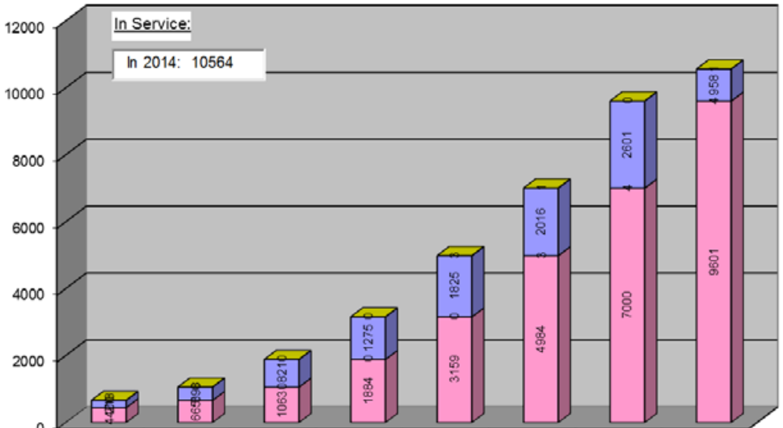
	2012 Existing	2013	2014	2015	2016	2017	2018	2019	2020
Solar Thermal	419	792	1,167	1,167	1,717	1,917	1,917	1,917	1,917
Solar PV	1,345	3,022	4,693	5,445	5,756	6,628	7,881	7,881	8,872
Wind	5,800	6,922	7,058	7,396	7,406	7,406	7,877	7,877	7,934

Figure I: California Planned VER Additions to Meet 33% Renewables Portfolio Standard (2013–2020)

2013 Special Reliability Assessment: Maintaining Bulk Power System Reliability While Integrating Variable Energy Resources – CAISO Approach, Joint NERC CAISO Report, November 2013

PHI: NEM &PJM Projects In Service (Cumulative By IS Year)

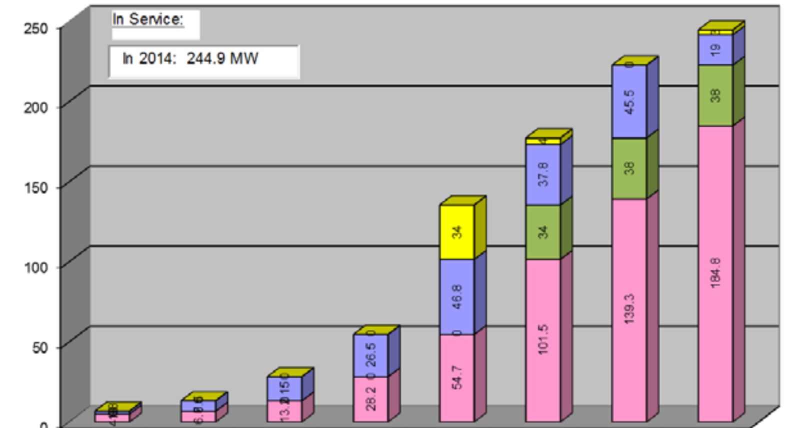
As Of: 5/1/2014



	2007	2008	2009	2010	2011	2012	2013	2014
PV-New (PJM)	0	0	0	0	3	1	0	1
PV-New (NEM)	218	398	821	1275	1825	2016	2601	958
PV-Existing (PJM)	0	0	0	0	0	3	4	4
PV-Existing (NEM)	447	665	1063	1884	3159	4984	7000	9601

PHI: NEM &PJM MW In Service (Cumulative By IS Year)

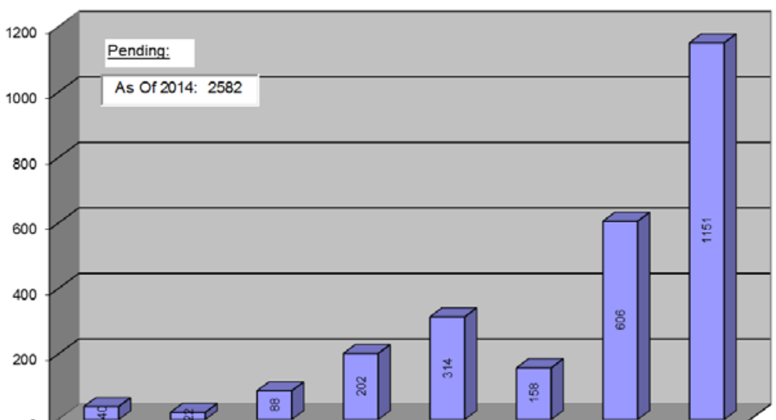
As Of: 5/1/2014



	2007	2008	2009	2010	2011	2012	2013	2014
PV-New (PJM)	0	0	0	0	34	4	0	3
PV-New (NEM)	1.8	6.5	15	26.5	46.8	37.8	45.5	19
PV-Existing (PJM)	0	0	0	0	0	34	38	38
PV-Existing (NEM)	4.9	6.7	13.2	28.2	54.7	101.5	139.3	184.8

PHI: NEM &PJM Projects Pending (By IS Year)

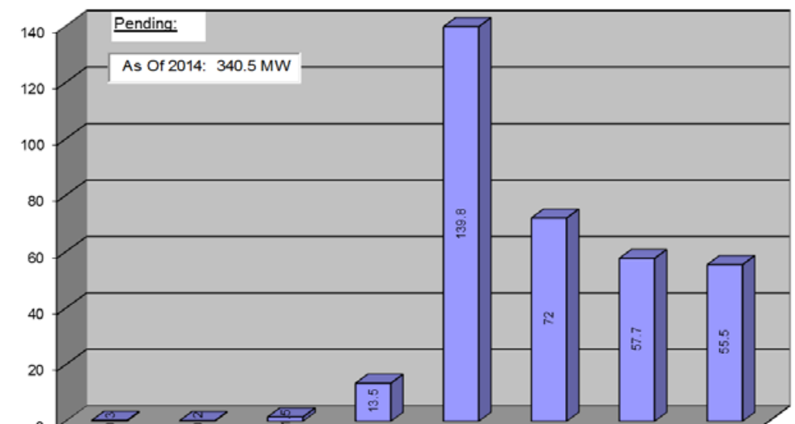
As Of: 5/1/2014



	2007	2008	2009	2010	2011	2012	2013	2014
PV-New (NEM & PJM)	40	22	88	202	314	158	606	1151

PHI: NEM &PJM MW Pending (By IS Year)

As Of: 5/1/2014



	2007	2008	2009	2010	2011	2012	2013	2014
PV-New (NEM & PJM)	0.3	0.2	1.5	13.5	139.8	72	57.7	55.5

Green Power Connection ™ Team

Brandon Bowles

Green Power Connection Team's Role

CUSTOMER ⟷

Green Power Connection Team (GPC)
Application Status
Technical
Information

"Owns the Customer Interaction"

- System Protection
- Distributed Energy Resources (DER) Planning Team
- Distribution Engineering
- Transmission Engineering
- Substation Engineering
- Project Management

Achieve PHI Key Results !

- Centralized point of contact for Net Energy Metering Projects
- Net Energy Metering Subject Matter Experts.
- Ensures compliance with jurisdictional rules/regulations
- Manages NEM project database and performance statistics
- Owns the NEM application process from end-to-end
- Resolves inquiries regarding complex interconnection requests and billing

Net Energy Metering Across PHI

	NJ	DE	MD	DC
Eligible Renewables/ Technologies	SAME: PV, Wind, Biomass, Anaerobic Digestion, Fuel Cells using Renewable Fuels NOT Same: Landfill Gas, Geothermal Electric, Solar Thermal Electric, Tidal Energy, Wave Energy,	SAME: PV, Wind, Biomass, Anaerobic Digestion, Fuel Cells NOT Same: Small Hydroelectric, Hydroelectric	SAME: PV, Wind, Biomass, Anaerobic Digestion, Fuel Cells NOT Same: CHP/Cogeneration,	SAME: PV, Wind, Biomass, Anaerobic Digestion, Fuel Cells NOT Same: Small Hydroelectric, Tidal Energy, Micro turbines, Hydroelectric, CHP, Solar Thermal Electric, Geothermal Electric
Applicable Sectors	Commercial, Industrial, Residential, Nonprofit, Schools, Local Govt., State Govt., Tribal Govt., Federal Govt., Agricultural, Institutional	Commercial, Industrial, Residential, Nonprofit, Schools, Local Govt., State Govt., Fed. Govt., Agricultural, Institutional	Commercial, Industrial, Residential, Nonprofit, Schools, Local Govt., State Govt., Fed. Govt., Agricultural, Institutional	Commercial, Residential
System Capacity Limit	No Limit	2 MW for non-residential 25 kW for all res. customers; 100kW for agriculture	2 MW generally, except 30 kW for micro-CHP	1 MW
% of Annual Consumption	100% Is intended primarily to offset all or part of the customer's own electricity requirements.	110%	200%	100% Is intended primarily to offset all or part of the customer's own electricity requirements.
Net Excess Generation	Generally credited to customer's next bill at retail rate; excess reconciled annually at avoided-cost rate	Credited to customer's next bill at retail rate. After 12-month cycle, customer may opt to roll over credit indefinitely or to receive payment for credit at the energy supply rate.	Generally credited to customer's next bill at retail rate;* reconciled annually in April at the commodity energy supply rate	Credited to customer's next bill indefinitely at retail rate for systems 100 kW or less, and at avoided-cost rate for larger systems

Green Power Connection Team - Present Process

GPC: Receives customers' interconnection requests, processes applications, and manages the overall customer experience

CUSTOMER

- Completes research
- Elects to install renewable energy generator
- Enters into installation contract with contractor
- Applicant submits Interconnection Application (Part 1) & Agreement to Company

COMPANY

- Acknowledges receipt of completed application within required timeframe
- Notifies customer of results of internal review
- Works with applicant to fulfill requirements for interconnection
- Provides applicant Approval to Install renewable energy generator

CUSTOMER

- Completes renewable energy generator installation
- Requests Local (County) electrical Inspection
- Submits Certificate of Completion Form & copy of local electrical inspection certificate to Company

COMPANY

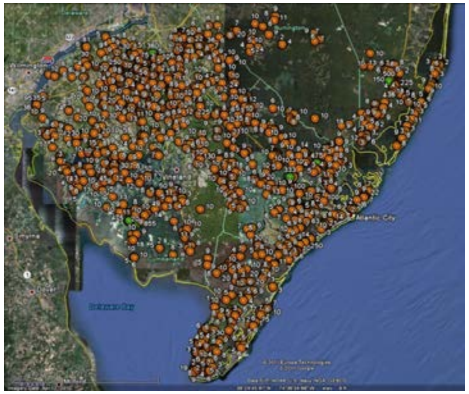
- Acknowledges receipt of Certificate of Completion & electrical inspection approval
- GPC Team sends Contractor & Customer notice that application has been sent to metering department for meter exchange
- Net-Capable meter will be installed
- GPC Team sends Contractor & Customer Final Written Approval to Interconnect/Operate

NEM Snapshot

Brand	Approved for Operation	Pending PHI Approval to Install	Pending Customer Install	Pending Final Approval to Operate
Atlantic City Electric	5,588	114	1,183	58
Delmarva Power	1,819	40	337	13
Pepco	3,001	68	486	62
Total	10,408	222	2,006	133

As of 2/28/13

Active NEM Customers



Successfully completed over 10,000 customer NEM interconnection request with greater than 99% acceptance

Green Power Connection™ Contacts

	Pepco	Atlantic City Electric & Delmarva Power
Email:	gpc-south@pepco.com	gpc-north@pepcoholdings.com
Telephone:	(202) 872-3419	(866) 634-5571
Fax:	(202) 872-3228	(856) 351-7523
Mail:	GPC – South Mail Stop 7642 701 9th St NW Washington DC 20068	GPC – North MS 84CP22 5 Collins Drive Carney's Point NJ 0**8063**

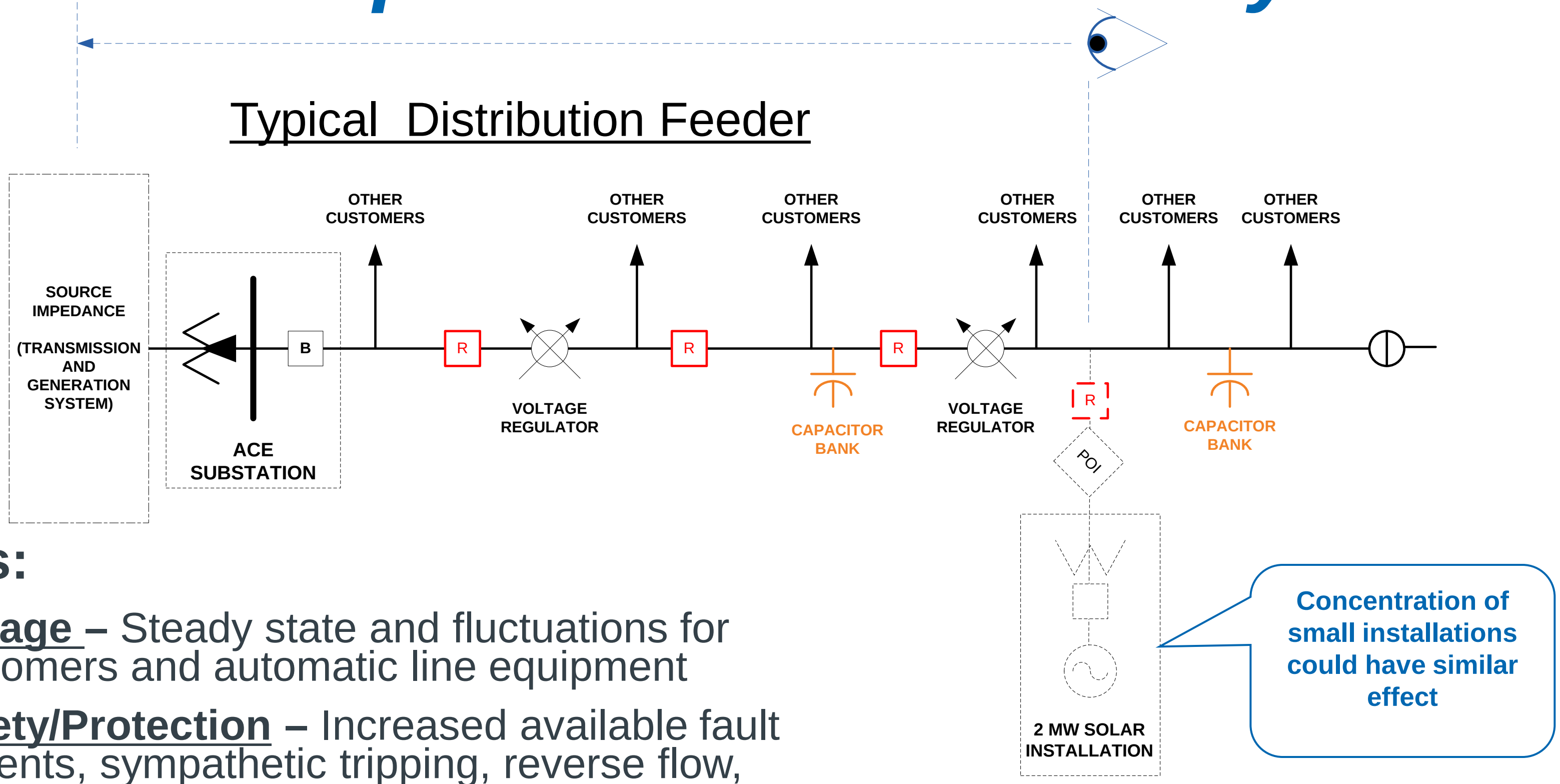
Lead Consultants:

Lisa Bladen (Pepco) — Joshua Cadoret (ACE/DPL)

Supervisor: Brandon Bowles (PHI)

Technical Impacts

Technical Impacts – Distribution System

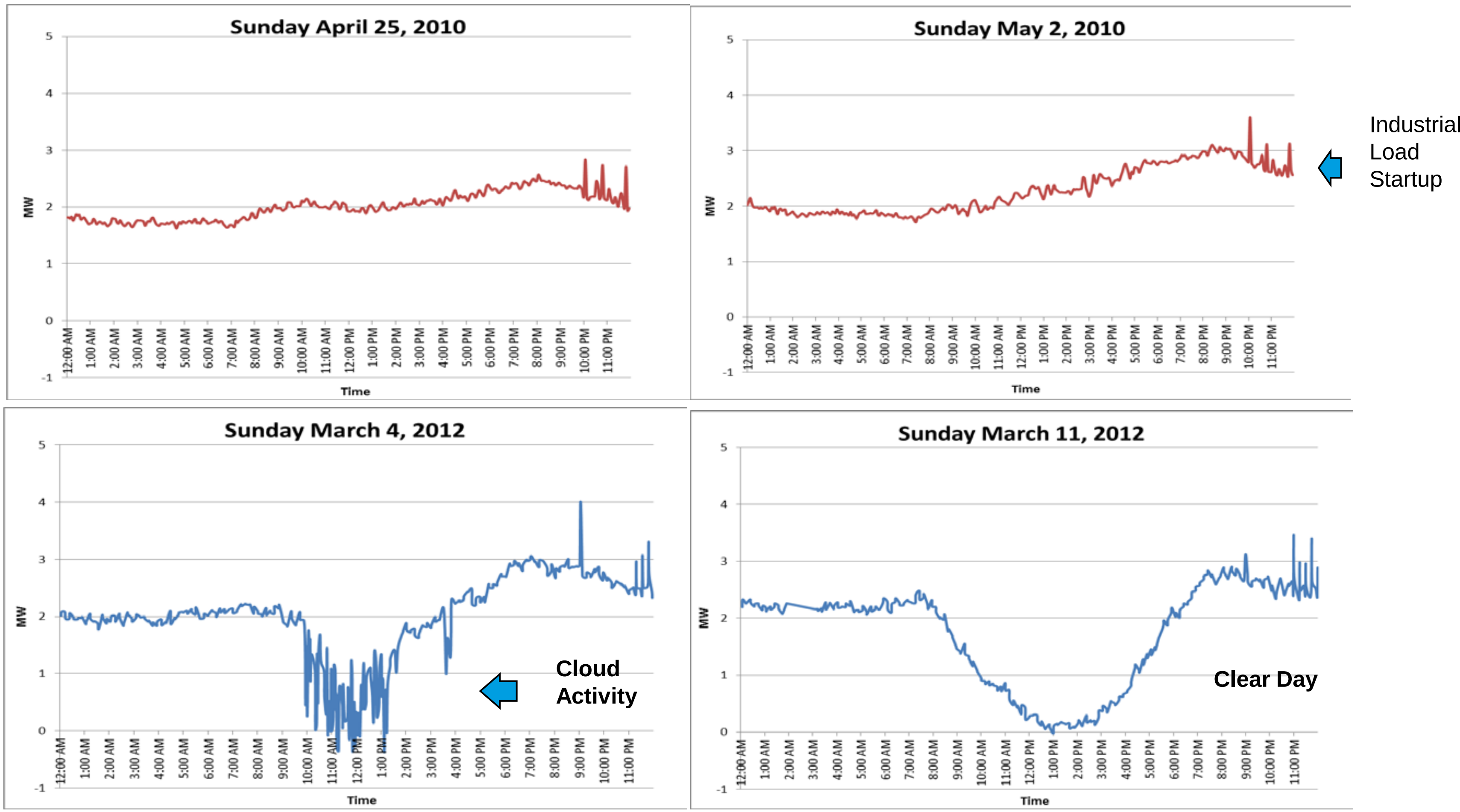


Impacts:

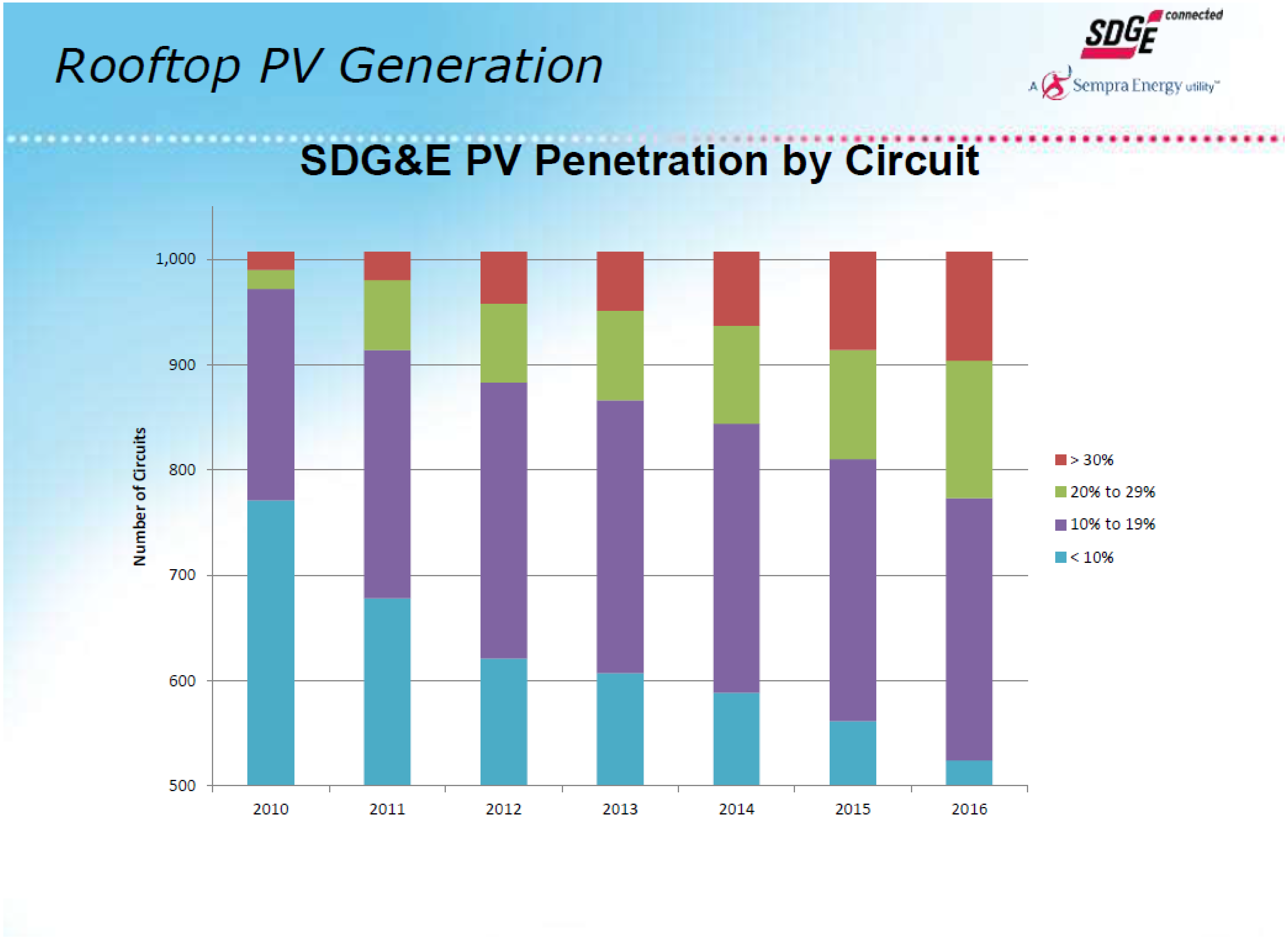
- **Voltage –** Steady state and fluctuations for customers and automatic line equipment
- **Safety/Protection –** Increased available fault currents, sympathetic tripping, reverse flow, reduction of protective reach
- **Loading –** Increases in unbalance, masking of demand, capacity overloads
- **Control Equipment –** potential for increased operations for voltage regulators, capacitors and under load tap changers
- **Power Quality –** potential for harmonic issues

Feeder Load Profile – Before & After PV

(Two PV systems 1.7 & 1.3 MWs)



Circuit Penetration

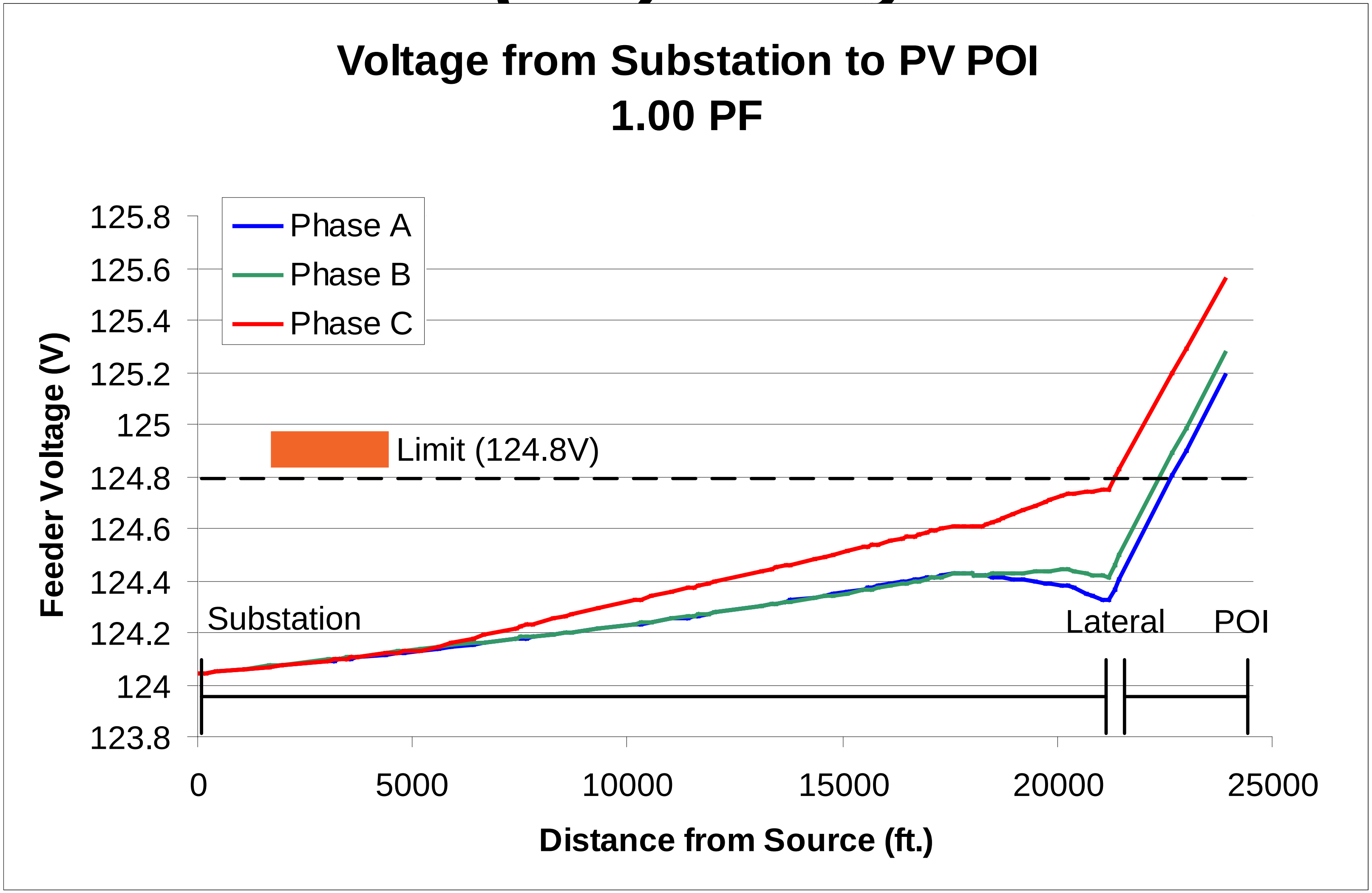


Pre-Screens, Screens, Study Requirements

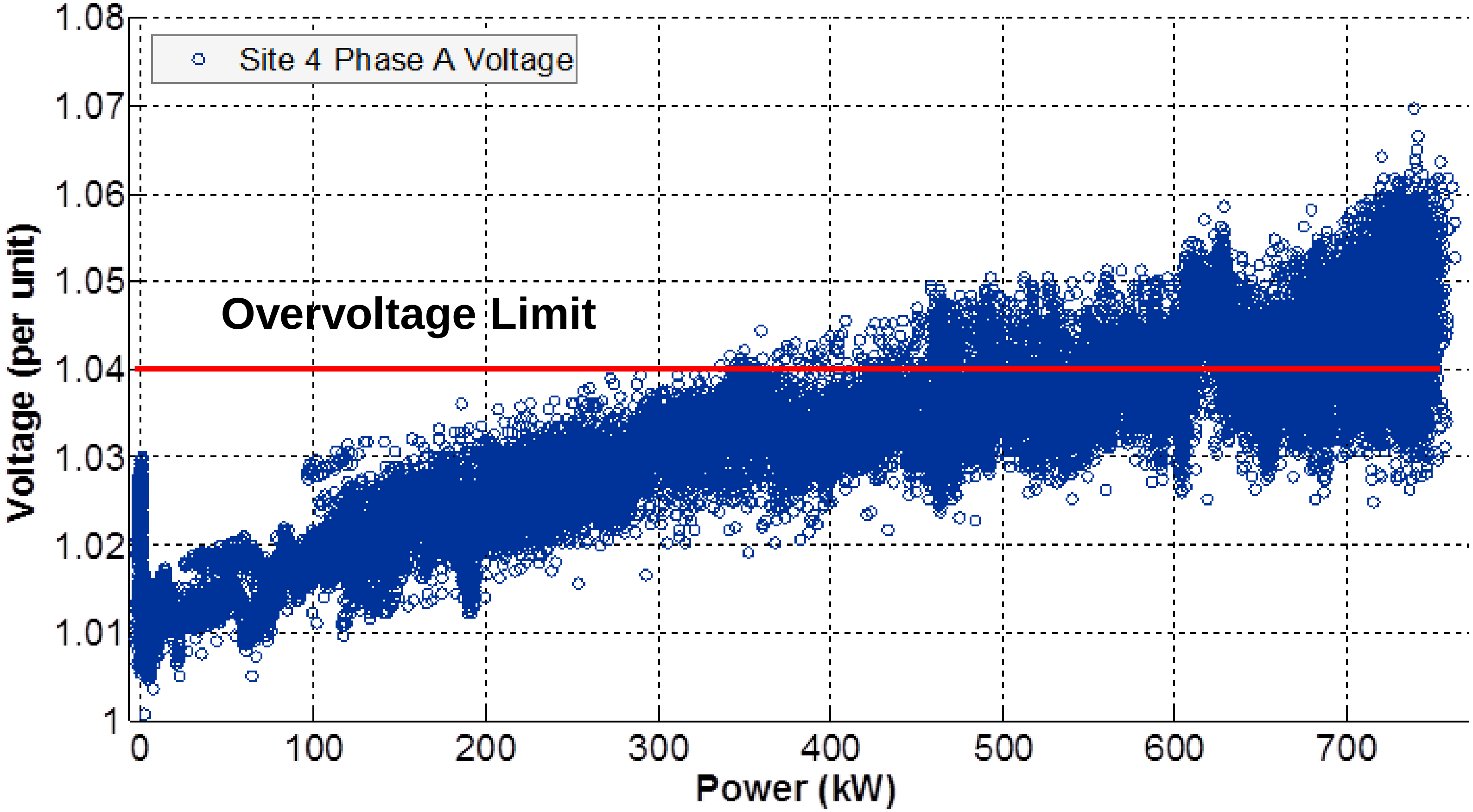
- Size range and requirements for a Pre-Screen (or very high level review): 50-250 kW
  - Insures systems at the end of rural feeders won't cause a problem (ie 100kW farm system on single phase lateral was identified as potentially adverse)
- Size range and requirements for a Screen (or static level load flow review): over 250kW
  - Determines if a larger system will have an impact requiring a more detailed study

- NOTE: Doing the load flows with all active and pending PV mapped onto the circuit and occasional aggregate analysis will catch areas that may become a voltage problem due to concentrations of small units.

1.7 MW (AC) PV System

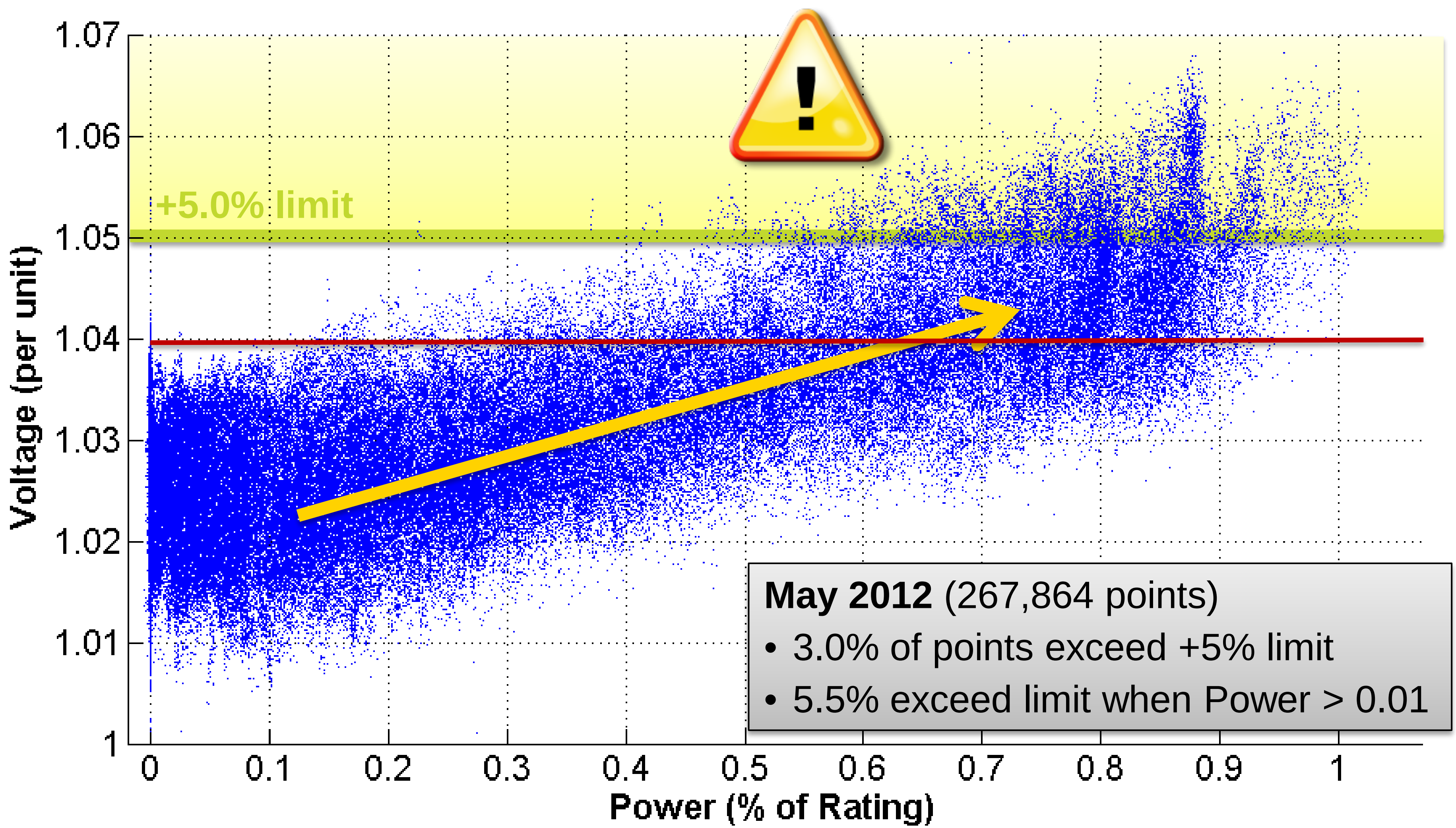


Overvoltage at a Group of Inverters

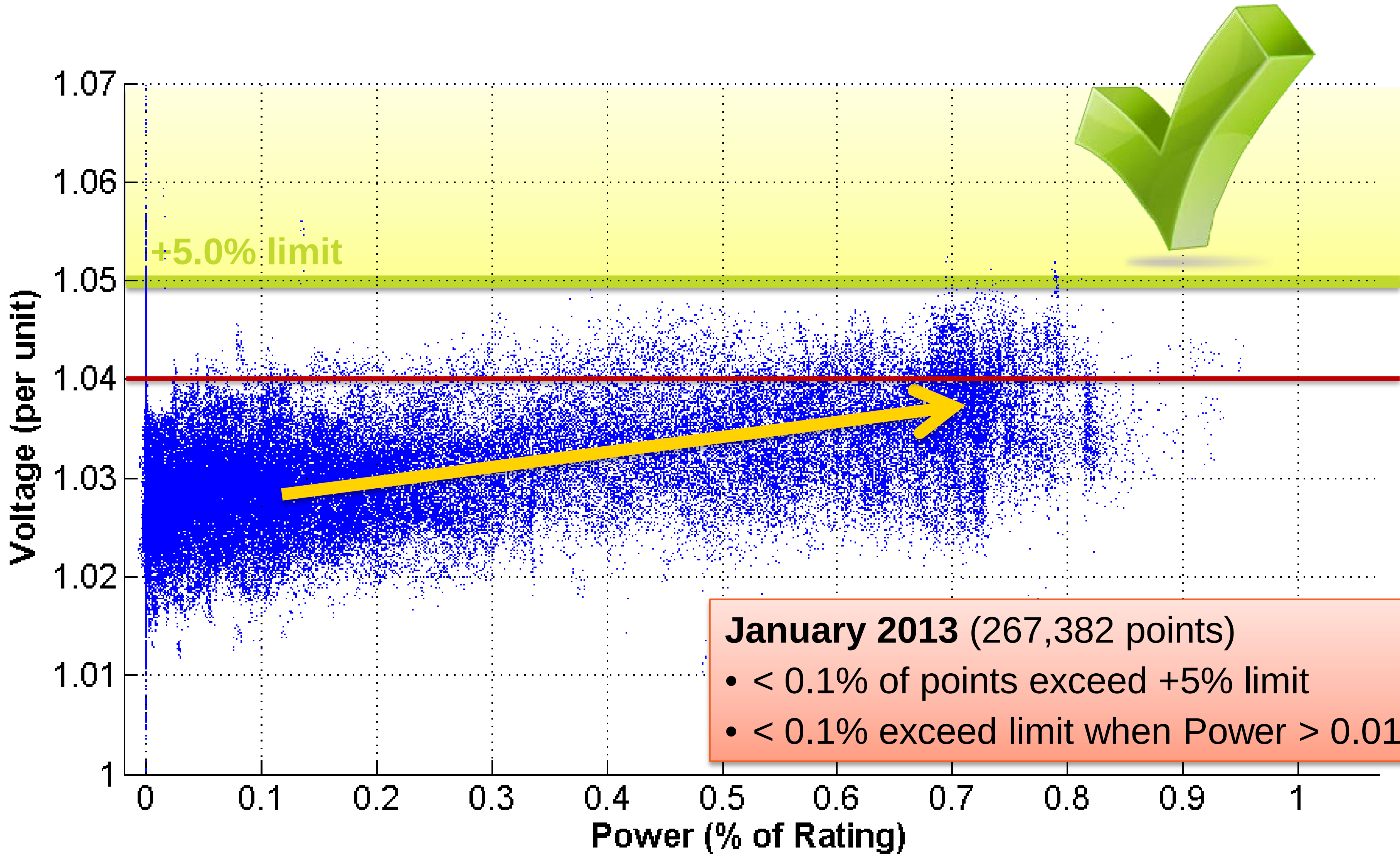


Source: EPRI Monitoring

Power Factor Set Incorrectly



Much Better: Power Factor Readjusted



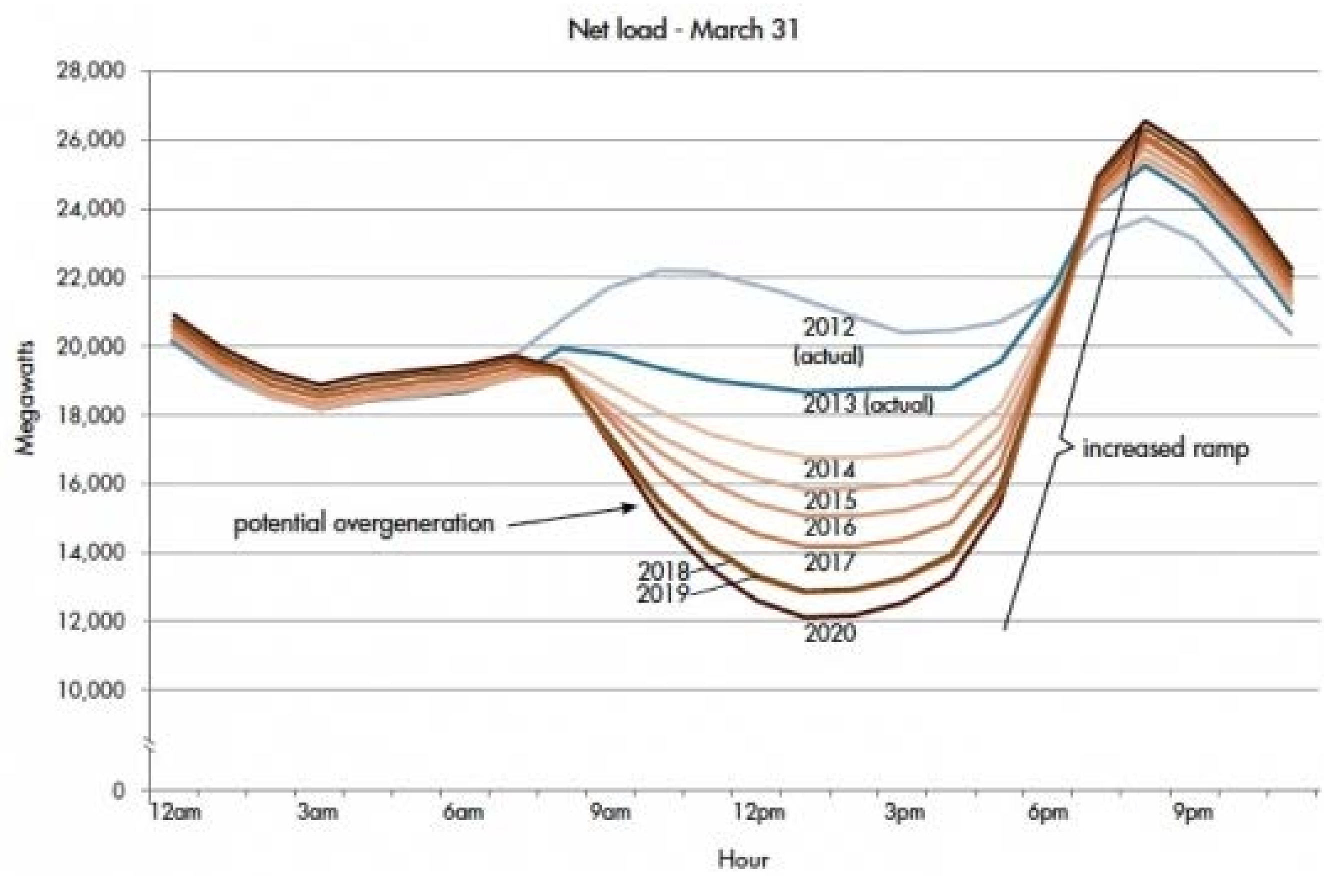
January 2013 (267,382 points)

- < 0.1% of points exceed +5% limit
- < 0.1% exceed limit when Power > 0.01

Technical Impact -- Transmission System

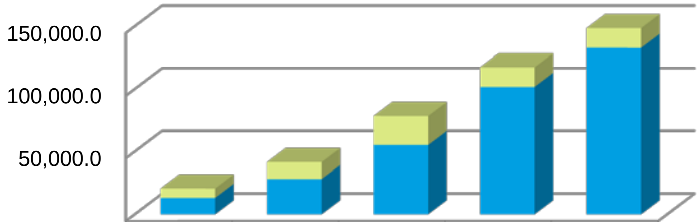
- The transmission system impact is still limited at this time in the PJM area due to the limited amount of intermittent resources -- wind and solar.
- In Europe, there have been some incidents with the transmission system because of the penetration levels – spurring action here in the US to avoid similar problems.
- Hawaii has small island loads and hence, the penetration already swings their frequency and effects the stability of the transmission system
- California anticipates large swings in balancing load with generation due to the solar output profile and load – called the duck curve

California's Future Ramp Rate Issue



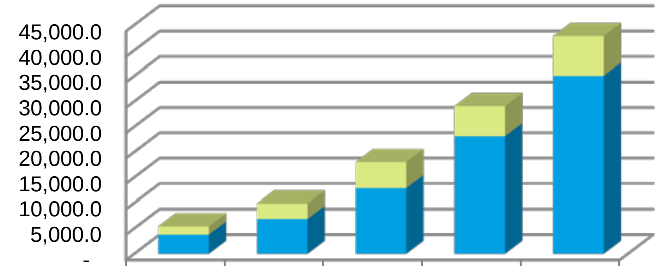
Financial Impact

ACE - Estimated MWHrs (NEM) Solar Output 2009-2013



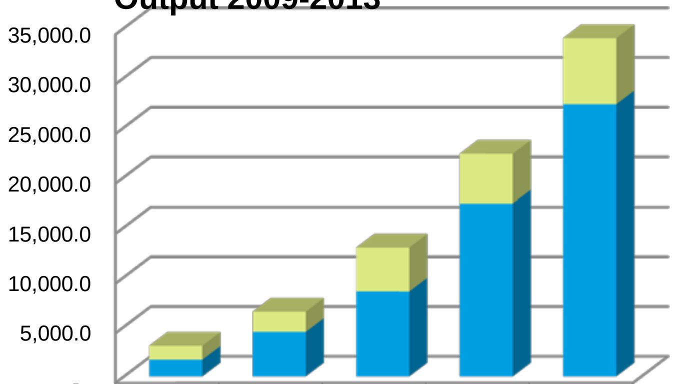
	2009	2010	2011	2012	2013
ACE-NEM NEW	7,498.6	13,525.	23,266.	15,557.	15,697.
ACE-NEM EXISTING	13,175.	28,172.	55,223.	101,756	132,871

DPL - Estimated MWHrs (NEM) Solar Output 2009-2013



	2009	2010	2011	2012	2013
DPL-NEM NEW	1,611.8	3,013.4	5,115.8	5,956.8	7,778.9
DPL-NEM EXISTING	3,784.3	6,867.8	12,894.7	23,126.4	35,040.0

Pepco - Estimated MWHrs (NEM) Solar Output 2009-2013



	2009	2010	2011	2012	2013
Pepco-NEM NEW	1,401.6	2,032.3	4,415.0	4,975.7	6,657.6
Pepco-NEM EXISTING	1,681.9	4,485.1	8,549.8	17,379.8	27,331.2

Based on 2013 Stats

- PV displaces delivered energy, and hence energy and delivery revenue
- At 14 cents per kWH, it would have resulted in 195,000,000 kWHrs or about $27,000,000 in total retail sales
- Approximate delivery loss @30% of bill = $8,100,000/yr increasing by $1 to 1.5 million/yr

The Future - Difficulties to Overcome

- Utilities may need a new financial construct – NEM Tariff, possibilities of reduced thruput (DERS, energy efficiency)
- The T & D system will likely encounter reduced stability, PQ issues and voltage issues
- To address the above issues, the distribution system will require increased monitoring and control along with expanded secure communications
- New equipment such as battery storage, and various new power electronic (dynamic) devices will be needed
- This will create big or even bigger data to properly control the distribution system and integrate commands from the transmission and bulk system operator
- Customers may eventually need a new economic system that may need to be managed by the utility

The Future – Opportunities to Consider

- Grid and DER Management
  - Added Field and Central Control Equipment going into Rate Base
- Central management of customer DERs to maximize their economic benefit
- Utility owned Solar or Community Solar, Wind, CHP
- Utility owned Battery systems, ancillary services
- Utility owned/operated micro grids

Activities Underway

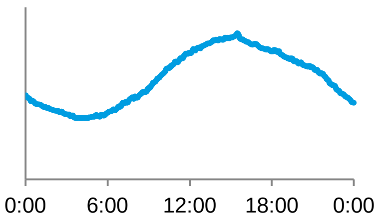
- Green Power Connection Team and Distributed Energy Resources Planning and Analytics formed
- Processes put in place to streamline customer applications
- Engaging FERC, State public officials, DOE and other industry groups to represent PHI interests
- Advanced load flow being implemented
- Collaborative R & D – Inverter technology, advanced voltage regulation control, penetration studies
- Micro grids – Technical and financial analysis

Why Pursue Advanced Modeling

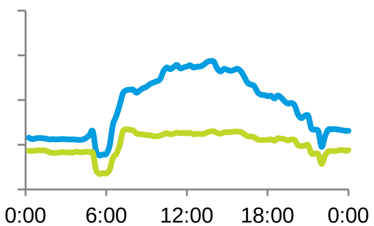
- Significant increase in DERs - aggregate impact must be assessed
- Masking/uncertainty of feeder peak load, need PV forecast
- Requires an automated mapping of DERs into the load flow model
- Many detailed studies require time series analysis
- Impacts on load tap changers, voltage regulators and switched cap banks must be checked
- Many applications - need for semi-automated impact assessment
- Impacts on protection must be checked
- Makes planning and operation of automatic sectionalizing and restoration schemes much more complex
- Some DER output reduces losses, some increase losses
- Must evaluate transmission on distribution impact and vice versa
- Need to simulate the secondary to model voltage at the meter

Where Do the Criteria Come From?

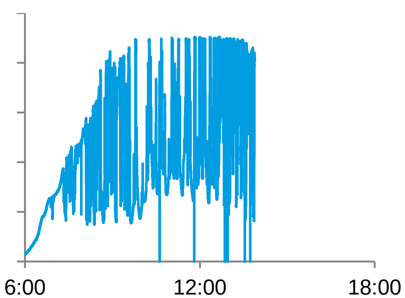
Time Varying Inputs



Load Curve

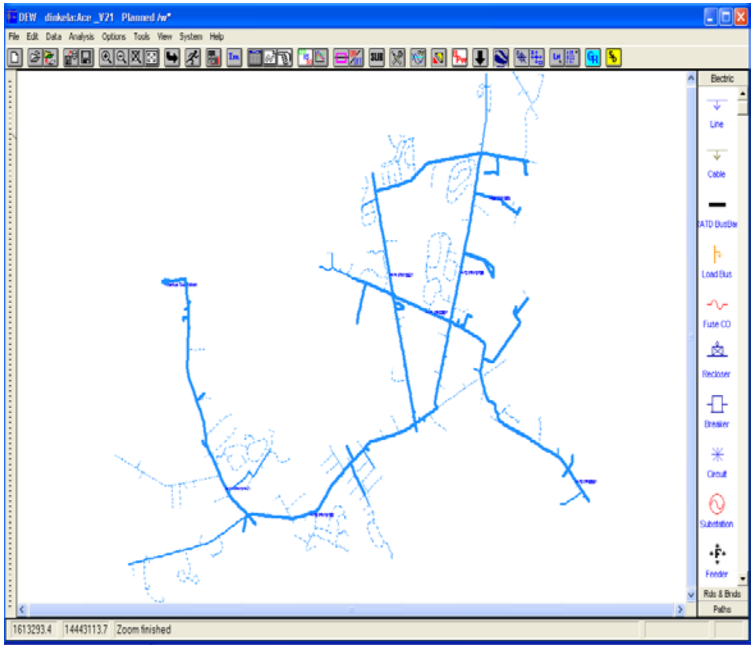


Customer Profile

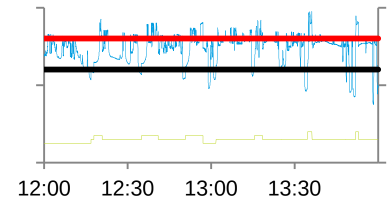


Generation Profile

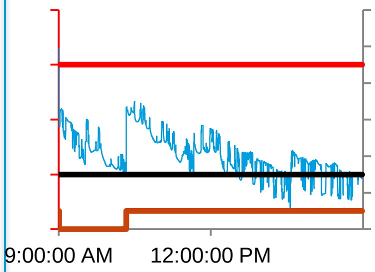
DEW Model



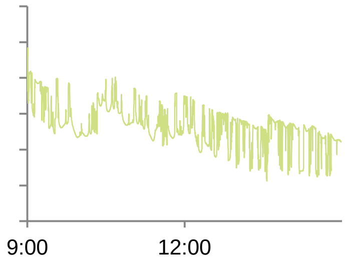
Time Varying Outputs



Regulator Voltage Position and Count



Cap voltage and status



Point of Interconnection Voltage

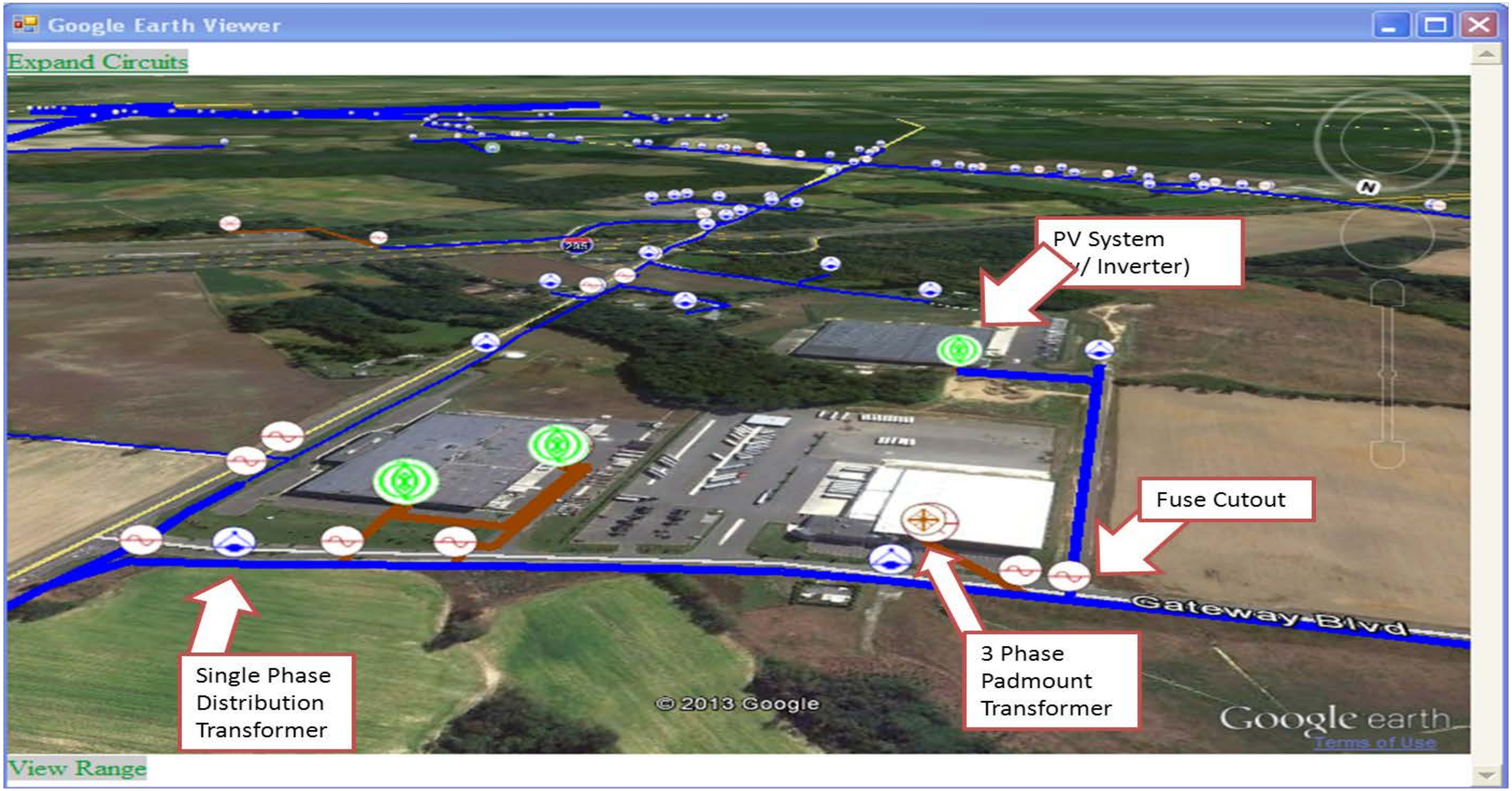
Simulate 1 second intermittent generation profiles interacting with 30 – 90 second voltage regulation time delays

DER Mapping and Controllable Device Settings

DER Mapping

- PV/DER engineering characteristics and control settings maintained by engineering in a "Settings" database
- Settings can be merged into model
- Settings from a model can be saved to the settings database
  - Actual and modified versions for analysis)
- Settings for protection devices and voltage control equipment a managed the same way

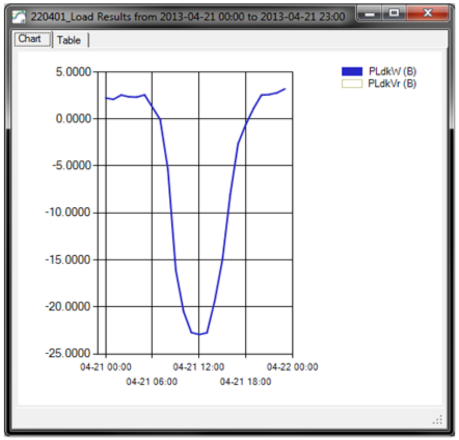
Circuit with Generation



Transformer with Reverse Flow

Transformer Loading with PV

When model is complete. Customer load and PV generator will be modeled separately.



Merged Model

Merged Transmission, Substation, and Distribution models at Substation with Google Earth Overlay

Secondary and Services

Benefits of Modeling

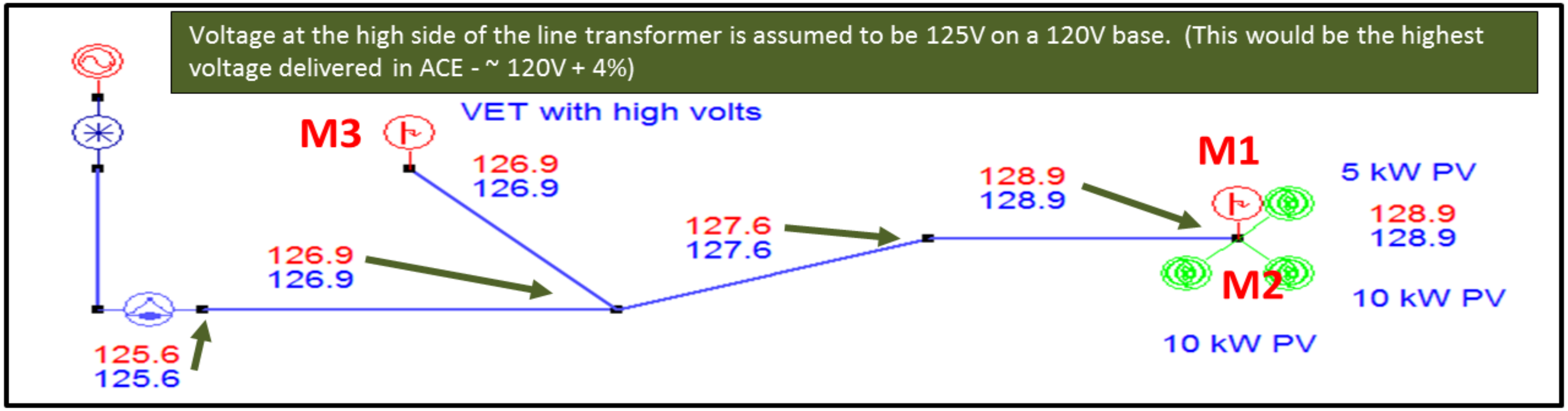
Most models use customers aggregated load at the low voltage side of distribution transformers

Modeling secondary/services can provide additional benefits especially where distributed resources are present.

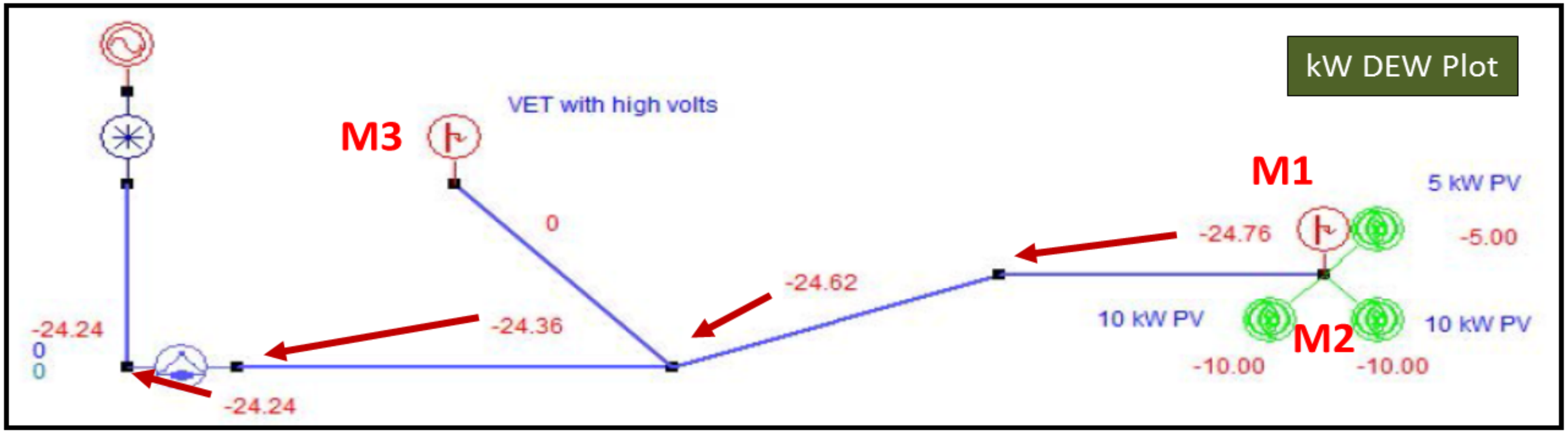
- Power flow results (amps, volts, kW, kVAR, percent loading, etc.) are available down to the customer meter
- Control strategies for PV including watt-VAR and volt-VAR can be determined for each installation allowing higher adoption percentages
- Secondary voltage and loading issues resulting from added PV installations can be identified and mitigated

Before -- (modeled in DEW)

Voltage at the high side of the line transformer is assumed to be 125V on a 120V base. (This would be the highest voltage delivered in ACE - ~ 120V + 4%)

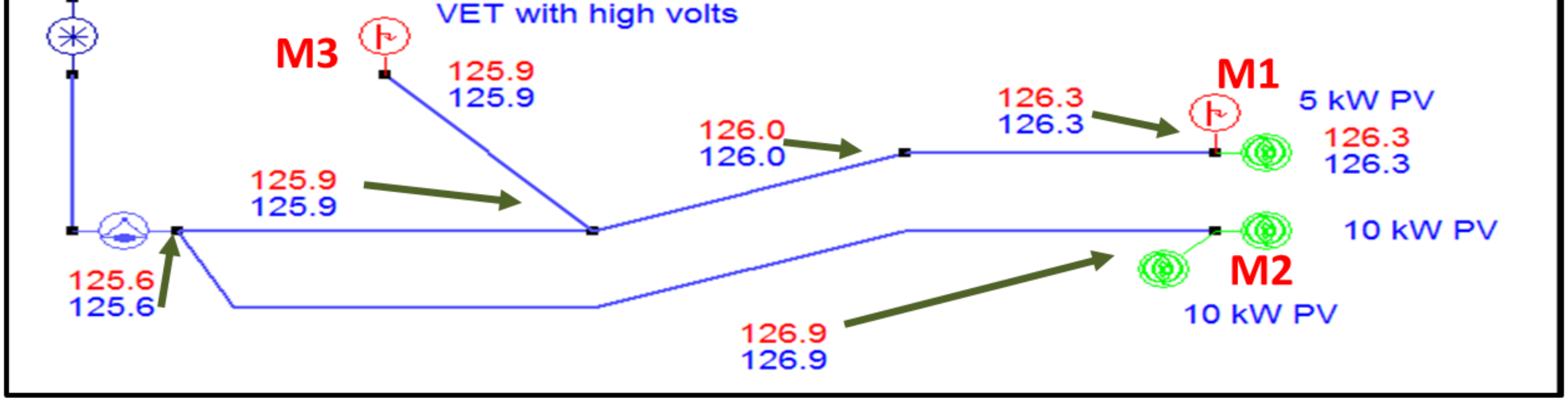


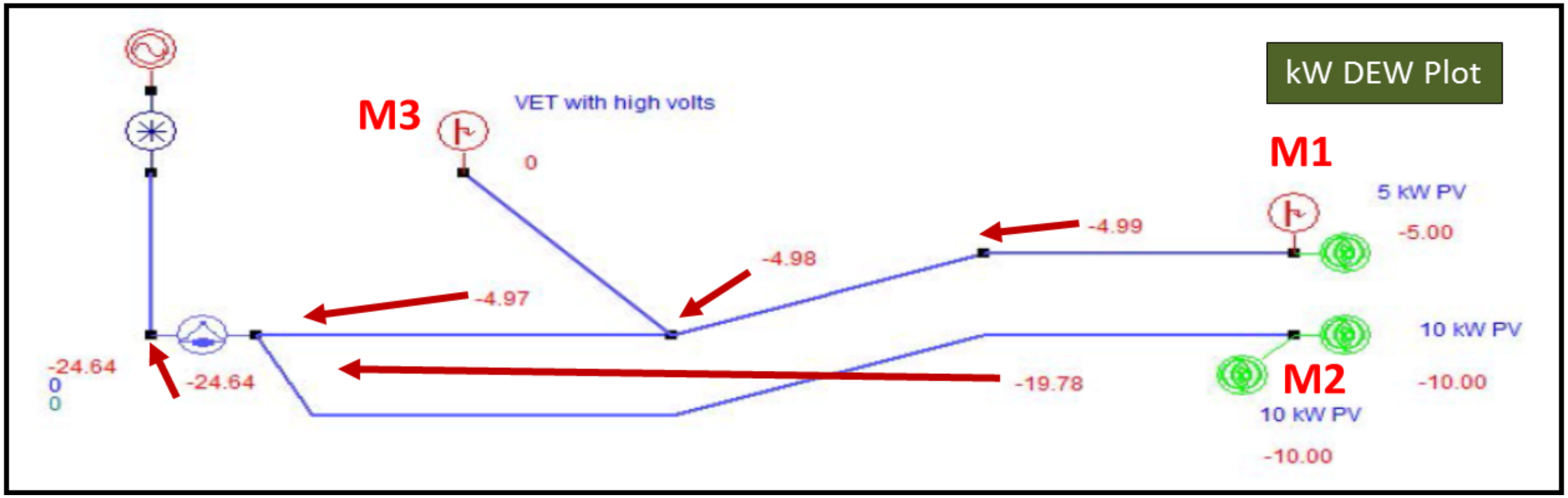
kW DEW Plot



After -- (modeled in DEW)

Voltage at the high side of the line transformer is assumed to be 125V on a 120V base. (This would be the highest voltage delivered in ACE - ~ 120V + 4%)





Collaborative Efforts to Develop Advanced Solutions

- DOE Grant for advanced voltage regulation strategies
- Collaborative R & D on new anti-islanding scheme
- Collaborative R & D on dynamic var control, centrally controlled vars
- Hosting Tests based on modeling Advanced Volt/VAR Control, smart inverters and
- Collaborative effort to verify the accuracy of atmospheric data, both historical and predicted
- AMI to monitor and provide control for small size inverters
- Implementing Cellular telemetry for systems over 2 MWs
- Integrating PV output data into Distribution Automation schemes
- Reviewing feasibility of online application and approval process

Outside Demo at ACE Training Yard with smart switch, incorporating load, and battery system.
(Work done with DOE SEGIS Grant to Petra Solar)

Outdoor Demo of Micro-grid mode – can operate off PV and battery, then resync with grid

(Work done with DOE SEGIS Grant to Petra Solar)

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Critical Mass -- Smart Energy

SMART GRID

- ISO (Independent Sys.Operator)
  - Bulk Generation
  - Bulk Transmission
    - Synchrophasors
  - Bulk Load Control
- LDC (Local Distribution Co.)
  - Transmission
  - Substation
    - Power Transformers
  - Distribution
    - Improved Comms
    - Distributed Automation
    - PMU Sensors
    - Microprocessor control
    - DMS
  - DSM, DR
- AMI
  - Outage Mgmt
  - Real Time Pricing
  - Load Profile Info
  - HAN (Home Area Network)
    - Price and other comm.

SMART INVERTER

- LV & Freq. Dev. Ride Thru
- Voltage & Ramp Control
- Autonomous & Centralized Control
  - -- VAR/PF Control
    - Fixed/Dynamic
    - Algorithm based
  - Curtailment
  - Remote Trip
- BATTERY (integrated or separate)
  - Premium Power
  - Voltage Control
  - Frequency Regulation
  - Spinning Reserve
  - Arbitrage (TOU or Real Time Pricing)
  - Demand Side Mgmt.
  - Peak Demand Mgmt.

SMART PREMISE

- HEMS (Home Energy Mgmt System)
  - Pricing Signal Response
  - Peak Load Control
- DER (Distributed Energy Resource)
- Renewables, CHP, etc.
- Smart Thermostat
- Smart Appliances
- Smart HVAC
  - Thermal Storage
- EV
  - Controllable Charging, V2G
- Remote Access and Control
- Energy Efficiency & Controls
  - Turn off Phantom Loads
  - Vacant space mgmt.
- Direct Use of DC

Thank You

- Feel free to contact us if you have any questions.

  - Brandon Bowles, Supv., Customer Relations, Green Power Connection Team

  - Steve Steffel, Mgr., Distributed Energy Resources Planning and Analytics