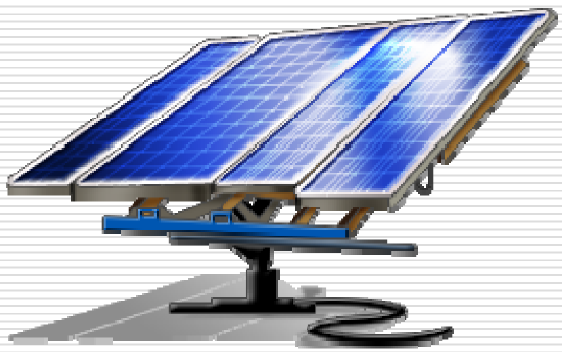
Solar Development in New Jersey, and PV Impacts on the Distribution System



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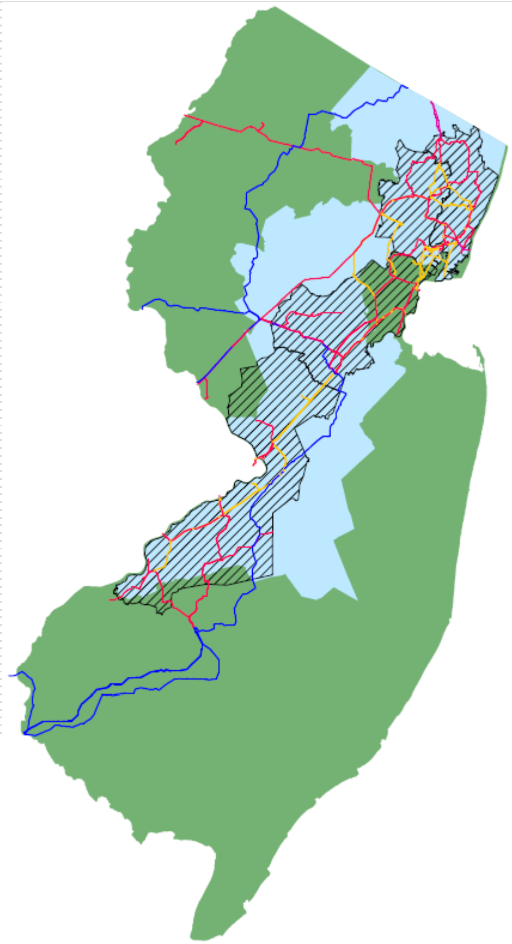
Overview

- This presentation is intended to be a brief discussion of PSE&G's solar development activities in New Jersey, and specifically the impact of the interconnection of large amounts of solar generation on the distribution system.
- The presentation will also discuss typical utility planning concepts, codes and standards, and federal vs. NJ interconnection procedures.
- My thanks to NREL (proceedings from the High Penetration PV Workshop from last May - http://www.nrel.gov/docs/fy10osti/48378.pdf), DOE, and others for some of the information in this presentation!

Public Service Electric & Gas is the largest utility in New Jersey providing electric, gas and transmission services

	Electric	Gas
Customers	2.1 Million	1.7 Million
Electric Sales	41,961 GWh	
Gas Sold and Transported		3,500 M Therms
Peak Electric Load	11,108 MW	
Sales Mix		
Residential	31%	60%
Commercial	58%	36%
Industrial	11%	4%

Renewables and Energy Efficiency	2009	Total
Solar Loan	11.6 MW	81 MW
Solar 4 All	1 MW	80 MW
Energy Efficiency Initiative (lifetime equivalent)***	230 GWh	13,512 GWh



*** Lifetime GWh + Lifetime Dtherms converted to GWh

Why Grid Connected Utility-Owned Solar Makes Sense

- Maximizes benefits to ratepayers
  - Returns value of electric sales, federal ITC and Solar Renewable Energy Credits (SRECs) to ratepayers
- Engages the solar industry
  - Uses local contractors and suppliers
- Provides stability in solar market
  - Financial and operational strength
- Ensures grid reliability
  - Planned for maximum system benefits

PSE&G Solar Programs

- More than $750 million invested in solar

  - Solar Loan Program
  - Solar 4 All Program

PSE&G's Solar 4 All Program

- Two main components:
  - 40MW Neighborhood Solar
  - 40MW Centralized Solar

PSE&G Neighborhood Solar: Activities and Achievements

About 76,000 units installed to date

- Up to 200,000 smart solar units on utility poles (40MW)
- 175 acres of land would be needed for 40MW
- Made locally by Petra Solar of South Plainfield, NJ

PSE&G Centralized Solar: Activities and Achievements

- 19.5MW installed
  - PSE&G-owned property
  - Third party leased sites
- More than 10 additional projects in process of development

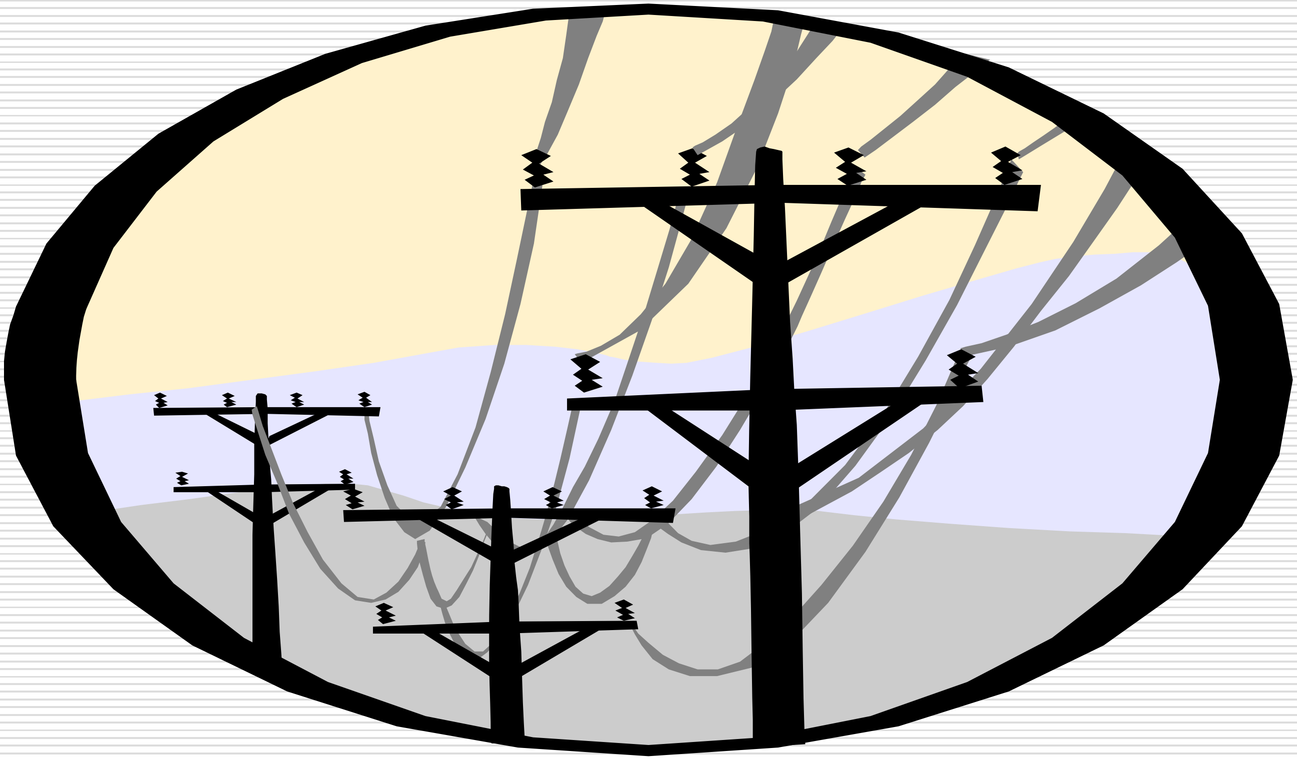
PSE&G's Solar Loan Program

- > $247M program
- 195 solar loans closed since April 2008
- 444 more in development/review
- $69.9M loaned
- Financed >19MW of solar capacity

Incentives for Solar Development in New Jersey

- Federal Solar Investment Tax Credit (ITC)/Solar Grant
  - 30% of the cost of the solar property in cash or take the ITC as a tax credit (commercial customers and utilities)
- Solar Renewable Energy Certificate (SREC) Program
  - Earn one (1) SREC for every 1,000 kWh the solar PV system produces. These can be sold or traded over a 15-year period; approx. $690 per mWh or $0.69 per kWh (2009-2010)
- Power Purchase Agreements (PPA)
- PSE&G Solar Loan Program
  - Loan provided for 40-60% of system cost
  - Customers repay using SRECs produced

Primer on Distribution Planning



Planning Criteria

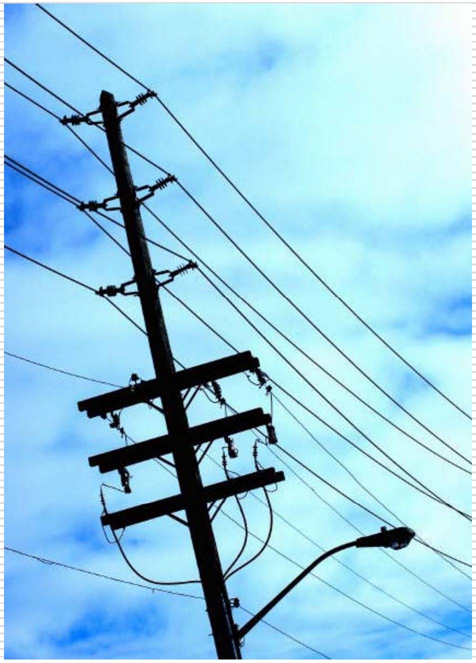
- A utility’s planning criteria are intended to be a guide to provide for the safe, reliable and low cost development of the utility’s electrical system as loads increase and reinforcements and/or new facilities are required.

Basic Planning Principles

- With all facilities in service:
  - Loads on the system must be within normal equipment ratings
  - Must provide acceptable voltages to connected customers
- With the outage of any single piece of equipment (N-1 Criteria Violation):
  - Affected load must be within the emergency rating of the remaining facilities
  - System must provide minimum emergency voltages

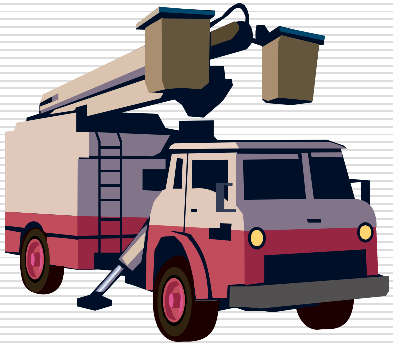
Basic Planning Principles

- N-1 criteria are applied in a similar fashion to:
  - Substations
  - Distribution Facilities
  - Subtransmission Facilities
  - Transmission Facilities



Basic Planning Principles

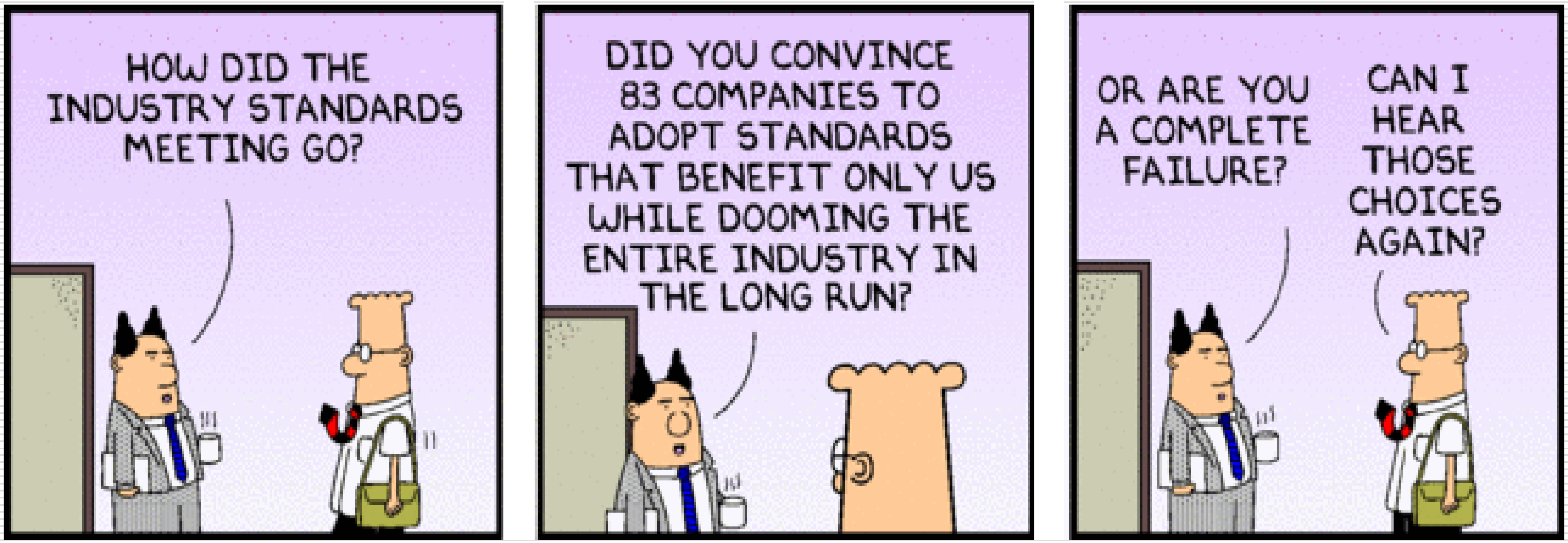
- Load Forecasting
  - Substation
  - Feeder
- Distribution Circuit Reinforcement
  - Ratings
  - N-1 Criteria
- New Business
  - Connected vs. Estimated Loads
  - Load Build-up Schedules and Load Shifting
  - Distributed Generation



Substation Forecast / Planning Process
Substation & Area Planning

- **Substation & Area Capacity**
  - Firm N-1 Criteria
  - Includes Automatic 13-kV ICT Transfers
- **Capacity Processing**
  - Load vs. Capacity Analysis
- **Load Relief Modeling**
  - Power Factor Correction
  - Load Transfers
  - Distributed Generation
- **System Reinforcement Modeling**
  - *Interstation Capacity Ties*
  - *Station Reinforcement*
  - *New Station*
  - *Generation*

Interconnection Standards


HOW DID THE INDUSTRY STANDARDS MEETING GO?
DID YOU CONVINCE 83 COMPANIES TO ADOPT STANDARDS THAT BENEFIT ONLY US WHILE DOOMING THE ENTIRE INDUSTRY IN THE LONG RUN?
OR ARE YOU A COMPLETE FAILURE?
CAN I HEAR THOSE CHOICES AGAIN?

Federal (PJM) Jurisdictional Interconnection Standards

- Applies to generators participating in PJM's wholesale market, regardless of size and interconnection voltage level
- Follows standard FERC-approved procedures developed under the authority of the PJM OATT
- Procedures and requirements are based on size
  - Large Generating Facilities (>20 MW)
  - Small Generating Facilities (<20 MW)
- PJM's Small Generator Interconnection Standards use a streamlined process for smaller generators
  - Fast Track Study Process for small generators
  - 10 kW Inverter Process for certified inverter based generators no larger than 10 kW
  - Small generators must meet IEEE 1547 (Manual 14a)

State Jurisdictional Interconnection Standards

- In NJ, applies to generators up to a certain size (2 MW), connected to the distribution system
  - Net Metering, PURPA or similar arrangement for "retail sales" of electricity to the host utility only
  - Distribution interconnections of "wholesale sales to PJM" projects on <u>non-PJM jurisdictional</u> distribution facilities are State regulated
  - Typically covers renewables and other small DR, all customer classes
- NJ's regulations generally conform with the FERC SGIP, but have some significant differences
- Technical standards focused on IEEE 1547, and for inverters, UL 1741 for connection to the grid

IEEE 1547 Interconnection Standards

1547- 2008 Standard for Interconnecting Distributed Resources with Electric Power Systems

1547.1 - 2005 Conformance Test Procedures for Equipment Interconnecting DR with EPS

1547.2 - 2008 Application Guide for IEEE 1547 Standard for Interconnection of DR with EPS

1547.3 - 2007 Guide for Monitoring, Information Exchange and Control of DR

Current 1547 Projects

- P1547.4 Guide for Design, Operation, & Integration of Distributed Resource Island Systems with EPS — Microgrids
- P1547.5 Guidelines for Interconnection of EPS >10 MVA to the Power Transmission Grid
- P1547.6 Recommended Practice for Interconnecting DR With EPS Distribution Secondary Networks
- P1547.7 Draft Guide to Conducting Distribution Impact Studies for DR Interconnection

P1547.8 (new)

Extend use of 1547,

e.g. grid support, energy storage, ride-thru, etc.

P1547.7 - Draft Guide to Conducting Distribution Impact Studies for DR Interconnection

- Describes criteria, scope, and extent for engineering studies of the impact of DR on distribution system.
- Provides methodology for performing engineering studies.
- Study scope and extent described as functions of identifiable characteristics of:
  - The distributed resource
  - The area electric power system
  - The interconnection
- Criteria described for determining the necessity of DR impact mitigation.
- Guide provides a methodology for determining:
  - When impact studies are appropriate
  - What data is required
  - How studies are performed
  - How the study results are to be evaluated

P1547.8 - Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for Implementation Strategies for Expanded Use of IEEE Standard 1547

- Needed to address industry driven recommendations, and NIST smart grid standards framework recommendations (e.g., NIST SGIP Priority Action Plan - “PAP 7”).
- Example considerations include: low voltage ride through (LVRT) of PV; VAR (reactive) support; grid support; two-way communications and control; advanced interactive grid to DR operations; high penetration of DR; area EPS with multiple DR interconnections; interactive inverters; energy storage; electric vehicles; etc.

IEEE 1547 Interconnection Standards Use: Federal, Regional, State and Local Authorities / Jurisdictions

IEEE 1547
Interconnection System and Test Requirements

- Voltage Regulation
- Grounding
- Disconnects
- Monitoring
- Islanding
- etc.

IEEE 1547.1
Interconnection System Testing

- O/U Voltage and Frequency
- Synchronization
- EMI
- Surge Withstand
- DC injection
- Harmonics
- Islanding
- Reconnection

UL 1741*
Interconnection Equipment

- 1547.1 Tests
- Construction
- Protection against risks of injury to persons
- Rating, Marking
- Specific DR Tests for various technologies

NEC

Article 690 PV Systems;

Article 705: interconnection systems (shall be suitable per intended use per UL1741)

PJM Interconnection, Inc.
Small Generator Interconnection Standards
FERC approved
(0-to<10MW and 10-to-20 MW; incorporate 1547 and 1547.1)

* UL 1741 supplements and is to be used in conjunction with 1547 and 1547.1

PV Impact Studies, Analysis, Challenges and Goals

Key Areas of Focus for PV Interconnection Impact Studies

- Voltage Regulation
  - Steady state conditions, fluctuating conditions (flicker), cap bank and tap changer cycling issues, reverse power flow issues, voltage unbalance
- Fault Currents and Protection Coordination
  - Impact on fault levels, device coordination, interrupting ratings, ground fault current detection desensitization
- Ground Fault Overvoltages
  - Important especially for non-effectively grounded DG, which is how PV devices are often configured
- Islanding
  - Important especially in complex situations with multiple DG present, or with fast reclosing and no live-line reclose blocking

Some Useful Penetration Ratios for Engineering Analysis

- Minimum Load to Generation Ratio -
  - Is the annual minimum load on the relevant area electric power system (EPS) section divided by the aggregate DG capacity on the area EPS
- Stiffness Factor -
  - Is the available utility fault current divided by DG rated output current in the area EPS
- Fault Ratio Factor -
  - Is the available utility fault current divided by DG fault contribution in the area EPS
- Ground Source Impedance Ratio -
  - Is the ratio of zero sequence impedance of DG ground source relative to utility ground source impedance in the area EPS

PV Penetration Ratios and Their Suggested Uses

Type of Ratio	What is it useful for? *(Note these ratios are intended for distribution and subtransmission system impacts of DG listed below, and not necessarily the overall bulk system stability impacts)*	Suggested Penetration Level Ratios[1]		
		Very Low Penetration (Very low probability of any issues)	Moderate Penetration (Low to minor probability of issues)	Higher Penetration[5] (Increased probability of serious issues.
Minimum Load to Generation Ratio[2]	▪ Ground fault overvoltage analysis *(use ratios shown when DG is not effectively grounded)* ▪ Islanding analysis *(use ratios 2/3 of those shown)*	>10 Synchronous Gen.	10 to 5 Synchronous Gen.	Less than 5 Synchronous Gen.
		>6 Inverters[4]	6 to 3 Inverters	Less than 3 Inverters
Fault Ratio Factor $(I_{SCUtility}/I_{SCDG})$	▪ Overcurrent device coordination ▪ Overcurrent device ratings	>100	100 to 20	Less than 20
Stiffness Factor $(I_{UtilitySC}/I_{RatedDG})$	▪ Voltage Regulation (this ratio is a good indicator of voltage influence. Wind/PV have higher ratios due to their fluctuations. Besides this ratio, may need to check for current reversal at upstream regulator devices.)	>100 PV/Wind	100 to 50 PV/Wind	Less than 50 PV/Wind
		> 50 Steady Source	50 to 25 Steady Source	Less than 25 Steady Source
Ground Source Impedance Ratio[3]	▪ Ground fault desensitization ▪ Overcurrent device coordination and ratings	>100	100 to 20	Less than 20

NREL *High Penetration PV Workshop : Defining High Penetration PV –Multiple Definitions and Where to Apply Them - Phil Barker, Nova Energy Specialists*

PV Penetration Ratios and Their Suggested Uses

- Notes:
  1. Ratios are meant as guides for radial 4-wire, multi-grounded neutral distribution system DG applications, and calculated based on aggregate DG on the area EPS.
  2. "Minimum load" is the lowest annual load on the *line section of interest* (up to the nearest applicable protective device). Power factor of load is assumed to be 0.9 inductive.
  3. Useful when DG or its interface transformer provides a ground source contribution. Must include the effect of the step-up transformer if present.
  4. Inverters are weaker ground fault sources than rotating machines, therefore a smaller ratio is allowable.
  5. If DG application falls in this "higher penetration" category it means some system upgrades/adjustments are likely needed to avoid power system issues.

PV Interconnection Issues and Barriers

- Descriptions of key issues/barriers for interconnecting PV
  - Lack of data, and system analysis techniques and tools to sufficiently model and simulate specific impacts of solar on the grid (Voltage effects, GFP, Islanding, PQ, etc.)
  - Need for intelligent bundling of PV with demand side management, communications and controls, and storage technologies
  - Need to enhance system protection and coordination capability through the use of advanced instrumentation, measurement and controls devices
  - Must develop methods, equipment and technologies to effectively mitigate the intermittency of solar
  - Development and investigation of codes and standards to determine limitations on grid integration equipment capabilities and to establish stakeholder consensus

DOE – EE&RE, *HPPV Systems into the Distribution Grid Workshop* – Feb 2009

PV Inverter Technical Challenges

- Implementing VAR Control, LVRT, and Dynamic Control – is technically achievable
- Most inverter modification can be done through software upgrades
- Minor hardware changes at minimal additional cost would include:
  - Additional sensors
  - UPS for LVRT capability
- In VAR Control mode inverter will operate at higher current levels when not at unity power factor – will also have impacts on efficiency and reliability, especially if running at night for regulation purposes.

PV Interconnection Goals

- Ensure safe and reliable two-way electricity flow
- Develop smart grid interoperability
- Develop advanced communication and control functionalities of inverters
- Integrate renewable systems models into power system planning and operation tools
- Integrate with energy storage, load management, and demand response to enhance system flexibility
- Understand high-penetration limiting conditions
- Understand how various climates and cloud transients affect system reliability

U.S. Department of Energy Solar Energy Technologies Program Goals

Any Questions?