Utility Distribution Planning 101

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Distribution Systems and Planning Training
for New England Conference of Public Utility Commissioners, Sept. 27-29, 2017

Set-up

- Presentation will be from 2:30 – 3:30
- Brief background on presenters

Michael Coddington

Kevin Schneider

Juliet Homer

- Learning objectives - desired outcomes of this session
- Questions welcome as we go through

Presentation Agenda

- Set-up
- Initial context
- Overview of traditional planning
- Maintaining Safety, Reliability and Cost
- Planning functions at small vs. large utilities
- Traditional functions
- How are investment decisions made?
- Where does the money go?
- Classes of distribution planning tools
- Advances in electric distribution planning
- Hosting capacity and modeling
- Key lessons learned in modeling
- Summary of practices at advanced utilities
- Discussion and questions

Juliet

Mike

Juliet

Kevin

Juliet

All

Context

- Distribution planning is changing
- Distribution planning has traditionally been focused on maintaining:
  - Safety
  - Reliability
  - At reasonable cost
- At the core distribution planning supports investment decisions
- As the grid and resource mix are changing, distribution systems are changing and distribution planning is changing
  - In many places, a lot of new gen is connected to the distribution system
  - Distribution system has least amount of utility visibility/control
- In some states, more detailed distribution plans are being required :
  - Hosting capacity
  - Locational benefits and non-wires alternatives
- New skill sets are required as well as coordination across entities within the utility

Traditional Key Areas of Focus for Distribution Planning Engineers

Electric Distribution System Planning – The Big Picture

Safety

- Design and maintain an electric system that does not place utility workers or the general public at risk

Reliability

- Provide the power that the consumers need
- Maintain power quality
  - Maintain stable voltage at point of delivery
  - Provide a stable frequency
- Reduce number of outages
  - Frequency of outages (S.A.I.F.I.)
  - Duration of outages (S.A.I.D.I.)

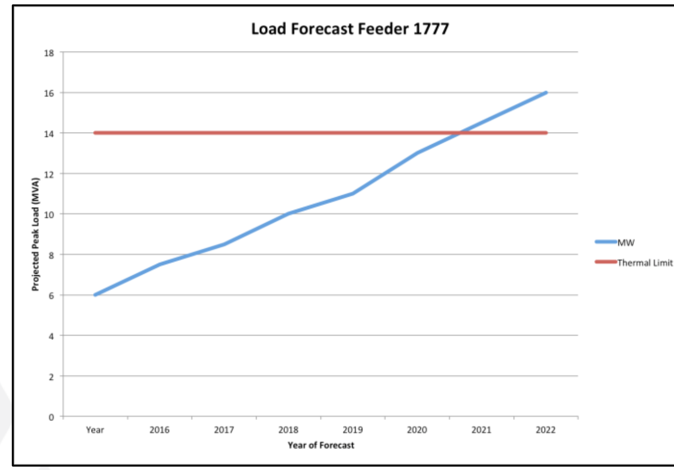
Cost

- Supply energy at an acceptable price

Traditional Areas of Focus for Larger Utilities**

Load Forecasting

- Track peak loads (using SCADA data)
- Publish annual long-range forecast
- Evaluate each distribution feeder for annual growth, new loads
- Feeder load forecasts aggregate to show substation status, need for expansion
- Substations may require upgraded transformers, new transformer banks, transmission, distribution equipment
- System Planning (transmission) use this to plan line upgrades (new lines, larger lines, higher voltages)
- Substation departments evaluate the need for larger transformers or additional transformer banks

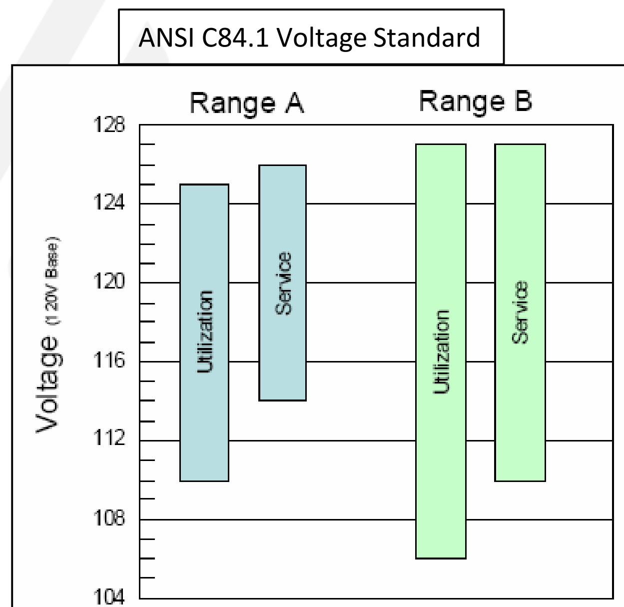


** Larger utilities often have groups of engineers that focus entirely on distribution planning functions

Traditional Areas of Focus for Larger Utilities - Continued

- Reliability (SAIDI, SAIFI)
  - Feeder-Level protection
  - Under Frequency Load Shedding (UFLS) schedules
  - PUC complaint resolution
- Power quality support
- Voltage support (ANSI C84.1)
  - Capacitor placement
  - Voltage regulator placement
- Evaluation of "special projects" such as large DER systems
- Large distribution project design

Image: NREL Pix 03207



Process of Identifying System Risks

Identify System Risks

- Determine N-0 (system intact overloads) and N-1 (based on one-point of failure) risks based on the peak demand and available capacity
- Other considerations
  - Power Quality (low or high voltage)
  - Reliability (line and equipment exposure)
  - Environmental considerations (e.g. line losses)
  - Safety
  - Legal
  - Financial

Create Risk Mitigation and Projects

- ► Traditional poles and wires solutions to mitigate system risks
  - New distribution feeders
  - Reconductoring existing feeders
  - New substations
  - Expanding existing substations

Source: NREL Pix 08216

Where Does the Money Go?

Annual Electric Distribution Budget

Create Annual Capital Budget

- ► Determine funding by program
- ► Evaluate Customer Minutes Out and value of service reliability
- ► Determine Cost Benefit Ratio
- ► Prioritize projects over a 5 year time
- ► Budget based on corporate guidelines

Example Electric Distribution Budget

Program	Percentage
New Service	19.9%
Elec Asset Health	11.2%
Street Lights	2.8%
Elec Capacity	9.6%
Elec Mandates	8.4%
Reliability	16.1%
Sub Capacity	12.4%
Sub Asset Health	5.5%
Equip Purchase	9.7%
Fleet	2.0%
Other	2.4%

Note: This complex planning approach may not be used by small and mid-sized utilities, but is important for larger utilities due to the scale of operations and number of customers

New Load Construction Allowance vs. Customer Paid DER Mitigation

- Most IOUs have Construction Allowance (CA) for new projects, sometimes results in zero up-front cost for new construction
  - Investments are recovered through tariff design, as investments are generally placed in the “rate base”
- Distributed Energy Resources (DER) such as PV systems often interconnect without system upgrades, but pay for any upgrades if required to mitigate potential problems

Source: NREL PIX, Coddington

The Brooklyn Queens Demand Management Project – A New Way to Plan?

System Expansion Project: Con Edison's BQDM

Deferral of ~$1 billion in traditional network upgrades with distributed solutions

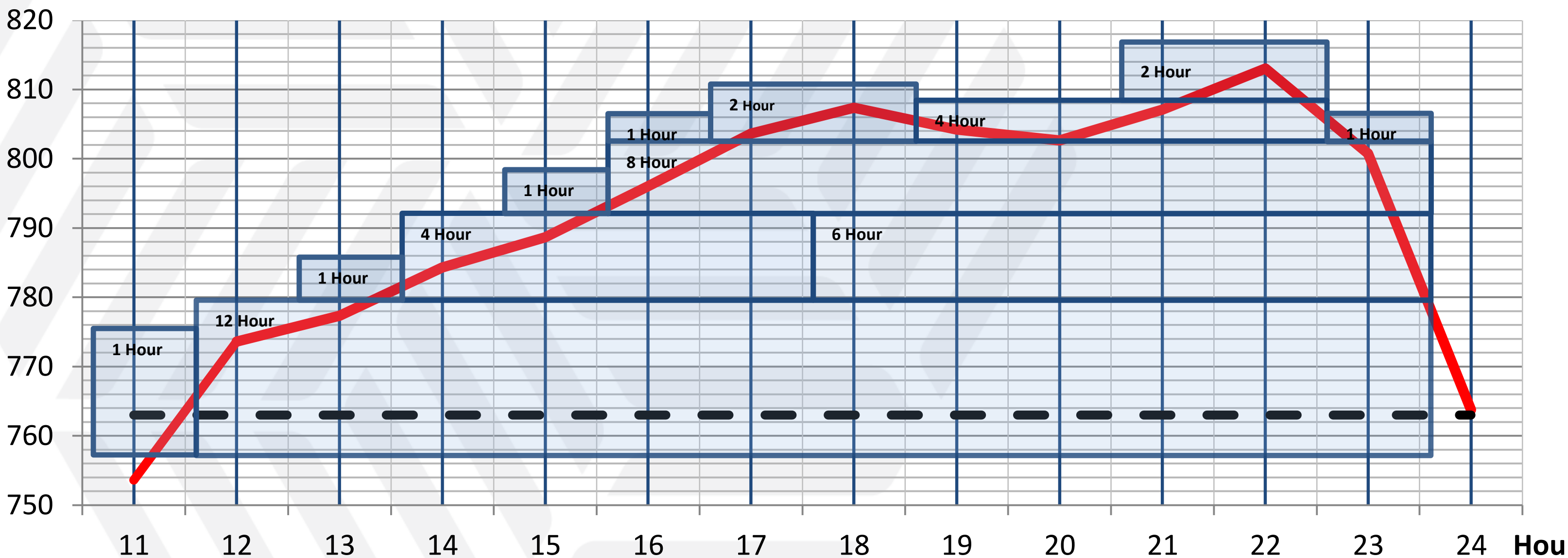
- Meets capacity shortfall via $200 million program
  - Non-traditional customer-sided 41 MW ($150 m)
  - Utility-sided solutions 11 MW ($50 m)
- Long duration, night peaking network requires a portfolio of solutions
- The effective DER contribution can be located anywhere within the foot print

Brooklyn-Queens Demand Management

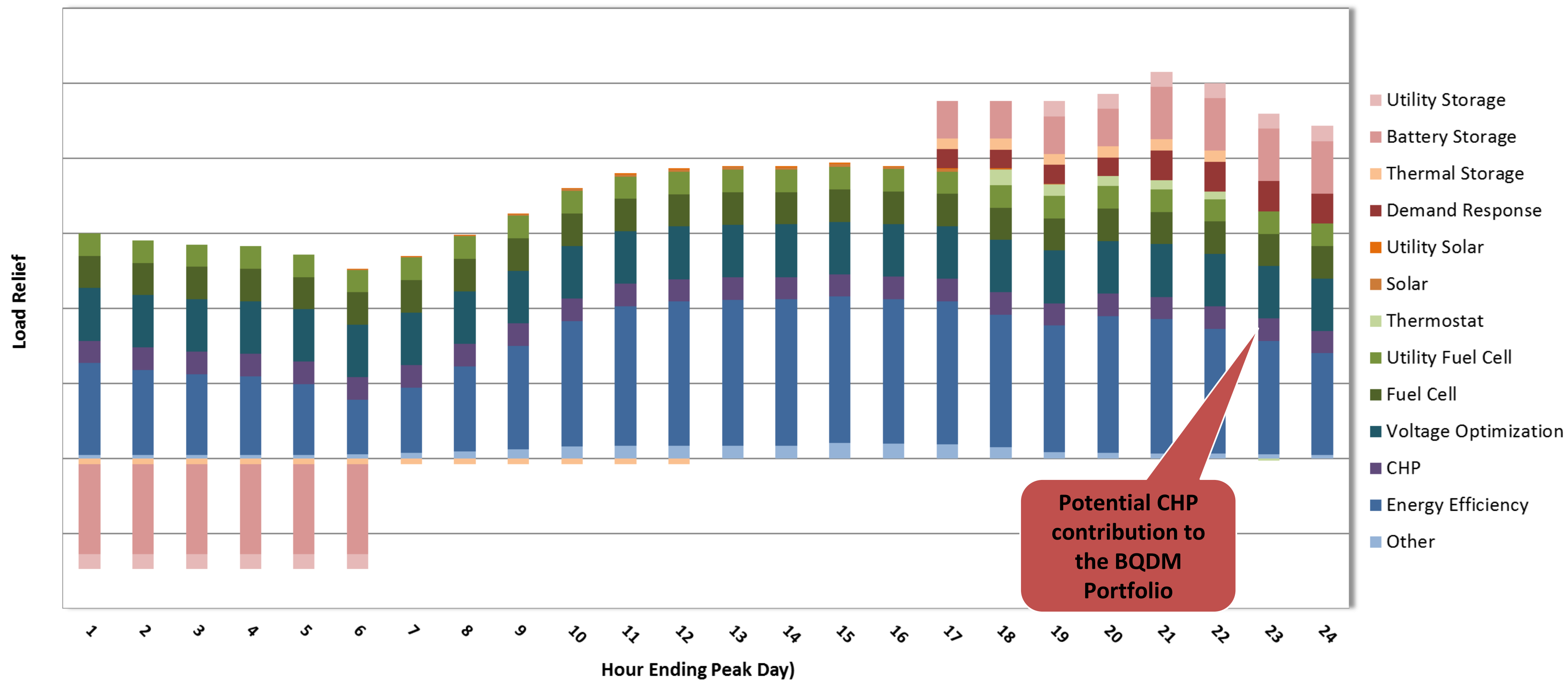
Description

- $1 billion substation deferral using portfolio of alternative investments in Brownsville network
- Earn rate-of-return plus incentive based on implementation

Example Network Peak Day Load Curve



Illustrative BQDM Portfolio



BQDM - Battery Storage System

12 MW-hoursof energy in Lithium Iron Phosphate batteries. Remotely controlled or automated unmanned operation. 1) Charge during off-peak, 2) Discharge for peak-shaving, 3) Repeat as needed. (Note the outdoor installation). Graphic – Con Edison

Planning Tools - Overview

Classes of Distribution Planning Tools

- Forecasting
  - DER forecasting
  - Load forecasting
- Power flow analysis
  - Peak Capacity Power Flow Study
  - Voltage drop study
  - Ampacity study
  - Contingency and restoration study
  - Reliability study
  - Load profile study
  - Stochastic power flow study
  - Volt/Var study
  - Real-time performance study
  - Time series power flow analysis
- Power quality analysis
  - Voltage sag and swell study
  - Harmonics study
- Fault analysis
  - Arc flash hazard study
  - Protection coordination study
  - Fault location identification study
- Dynamic analysis
  - Long-term dynamics study
  - Electromechanical dynamics study
  - Electromagnetic transients study
- Advanced optimization

Advances in Electric Distribution System Planning (example PV analysis)

- Traditional planning studies have focused on:
  - Capacity planning
  - Cost
  - Safety

- Because of the newer technologies that are being deployed at the distribution level, the planning process must change. Capacity is not the only factor to consider.

- As an example, the future deployment of small scale residential solar cannot be predicted, the planning process must take into account this uncertainty.

- 15 prototypical circuits were used to examine the larger parent population of SCE circuits.

- The following is an example process that was developed by Southern California Edison as part of California Solar Initiative #4.

Grid Hosting Capacity Modeling

GRID MODERNIZATION LABORATORY CONSORTIUM
U.S. Department of Energy

Determining Native PV Limits of a Circuit

- Step 1-Define key metrics: What is, and what is not an operational limit that would prevent the deployment of additional solar. (utility dependent)

- Step 2-Clear base case models of violations: Time-series models of representative circuits were developed and the base condition must be free of violations.

- Step 3- Deploy Monte-Carlo PV adoption models: A socio-economic PV adoption model provides different “likely” future scenarios for each circuit.

- Step 4- Run simulations on various scenarios to determine the native PV limit for the circuit. In this case, 50 simulations were conducted at each penetration level.

Table 4.1 - Circuit Operational Limits and Thresholds For determining Native Limits

Violation #	Violation	Violation Description
1	Thermal Overloads	Limit: Exceeding any device thermal limit, 100% rating (200% for secondary service transformers)
2	High Instant Voltage	Limit: Any instantaneous voltage over 1.10 p.u. at any point in the system.
3	5 min ANSI Violation	Limit: ANSI C84.1: 0.95>V>1.05 p.u. for 5 minutes at >10% of meters in the system.
4	Moderate Reverse Power	Warning: Any reverse power that exceeds 50% of the minimum trip setting of the substation breaker or a recloser. (Requires analysis of protection coordination)
5	High Reverse Power	Limit: Any reverse power that exceeds 75% of the minimum trip setting of the substation breaker or a recloser.
6	Voltage Flicker	Limit: any voltage change at a PV point of common coupling that is greater than 5% between two one-minute simulation time-steps. (Adapted from the Voltage fluctuation design limits, May 1994)
7	Voltage Drop/Rise on Secondary	Limit: 3V drop or 5V rise across the secondary distribution system (Defined as the high side of the service transformer to the customer meter)
8	Low Average PF	Warning: Average circuit power factor <0.85 (Measured at substation)
9	Circuit Plan Loading Limit	Warning: Nameplate solar exceeds 10MVA for a 12 kV circuit, 13 MVA for a 16 kV circuit, or 32 MVA for a 33 kV circuit.
10	High Short Circuit Contribution	Warning: Total short circuit contribution from downstream generation not to exceed 87.5% of substation circuit breaker rating

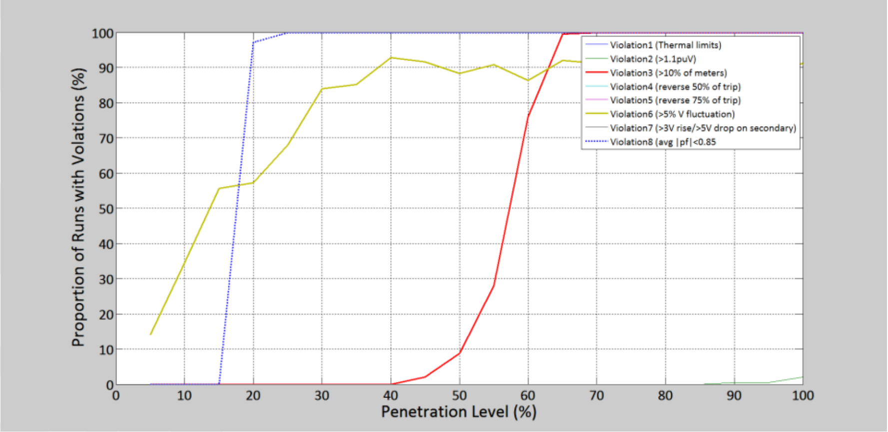
Determining Native PV Limits of a Circuit (Hosting Capacity Determination)

- For each circuit, 4,000 time-series simulations are conducted.
  - At each penetration level there are 50 simulations conducted
  - Penetration levels at 5% are examined
  - Each simulation is a different adoption scenario of solar

- The results of these simulations are distilled into a single plot for each circuit. Example shown at the right.

- The plot can then be used to determine the native limit, and to identify what the limiting factor are.

- The plot forms a basis to determine how to support higher penetration levels of PV, and which technologies might enable this.



Determining Native PV Limits of a Circuit (Mitigation for PV Limits)

- Each of the native limits can be avoided through circuit upgrades.

- Traditional methods:
  - Adjustment of existing voltage regulators
  - Installation of voltage regulators
  - Adjustment of existing capacitors
  - Reconductoring secondary segment
  - Reconductoring primary segment

- Advanced technologies
  - Fixed pf PV inverters
  - Advanced inverter control (CES Rule 21)
  - Centralized battery storage
  - Behind the meter battery storage

- The simulation provide the basis for selecting the best mitigating technologies, but there are many

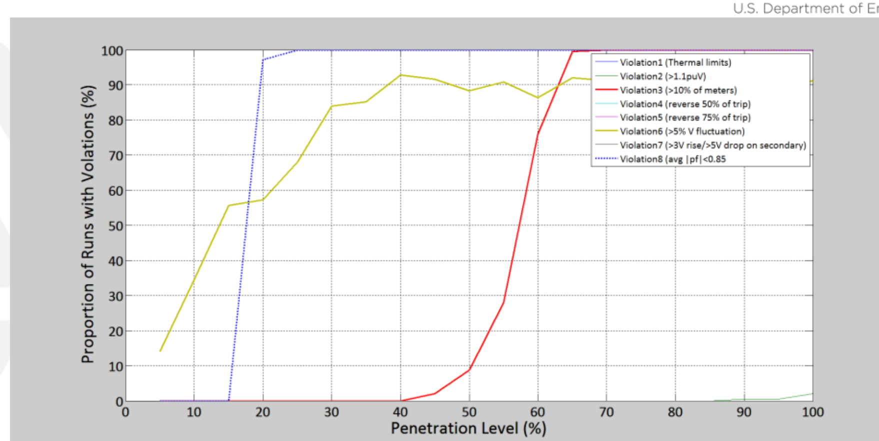


Table 5.1 - Summary of Mitigation Types and Strategies

Traditional Upgrade Strategies		Non-Traditional Mitigation Strategies	
T1	Adjustment of existing shunt capacitor set points	NT1	Fixed power factor on solar inverters
T2	Removal of existing shunt capacitors	NT2	Advanced Controls on PV Inverters
T3	Addition of shunt capacitors	NT3	Centratlized Energy Storage (utiltity)
T4	Installation of voltage regulators (regulating their output voltage magnitude)	NT4	Commercial Behind Meter Energy Storage
T5	Reconductoring of a primary line/cable segment		
T6	Reconductoring of a secondary line/cable segment		
T7	Upgrade of secondary service transformer		

Determining Native PV Limits of a Circuit (Key Lessons Learned)

- Most SCE circuits could support 100% penetration of PV once the proper mitigation strategies have been applied.
- Nearly 50% of SCE circuits can host less than 50% PV, where approx. 40% can host less than 25% PV
- Determining how to achieve 100% penetration on legacy circuits can be challenging, with a mitigation leading to new violations. (domino effect)
- The most common violations experienced were power factor and voltage based.
- Proper sizing of secondary drops when new solar is installed is essential.

Summary of practices at advanced utilities

GRID MODERNIZATION LABORATORY CONSORTIUM
U.S. Department of Energy

- ► Performing detailed load and DER forecasts, by location
- ► Conducting hosting capacity studies for some or all feeders and making information publicly available via online maps
- ► Systematically considering non-wires alternatives (NWA) to traditional distribution system investments – developing NWA suitability criteria
- ► Investing in automation, communication and information technology improvements to provide greater visibility and flexibility and enable greater levels of DERs
- ► Looking at value components of DERs by location and incorporating into tariffs. Value components include:*
  - ☐ Energy
  - ☐ Capacity
  - ☐ Environmental
  - ☐ Demand reduction and system relief

* From New York REV Value Stack tariff

Discussion and questions

- Thanks!