Energy Technologies Area Lawrence Berkeley National Laboratory

Future Opportunities and Challenges with Using Demand Response as a Resource in Distribution System Operations and Planning Activities

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Report Overview Presentation

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Overview

- Background
- Distribution System Management
- Intersection of Distribution System Management and Demand Response Opportunities
- Issues/Concerns at this Intersection
- Conclusions

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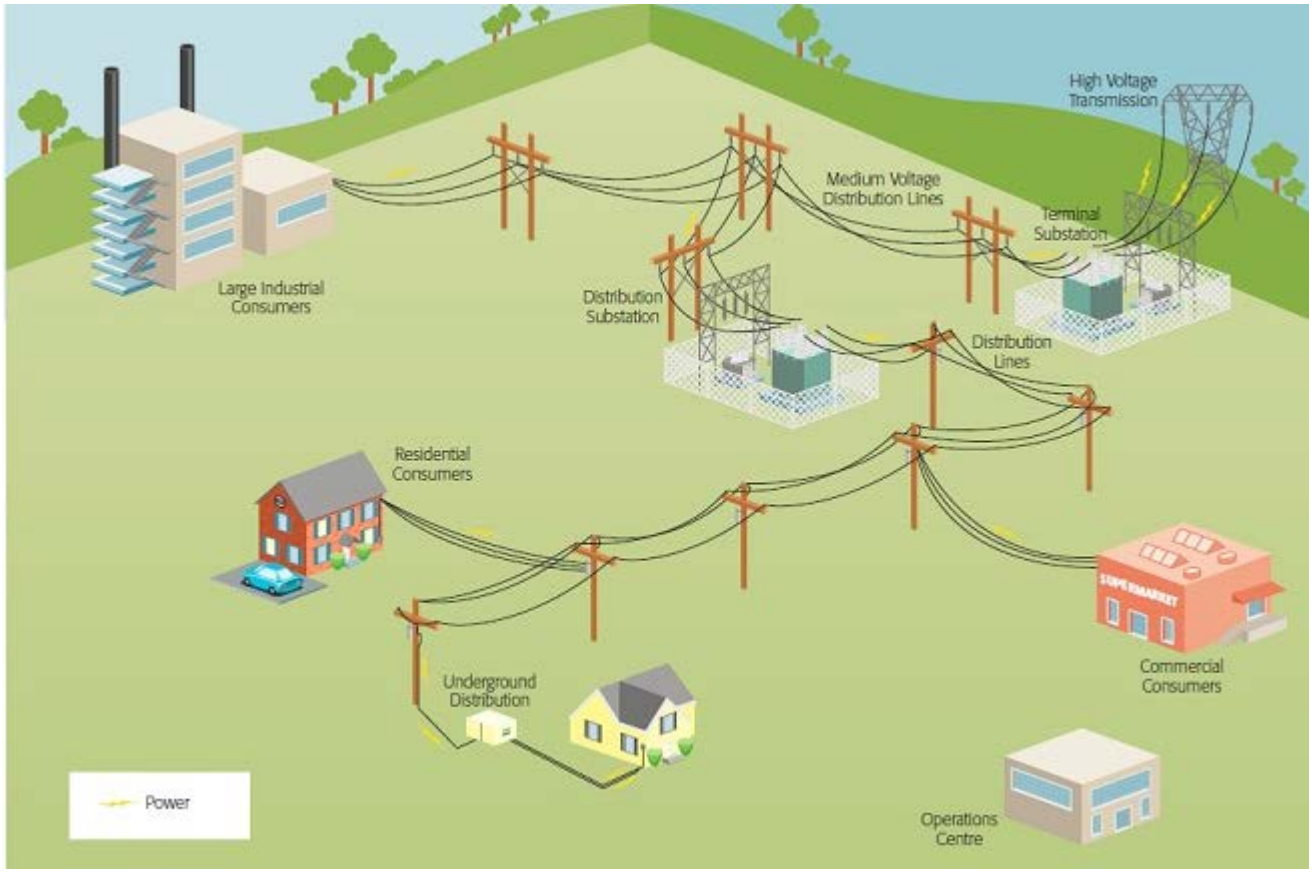
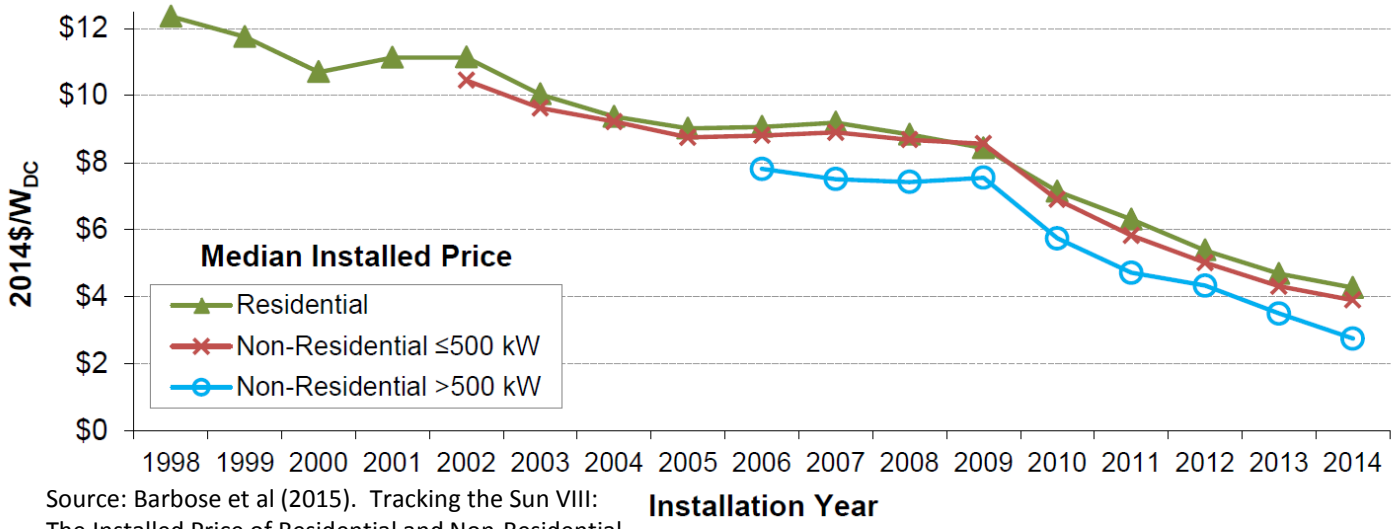
Historical Look at Distribution Systems

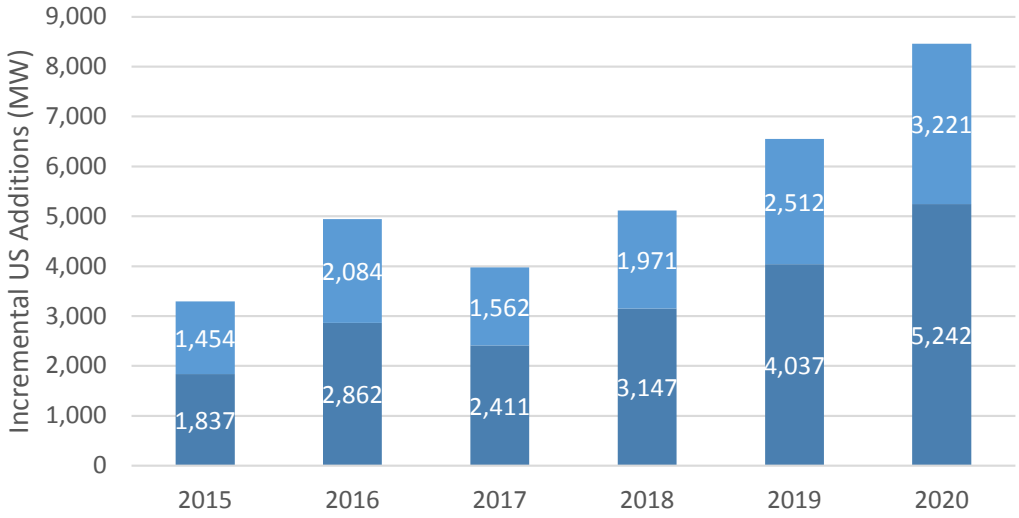


- Simple radial “hub-and-spoke” design of the distribution system has worked efficiently and effectively

Forecast Increased Penetration of DER



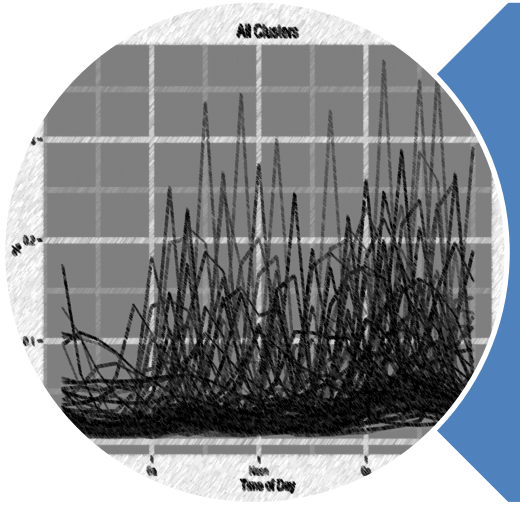
Source: Barbose et al (2015). Tracking the Sun VIII: The Installed Price of Residential and Non-Residential Photvoltaic Systems in the United States.



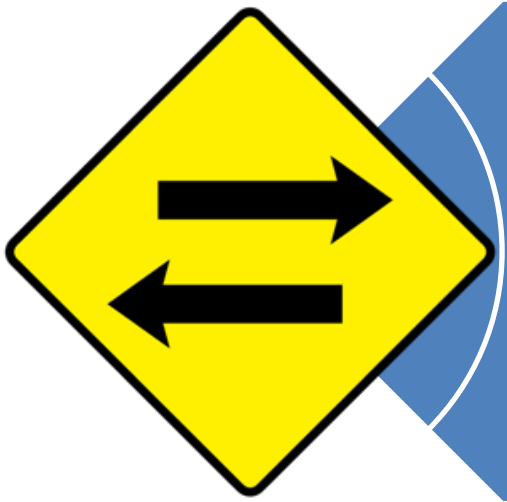
Source: Greentech Media, Inc. and Solar Energy Industries Association. U.S. Solar Market Insight Report: 2014 Year in Review.

- Major recent cost reductions in solar PV
- Net Energy Metering and associated compensation policies have valued energy output at the full retail rate
- When taken together, national forecasts for next 5 years suggest compound annual growth rate of 25% for solar PV

High Levels of DER Can Impact Net Load Shape



Power flow will be more variable



Power flow will be two-way

Substantial Investment in Aging Grid

- 75% of the transformers in the US and Canada are over 25 years old but have useful lifetimes of 20 years
- IOUs acknowledge 35-48% of T&D assets either current need or will soon be replaced

DR as a Tool for Distribution System Management

- DR was identified back in the late 70's a potential resource well suited to help in the management of the distribution system
- Subsequent simulation studies illustrated how DR could support very specific aspects of distribution system operations, more recently under high DER penetration levels
- During the 80's, several utilities undertook pilots to illustrate DRs capabilities at this level of the power grid
- But since then, few utilities outside of New York have used DR in this way; instead it has been largely viewed as a bulk-power system resource
- Recent investments in AMI digitally connect homes and small businesses with the utility at levels of the distribution system where they could potentially act as a resource to meet grid needs

Scoping Study

- Identify the needs of a distribution system with high penetration levels of distributed energy resources;
- Define a suite of services based on those changing operational needs that could be provided by local resources;
- Identify existing and future DR opportunities' ability to provide these distribution system services; and
- Provide a qualitative assessment of coordination issues that bulk-power and distribution system providers of DR opportunities will need to address.

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Characteristics of Services to Manage Distribution System

System Issue	Proactive/Reactive management strategy	Present (often manual) strategies	Potential active management strategies
Maxiumum Capacity Relief	Proactive	Load transfer	Automated reconfiguration / net load reduction
Emergency Load Transfer	Reactive	Load transfer	Automated reconfiguration / net load reduction
Steady State Voltage Management	Proactive	Load-tap changers, regulators, capacitor banks (normally automatic)	Inductive load and inverter-based load management, reactive power injection
Power Quality (transient voltage, harmonics)	Reactive	Manual ad hoc response	Inverter-based load management
Phase Balancing	Proactive	Manual redistribution	Reducing or increasing phase loading
Outage Recovery	Reactive	Manual reconfiguration and load recovery	Automated reconfiguration, Managing through staggered load pickup

Challenges of Increased DER Penetration

- Recent rapid deployment of DER has largely been and is likely to be in the near future uncontrolled and unmanaged in most parts of the United States
- DER introduces stochastic output, two-way power flows, rapid changes in real power flows, and new loading patterns on distribution system equipment all of which can create problems for system operators and planners
- At low penetration levels of DERs, current operational practices and distribution system equipment are adequate to maintain the reliability and stability of the local distribution system
- As DER penetration approaches the hosting capacity of the network or circuit, they can cause a myriad of distribution grid management challenges for system planners and operators

Benefits of Increased DER Penetration

- Locational benefits inure due to the reduction of system losses as the DER reduces the need to deliver power from generators that are miles away.
- The emergence of interconnected “microgrids” with controllable DER may ensure grid functionality in specific locations despite outage conditions elsewhere.
- If through planning efforts, these resources can be incentivized to be located in the right place in the distribution grid, then they may defer or replace conventional infrastructure build-out.

Characteristics of Services to Manage Distribution System

	Procurement or Schedule	Advanced Notice	Response Time	Duration of Response	Frequency	Geographic Specificity
Max. Capacity Relief	Years (planning) or Day-ahead (operation)	Day-ahead	10-30 mins	<4 hrs	Seasonal but potentially multiple times per day	One level below overloaded equipment
Emergency Load Transfer	Years (planning)	0.5 to 4 hours	Up to 30 mins	<4 hrs	Infrequent	Substation to transformer
Steady State Voltage Mgmnt	Years (planning)	<1 min	Secs to mins	Continuous	Continuous	Close proximity to affected area
Power Quality	Years (planning)	<1 min	<1 sec	Continuous	Continuous	Substation to transformer
Phase Balancing	Years (planning) or Day-ahead (operation)	Day-ahead	Secs to mins	Continuous	Continuous	Substation to secondary feeder
Outage Recovery	Years (planning)	<1 min	Secs to mins	<1 hour	Infrequent	Substation to transformer

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Types of DR Opportunities

Time-Based Retail Rates DR signal: Price Level	Incentive-Based Programs DR signal: System State
Time-of-Use (TOU)	Disconnectable
Critical Peak Pricing (CPP)	Configurable
Day-Ahead Real-Time Pricing (DA-RTP)	Manual
Real-Time Real-Time Pricing (RT-RTP)	Behavioral
	Energy Bidding
Wholesale DR Programs	*Capacity Bidding*
	Ancillary Services Bidding

Interruptible
DLC w/ A/C Switch

Curtailable w/ Control
DLC w/ PCT

Curtailable w/o Control
Peak-Time Rebate

Home Energy Report

Characteristics of DR Opportunities

Level	High	Moderate	Low
Signal Variability	DR Signal level is able to adjust dynamically to reflect system or market outcomes	DR Signal level is able to adjust according to pre-assigned level(s)	DR Signal level is static
Targeted Geographic Specificity	DR Signal set at primary feeder	DR Signal set at secondary feeder	DR Signal set system wide
Temporal Variability	DR Signal level is able to adjust at any time	DR Signal able to adjust only over pre-defined periods	DR Signal is always constant
Availability	Frequency of DR Signal change is unlimited	N/A	Frequency of DR signal change is limited
Advanced Notice	Five minutes or less notice required of a DR signal change	Four hours to 5 minutes of a DR signal change	More than 4 hour notice of a DR signal change
Automation	Response to DR Signal change relies on technology without customer override	Response to DR Signal change relies on technology with customer override	Response to DR Signal change may or may not rely on technology

Characterization of Current DR Opportunities

DR Opportunity (1)	Targeted Geographic Specificity (2)	Signal Variability (3)	Temporal Variability (4)	Availability (5)	Advanced Notice (6)	Automation (7)
TOU	○	⊙	⊙	○	○	○
CPP	○	⊙	⊙	○	○	○
DA-RTP	○	●	●	●	○	○
RT-RTP	○	●	●	●	⊙	○
Disconnectable	○	⊙	●	○	●	●
Configurable	○	⊙	●	○	●	⊙
Manual	○	⊙	⊙	○	⊙	○
Behavioral	○	○	○	○	○	○
Ratings Legend	○=System, ⊙=Secondary feeder ●=Primary feeder	○=Static ⊙=Pre-set ●=Dynamic	○=None ⊙=Set of hour ●=Any time	○=Limited ●=Unlimited	○=More than 4 hours ⊙= 6 min – 4 hours ●= 5 min. or less	○=Manual, ⊙=Automation with customer override ●=Automation without customer override

Lack of Geographic Specificity in DR Signal Makes DR Opportunities Ineffective at Providing Any Distribution Services

Distribution System Service	Max Capacity Relief	Emergency Load Transfer	Voltage Management	Outage Recovery	Power Quality	Phase Balancing
TOU	•	•	•	•	•	•
CPP	•	•	•	•	•	•
DA-RTP	•	•	•	•	•	•
RT-RTP	•	•	•	•	•	•
Disconnectable	•	•	•	•	•	•
Configurable	•	•	•	•	•	•
Manual	•	•	•	•	•	•
Behavioral	•	•	•	•	•	•

Legend

•	Ineffective at providing distribution system service
○	Minimally effective at providing distribution system service
◎	Reasonably effective at providing distribution system service
●	Highly effective at providing distribution system service

Geographic Specificity in DR Signal Enables DR Opportunities to Provide More Distribution Services

Distribution System Service	Max Capacity Relief	Emergency Load Transfer	Voltage Management	Outage Recovery	Power Quality	Phase Balancing
TOU	•	•	•	•	•	•
CPP	○	•	•	•	•	•
DA-RTP	○	•	•	•	•	•
RT-RTP	○	•	•	•	•	•
Disconnectable	●	◎	◎	◎	•	•
Configurable	○	•	•	•	•	•
Manual	○	•	•	•	•	•
Behavioral	•	•	•	•	•	•

Legend

•	Ineffective at providing distribution system service
○	Minimally effective at providing distribution system service
◎	Reasonably effective at providing distribution system service
●	Highly effective at providing distribution system service

Control Tech of Inverter Loads and Advanced Grid Sensors Enables More Services to be Provided

Distribution System Service	Max Capacity Relief	Emergency Load Transfer	Voltage Management	Outage Recovery	Power Quality	Phase Balancing
TOU	•	•	•	•	•	•
CPP	○	•	•	•	•	•
DA-RTP	○	•	•	•	•	•
RT-RTP	○	•	•	•	•	•
Disconnectable	●	◎	◎	◎	○	◎
Configurable	○	○	•	•	○	○
Manual	○	•	•	•	•	•
Behavioral	•	•	•	•	•	•

Legend

•	Ineffective at providing distribution system service
○	Minimally effective at providing distribution system service
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Issues/Concerns/Challenges

- Joint use of DR for bulk power and distribution system operations may create new challenges
  - Load increases/decreases called for at one level of the system may create or exacerbate problems at other levels
  - Dispatch in opposing directions by bulk and distribution system program providers
  - Joint dispatch in same direction by bulk and distribution system program providers

Greater Coordination Will Be Required

- Bulk power and distribution system program providers will need to be better coordinated
  - Promulgate market and/or program rules
    - Identification of minimum load change that warrants communication and/or coordination
    - Hierarchy of dispatch or performance
  - Central authority that coordinates efforts of all program providers

Conclusions

- Given current designs and use of DR Opportunities, the lack of distribution-level geographic specificity makes it unlikely can positively effect distribution system operations and planning activities
- Simple changes to design can enable DR Opportunities to provide a subset of distribution system services
- In order to efficiently consider all resource options, utilities could move towards increased reliance on integrated resource planning at the distribution level which would also support greater coordination between bulk power and distribution system planners
- Increased deployment of DR opportunities can only occur regulators better align incentives for distribution utilities to vigorously pursue them and effectively design and market them

Questions/Comments

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