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Governor's Two-Storm Panel: Distribution Infrastructure Hardening Options and Recommendations

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December 14, 2011

Topics for today's presentation

- Review of infrastructure hardening/expected outcomes
- Share experiences from other utilities and states
- Describe options, unit costs and total costs for infrastructure hardening scenarios at CL&P
- Discuss CL&P's initial infrastructure hardening recommendations and implications

Reprise of Distribution Infrastructure Hardening Techniques and Application Options

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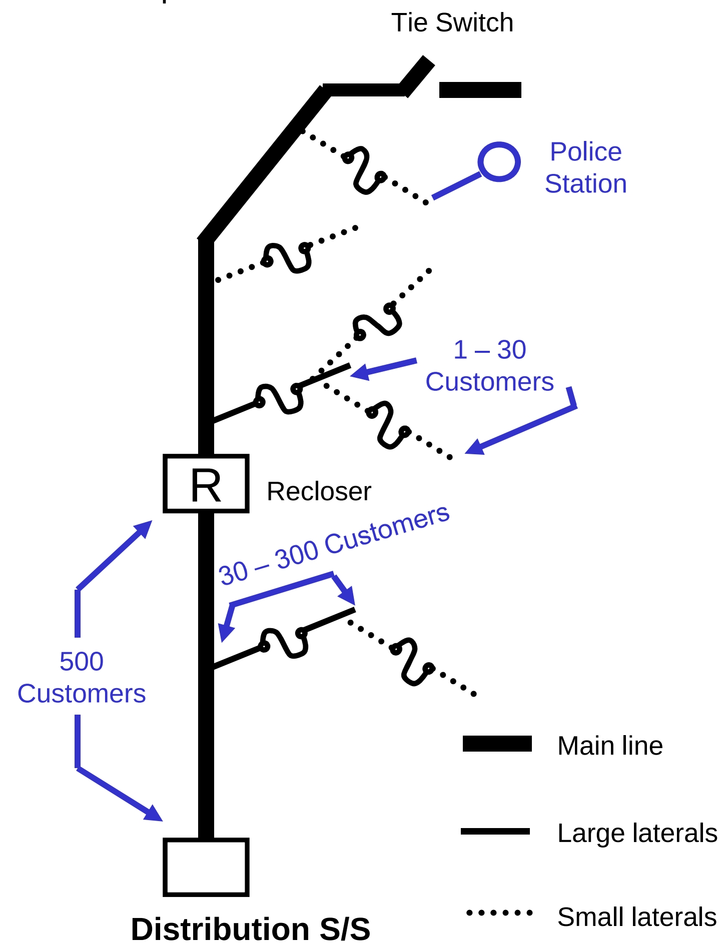
As we discussed previously….

Distribution infrastructure hardening techniques fall into four general categories

- Vegetation Management
  - Cycle – Frequency of trim
  - Clearance specifications
  - Risk tree removal
  - Incremental overhang removal
- Structural Hardening
  - Poles, cross arms, wire ties
  - Pole guying
  - Span length control
- Electrical Hardening
  - Wire size and type
  - Line sectionalizing
  - Lightning protection
- Undergrounding
  - Replace overhead conductors with underground
  - Requires replacement of some customer-owned equipment

These techniques can be applied to different portions of the infrastructure



An optimal hardening program will apply effective technique(s) to the portions of the circuit where there will be significant impact.

Effects of Vegetation Management Techniques

How does storm hardening reduce the impact of major storm events?

Hardening Technique	Targeted Areas	Description of Effect of Hardening
Vegetation Management	Trees	• Removal of overhanging branches and trees at risk of falling into utility lines reduces tree initiated weather related interruptions

Trimmed to specifications, but with overhangs

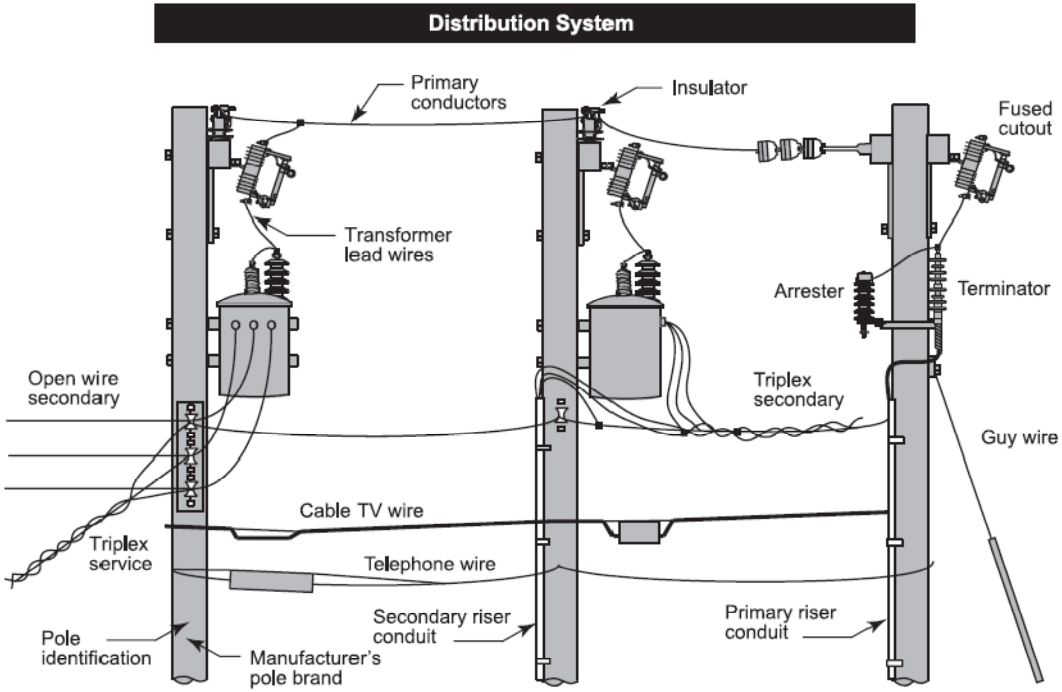
After enhanced tree trimming

Expanded or enhanced tree trimming is the most cost effective way of reducing storm impact on distribution systems.

Effects of Structural Hardening Techniques

How does storm hardening reduce the impact of major storm events?

Hardening Technique	Targeted Areas	Description of Effect of Hardening
Structural	Poles, pole tops, cross arms, guying	• Replaced, upgraded or "unloaded" structures supporting utility lines will better withstand higher mechanical stresses which occur during (ice, snow, wind) events



Structural upgrades are generally targeted toward bringing older construction up to more modern requirements and standards which result in a stronger infrastructure.

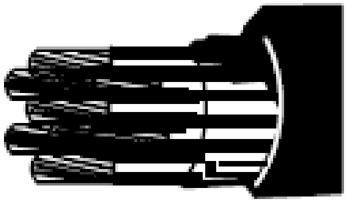
Effects of Electrical Hardening Techniques

How does storm hardening reduce the impact of major storm events?

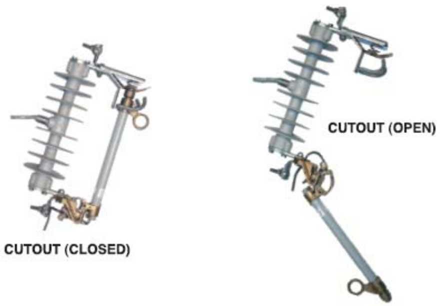
Hardening Technique	Targeted Areas	Description of Effect of Hardening
Electrical	Wire, circuit protection	• Replacement of "bare" wire with "covered" tree resistant wire reduces number of tree related outages and is often mechanically stronger • Adding in line protective devices (fuse/cutout) reduces numbers of customers impacted by outages

Bare Wire Cable

Spacer Cable



Covered Wire Cable



Fuse cutout

Effects of Undergrounding Techniques

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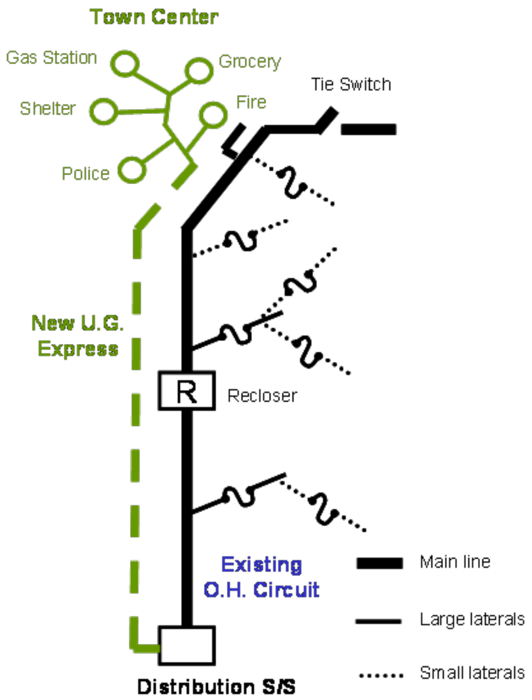
How does storm hardening reduce the impact of major storm events?

Hardening Technique	Targeted Areas	Description of Effect of Hardening
Undergrounding	Overhead circuitry	• Underground circuitry which replaces or supplements overhead circuitry is largely impervious to most storm events



The "express" underground circuit concept places important facilities in town or regional centers on a supply that is unlikely to be impacted by major storms in the northeast.

Infrastructure Hardening Experience in Florida

- Florida Public Service Commission mandated a series of storm hardening activities after 2005 hurricanes[1]
  - Eight-year wooden pole inspection program
  - Reduction in the vegetation management cycle
  - Distribution geographic system (GIS) enhancement
  - Post-storm data collection and forensic analysis
  - Collaborative research
    - Effects of hurricane winds and storm surge
    - Vegetation management
    - Undergrounding of utility infrastructure

- Florida Power & Light (FPL) also implementing new standards for key facilities including revision of pole design criteria and is conducting incremental hardening strategies to increase strength of circuit backbones, including[2]:
  - Use of non-wood pole materials (steel, concrete) for critical poles
  - Shorten the span between poles
  - Install guy wires and upgrade cross arm materials

1 Represent distribution and storm hardening related initiatives identified in Order No. PSC-06-0351-PAA-EI.
2 FPL Electric Infrastructure Storm Hardening Plan, filed May 3, 2010.

Infrastructure Hardening Experience in Texas and Oklahoma

Texas Analysis of Cost effective Storm Hardening Programs after Hurricanes Rita and Ike [1]

- Improved post-storm data collection or carefully designed post-storm data collection programs that capture key features at failure sites and are statistically significant.
- Hazard tree removal (dead or diseased trees outside of a utility's right of way).
- Targeted electric distribution hardening focusing spending to high-priority circuits, important structures, and structures that are likely to fail.

Oklahoma Gas & Electric after the December 2007 Ice Storm[2]

- Aggressive Vegetation Management Investment Breakdown
  - Move to a four year cycle
  - Removal of risk trees
  - Herbicide program for rural areas
  - 4 ft additional clearance over standard
  - Removal of large trees on feeder lines
  - Remove overhang during cycle
  - "Right tree in the right place" program
- Pilot to install breakaway connectors on the pole side of the service drops.
- Pilot to convert overhead services to underground.
- Increased investments in distribution automation/smart grid.

1 Cost-benefit analysis of the deployment of utility infrastructure upgrades and storm hardening programs. Quanta Technologies for Public Utilities Commission of TX. March 2009.
2 OG&E Distribution Hardening Plan presentation to Oklahoma Corporation Commission. August 2008.

Summary of Recent Undergrounding Studies

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Texas – 2009[1]

- Cost of undergrounding was estimated at $35 billion for the entire regional distribution system making it cost prohibitive.
- Selective undergrounding could make sense for new land development and to serve critical facilities when other excavation work is ongoing.

Oklahoma – 2008[2]

- Information gathered indicated that undergrounding all the facilities is not a feasible solution.
- Found that no Public Utility Commission has found a mechanism to permit undergrounding on an universal basis.
- Preferred approach for undergrounding is to focus on certain areas (i.e., poorly performing circuits, secondary line extensions).
- Estimated costs at $30 billion for just distribution and that electric bills would go up $80 to $260 per month.

Florida – 2008[3]

- Determined that it is well-known that the conversion is costly and costs always exceed benefits.
- Found that there is insufficient data to show that this high cost is 100% justifiable by quantifiable benefits such as reduced O&M and reduced hurricane damage.

1 Electric Service Reliability in the Houston Region, Mayor's Task Force Report, April 2009.
2 Oklahoma Corporation Commission's Inquiry into Undergrounding Electric Facilities in the State of Oklahoma, Prepared and Submitted by Oklahoma Corporation Commission Public Utility Division Staff, June 2008.
3 Undergrounding Assessment Phase 3 Report: Ex Ante Cost and Benefit Modeling, by Quanta Technology. May 2008.

Studies have shown that undergrounding is not a cost effective solution, except on specific targeted situations.

Unit Cost Estimates of Different Hardening Activities

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Initial estimates

	Hardening activity	Unit cost	Installed cost per unit[1]
Vegetation management	Four year cycle	Mile	$6,000
	Enhanced tree trim and removal, focusing on overhang and risk tree removal	Backbone mile Lateral mile	$20,000 $40,000
Structural hardening	Pole replacement to improve storm performance	Backbone pole Lateral pole	$6,000 $5,000
	Pole top/cross arm/pin/tie refurbishment	Pole	$1,000
	Pole guying	Pole	$2,000
Electrical hardening	Bare wire reconductoring with tree wire (includes poles, cross-arms, covered wires)	Backbone mile Lateral mile	$700,000 $450,000
	Fuse sectionalizing	Pole	$1,500
Undergrounding	Express circuit to town center areas undergrounding	UG Mile	$1,000,000 - $3,000,000[2]

1 All-in costs including labor, materials, trucks/vehicles, etc.
2 Based on estimates and review of analysis conducted in other jurisdictions

Initial estimates of 10-Year Total Costs of Hardening Activities by Infrastructure Segment on CL&P System

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Initial estimates

	Hardening activity	Harden circuit backbones	Harden large laterals	Harden small laterals	UG express circuits	Total
Vegetation management	Four year cycle	$13M 208 miles/yr	$19M 313 miles/yr	$19M 313 miles/yr	--	$51M
	Enhanced tree trim and removal	$84M 4,180 miles	$250M 6,260 miles	$250M 6,260 miles	--	$584M
Structural hardening	Pole replacement	$157M 26,200 poles	$197M 39,400 poles	$197M 39,400 poles	--	$551M
	Pole refurbishment	$18M 17,500 poles	$26M 26,250 poles	$26M 26,250 poles	--	$70M
	Pole guying	$7M 3,500 poles	$11M 5,250 poles	$11M 5,250 poles	--	$29M
Electrical hardening	Bare wire reconductoring	$0.7B 1,045 miles	$0.7B 1,565 miles	$0.7B 1,565 miles	--	$2.1B
	Fuse sectionalizing	NA	$8M 5,000 poles	$8M 5,000 poles	--	$16M
Under-grounding	Express circuit to town center areas	--	--	--	$1.0B 500 mi. for 100 circuits	$1.0B
Total		$1.0B	$1.2B	$1.2B	$1.0B	$4.4B
Res. monthly bill impact (year 10)		$5.89	$7.13	$7.13	$5.88	$26.03

CL&P's Infrastructure Hardening Recommendation Objectives

- Achieve a significant improvement on infrastructure performance during weather events (small, medium and large).
- Use techniques that have been proven effective at CL&P or elsewhere in the industry.
- Focus on comprehensive review of existing standards to enact changes on an ongoing basis.
- Manage customer bill impacts by focusing on cost-effective solutions and deploying the infrastructure hardening program over time.
- Leverage new distribution automation and smart grid technologies to improve the real time monitoring and operations of the distribution system.

CL&P Key Recommendations

CL&P recommends implementing a 10-year hardening program focused on the circuit backbones and large laterals.

	Hardening activity	Harden circuit backbones	Harden large laterals	Total
Vegetation mana-gement	Four year cycle	$13M 208 miles/yr	$19M 313 miles/yr	$32M
	Enhanced tree trim and removal	$84M 4,180 miles	$250M 6,260 miles	$334M
Structural hardening	Pole replacement	$157M 26,200 poles	$197M 39,400 poles	$354M
	Pole refurbishment	$18M 17,500 poles	$26M 26,250 poles	$44M
	Pole guying	$7M 3,500 poles	$11M 5,250 poles	$18M
Electrical hardening	Bare wire reconductoring	$0.7B 1,045 miles	$0.7B 1,565 miles	$1.4B
	Fuse sectionalizing	NA	$8M 5,000 poles	$8M
Total		$1.0B	$1.2B	$2.2B
Res. monthly bill impact (year 10)		$5.89	$7.13	$13.02

Program would include two key elements:

- Implementation of an enhanced **vegetation management** program.
- Implementation of a **structural and electric hardening** program.

CL&P recommends the initial evaluation of **selective underground options** and **back-up generation** alternatives for town centers and other critical locations.

CL&P is beginning the implementation of three other infrastructure hardening initiatives:

- Evaluation of **existing design standards** to address recent extreme weather conditions.
- Expansion of existing **distribution automation/smart grid** capabilities to enhance real time monitoring and operations of the distribution system through targeted pilots.
- Enhancement of **post-storm forensic** process and capabilities.

Beyond year 10, CL&P might extend **enhanced tree trimming** for small laterals.

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Performance Impact from a Hardening Program

Preliminary Estimates

We estimate that the recommended program would have the following benefits:

- Reduction in numbers of customers out by 30-40%
  - Storm like Irene would reduce customers out from 671k to ~430k
  - Storm like the Nor'Easter would reduce customers from 831k to ~590k
- Reduction in restoration duration by ~2 days in similar events, which leads to reduced storm restoration costs and reduced impact to economic activity in the state.
- Improvement of 35% in annual SAIDI – System Average Interruption Duration Index (from 135 to 100 minutes).
- Reduction in the number of customers with multiple outages and customers with long outage durations
- Reduction in annual O&M expense of ~$13M.

Additional Impact of a Hardening Program

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In addition we believe a hardening program would have additional second level benefits including:

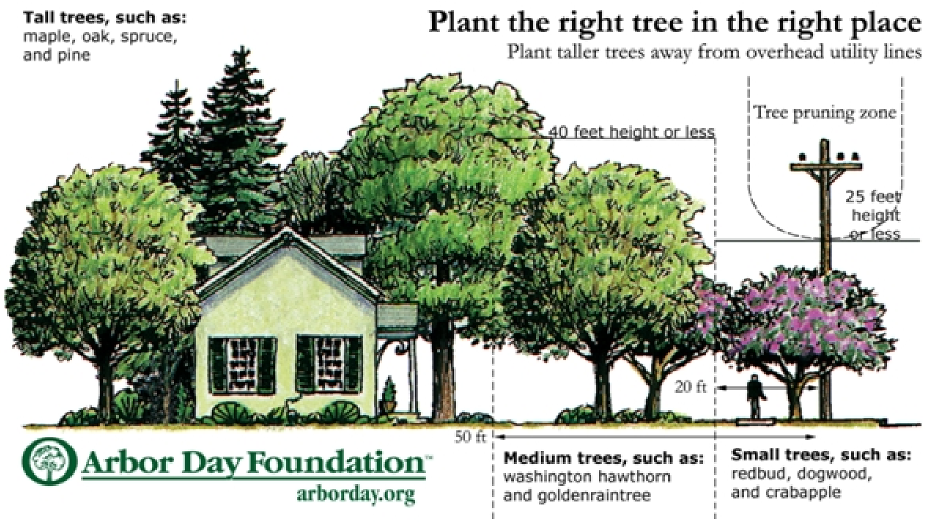
- Enhanced storm preparedness as the company would have permanent access to a higher number of crews.
- Economic boost from the hardening investment leading to increased number of jobs, increased economic activity and increased taxes both for the state and municipalities.
- Important reduction in electric line losses by reconductoring bare wire.
- Ability to establish a plan to address attrition due to an aging workforce.
- Proactive mitigation of the impact of an aging infrastructure.

Questions

Appendix – Key initiatives

Implement an enhanced vegetation management program

- Move to a 4 year cycle, including a 2-year mid-cycle inspection/trim on backbones.
- Conduct an enhanced tree trimming program on all backbone and large laterals rights-of-way, with special focus on removal of overhangs and risk trees.
- Incent a Right Tree, Right Place program.



Source: Arbor Day Foundation.

Appendix – Key initiatives

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Implement a long-term structural and electric hardening program

- Invest significant capital over the next 10 years to harden the system, with initial focus on circuit backbones, large laterals, and town centers.

- Develop a hardening program based on a detailed assessment by circuit and pole using outside engineering services where necessary. Options for circuit/pole will include:
  - Older (higher class) pole replacements
  - Addressing heavily loaded poles
  - Refurbishment of pole tops, cross-arms, pins, ties, etc. where need is indicated by age, visual inspection or loading
  - Guying upgrade as needed for critical structures
  - Bare wire reconductoring in heavily treed areas
  - Sectionalize fusing

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Appendix – Key initiatives

Evaluate selective underground options and back-up generation alternatives

- Given the wide variance in undergrounding cost estimates and CL&P's limited practice, CL&P recommends a partnership with a university to conduct a detailed assessment of undergrounding to truly assess the costs and benefits in the specific circumstances of CL&P's territory.

- In addition CL&P recommends conducting a parallel analysis of the trade-offs between undergrounding and multiple back-up generation options including:
  - Diesel
  - Natural gas
  - Combined heat and power (CHP)
  - Micro-turbine
  - Combustion turbine
  - Fuel cell
  - Emerging/future applications such as battery energy storage and/or use of electric vehicles as back-up generators

State Reports Conversion Cost Comparison

State Year of Study	Estimate / Actual Cost	Project Information	Cost per Mile
EEI, 2009	Estimate	Minimum Cost	$80,000
North Carolina, 2003	Estimate	Minimum Cost	$151,000
Maryland, 1999	Estimate	Minimum Cost	$350,000
Florida, 2007	Actual	Allison Island	$414,802
Florida, 2007	Actual	County Road 30A	$893,470
Florida, 2007	Actual	Sand Key	$917,532
Virginia, 2005	Estimate	Average Cost	$1,195,000
Oklahoma, 2008	Estimate	Average Cost	$1,540,000
Florida, 2007	Actual	Pensacola Beach	$1,686,275
Maryland, 1999	Estimate	Maximum Cost	$2,000,000
EEI, 2009	Estimate	Maximum Cost	$2,130,000
North Carolina, 2003	Estimate	Maximum Cost	$3,000,000

Source: Out of Sight, Out of Mind Revisited - An Updated Study on the Undergrounding Of Overhead Power Lines produced by EEI, December 2009

Source: EPRI.

Appendix – Key initiatives

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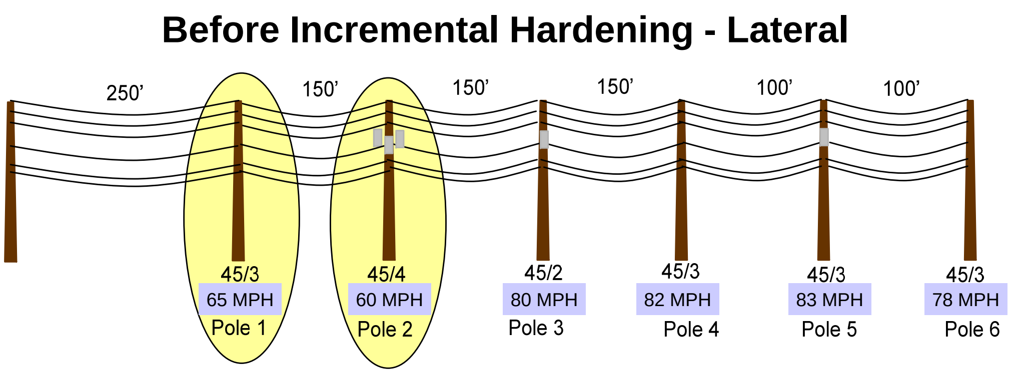
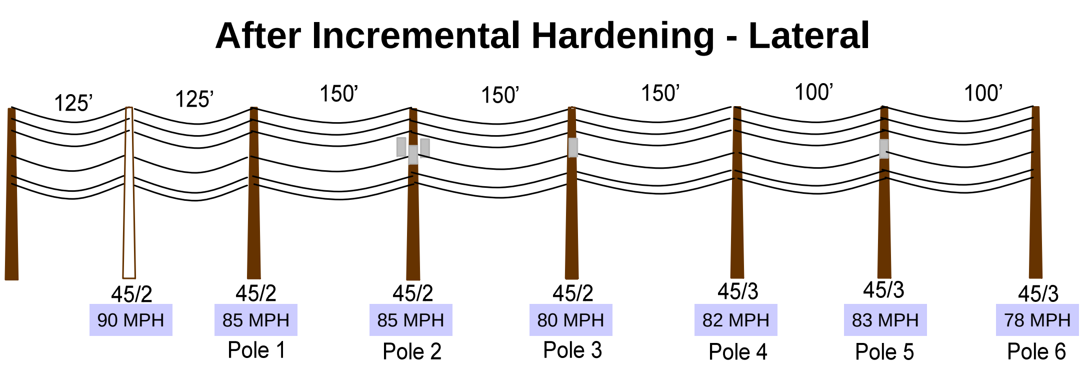
Consider new design standards to address recent extreme weather conditions

- Re-evaluate design standards for all critical infrastructure assets. Standards to be re-evaluated include at a minimum:
  - Pole classes and alternative materials
  - Cross arm material options
  - Depth of poles depending on soil condition and pole class
  - Structure loading guidelines/practices
  - Spacing between poles
  - Guying upgrades
  - Break-away conductors/taps
  - Others
- Determine like for unlike program replacements
- Use new standards for any going forward construction during normal course of business replacement

Illustrative





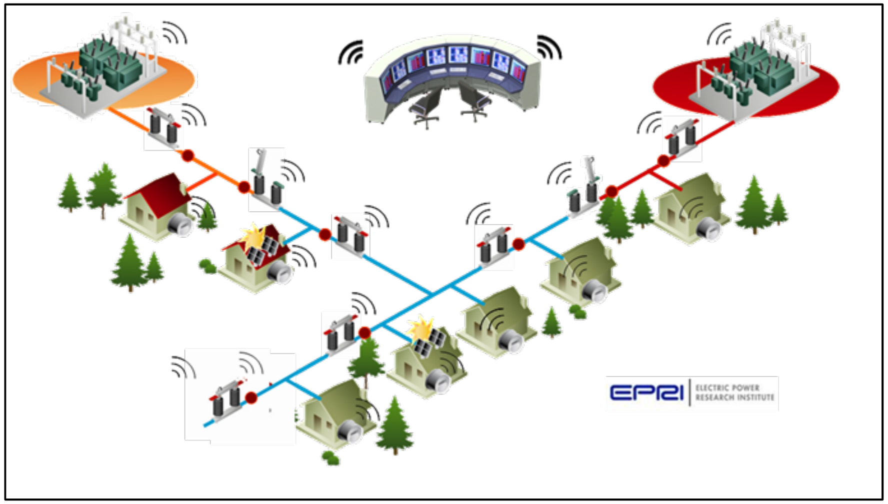
Appendix – Key initiatives

Expand distribution automation/smart grid capabilities to enhance real time monitoring and operations of the distribution system

- CL&P already is able to isolate faults and restore service automatically without operator intervention, representing one of the most automated systems in the country.

- CL&P is considering further automation of the system by launching a pilot to determine the operational implications, costs and benefits of the following next generation smart grid capabilities:
  - Moving from 500 to 250 customer segments through the installation of sectionalizing switches
  - Smart sensors to detect underground, direct buried cable and overhead faults
  - Smart meters to be used for outage detection

- Implement technology initiatives that will enhance CL&P's real time awareness of the system (i.e., trouble spots, internal and foreign crew location, work package status, town priority lists, restoration projections) as well as provide enhancements to information available to customers (i.e., web page, mobile applications).



Navtrak GPS Vehicles Statewide View