Seismic Resiliency
What a Utility Should Know to Keep the Lights On

PRESENTED BY
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Introduction

- Seattle City Light
  - Over 100 Years Old!
  - Serves City of Seattle
  - 700,000 Customers

- Infrastructure
  - 7 Hydroelectric Facilities
  - 150 Miles of Transmission
  - 14 Substations
  - Network Distribution

- Infrastructure Support
  - Line Crews, Steel Shop, Carpentry, Civil and Substation Crews
  - System Operation Center and Service Centers
Abstract

• Worried About the Big One?
• What about Costs to Upgrade?
• The Easy Fix?
Seismic Resiliency

• Seattle – Diverse and Growing
  • Economic
  • Educational
  • Health
  • Community Services
  • Media
  • Religious
  • Cultural
  • Government
  • Family
Seismic Resiliency

• City Life Dependent on Functional Framework
Seismic Resiliency

• Functional Framework Is Inter-dependent
Seismic Resiliency

- Framework Interaction Extremely Complex

Energy
- Federal
- State
- Local

Transportation
- Airports local/central
- Highway (state/city)
- Water (state/local)

Buildings
- Business
- Government
- Hospitals
- Education
- Residential
- Emergency Response

Communication
- Phone
- Television
- Emergency
- Internet

Water
- Local
- Municipal

Wastewater
- Local
- Municipal
• When is Functional Framework Non-Functional?
Seismic Resiliency

• Post Disaster Provisions...days, weeks, months?
• The Really Big One – The New Yorker

“When the next full-margin rupture happens, that region will suffer the worst natural disaster in the history of North America....FEMA calculates that, across the region, something on the order of a million buildings—more than three thousand of them schools—will collapse or be compromised in the earthquake.”

-Kathryn Schulz
• The Really Big One Vs Aging Infrastructure...Who Wins?
Seismic Resiliency

- System Earthquake Risk Assessment – SERA
- Many West Coast Utilities Conducting Evaluations

<table>
<thead>
<tr>
<th>Earthquake</th>
<th>Equip. Damaged</th>
<th>Damaged XFMR</th>
<th>Repair Cost (million $)</th>
<th>Outage in Days</th>
<th>Repairs in Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seattle Fault M7.1</td>
<td>105</td>
<td>0</td>
<td>$5-$17</td>
<td>2.1-6.8</td>
<td>19-63</td>
</tr>
<tr>
<td>S. Whidbey Island M7.0</td>
<td>98</td>
<td>4</td>
<td>$5-$24</td>
<td>2.0-8.1</td>
<td>21-92</td>
</tr>
<tr>
<td>Cascadia M9.0</td>
<td>611</td>
<td>13</td>
<td>$30-$107</td>
<td>11.2-42</td>
<td>117-410</td>
</tr>
<tr>
<td>Cascadia M8.0</td>
<td>432</td>
<td>8</td>
<td>$18-$68</td>
<td>6.8-24</td>
<td>71-263</td>
</tr>
</tbody>
</table>
• Imagine the Lights On!
  • Exceed Customers Expectation
  • Electrical Grid not Being Serviced
  • Aid to Business and Residential Recovery
  • Supporting Emergency Response of Hospitals, Fire, Police and Communications
Where or Rather When to Start?

• Earthquake Probabilities
  • 10% in 50 Years it Will Happen
  • 90% in 50 Years Says it WON'T!
  • How to Spend the Next 50 Years?

• Equipment Life
  • Typical Substation Equipment has 20-50 Year Life
  • In the Next 50 Years Equipment Will Be Replaced
  • If Each Installation Meets Seismic Criteria, in 50 Years the Substation will be Ready for the Shaker!
  • Easy Fix - START NOW!
• Setting the Standard
  • Essential Objective
    • Life Safety for Very Rare Earthquake
    • Immediate Occupancy for Rare Earthquake
  • Equipment, Design, Installation to Meet or Exceed Standard
Seismic Resiliency

- Rough Road Ahead!
  - New Approaches and Old Timers.
  - Added Cost?
  - New Construction Techniques
  - Seismic Considered Early in Project Conception
  - Communication/Education is Critical
  - Seismic Policy and Seismic Specifications!
## Seismic Resiliency

### Substation Seismic Upgrade Approaches

<table>
<thead>
<tr>
<th>Design Approach</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strength</strong></td>
<td>Low tech/cost, traditional method</td>
<td>Large force, field complications, performance?</td>
</tr>
<tr>
<td><strong>Stiffness</strong></td>
<td>Lower forces, minimal costs</td>
<td>Field and supplier coordination, performance?</td>
</tr>
<tr>
<td><strong>Displacement</strong></td>
<td>Low forces, operational performance</td>
<td>Higher first costs, displacement requirements,</td>
</tr>
<tr>
<td><strong>Damping</strong></td>
<td>Lower forces, less impact on existing structures</td>
<td>Raised cost? Engineering, shake table testing, detailing</td>
</tr>
</tbody>
</table>
Seismic Resiliency
Seismic Resiliency

• Strength Approach - Batteries
  • Battery Rack Replacements
    • 20 year Life
    • Specifications
  • Strength - Large Forces and Overturing Demands
  • Seismic Qualification?
    • Not Zone IV, IBC
    • Use IEEE 693 High Seismic
  • Drilling into Air?
Seismic Resiliency

• Strength Approach - Batteries
• Other Construction Surprises
  • Battery Room and Clay Partition Wall
    • Wall Hazard to Equipment
    • Strongback Required
  • Costs
    • Seismically Qualified Rack
    • Strong Back Construction
  • Schedule Delay
  • Seismic Project Review Early
• **Strength Approach - Transformers**
  - Screen
  - Evaluate
    - Fv = Sa/R/I
    - Sa1 = 0.5
    - Sa2 = 1.0
    - Sa3 = 1.5
    - R = 1
    - I = 1.5
  - Upgrade
  - IEEE 693
Seismic Resiliency

• Strength Approach – Transformers – Field Coordination
Seismic Resiliency

• Discplacement Approach - Transformers
  • Transformers – 2015 ETS Conference Paper
  • Seismic Base Isolation of High Voltage Transformer – RS Cochran
    • SCL w/ (4) Isolated Transformers
    • Isolates from Ground Motion
    • Flexible Connections
    • Floating Slab/Stair
    • Triple Friction Pendulum Bearings
Seismic Resiliency

• Stiffness Approach – Substation Expansion
  • Structures with Frequencies $f>10$ hz and Seismic Amplification
Seismic Resiliency

- Stiffness Approach – Substation Expansion
  - Footprint of Stiff Structures and Yard Mobility
Seismic Resiliency

- Stiffness Approach – Substation Expansion
  - Design Priorities
    - Stiffness $f > 33$ hz
    - Maximize Usage of Yard
    - Aesthetics
Seismic Resiliency

• Stiffness Approach – Substation Expansion
  • CADD Files Used to Cut Steel
  • Fabrication by City Light Steel Crew
Seismic Resiliency

- Stiffness Approach – Substation Expansion
  - Circuit Switcher – Qualified to 14 ft – Installation Required 20ft!
  - Fabrication by City Light Steel Crew
Seismic Resiliency

• Stiffness Approach – Substation Expansion
  • 33 hz Structures, Open Spaces Vs. the Old Forest
Seismic Resiliency

- Damping Approach – Capacitor Bank
  - Tall, Narrow, Heavy = Seismic Nightmare
  - Already Purchased/Ready to Install/Not Qualified
Seismic Resiliency

• Damping Approach – Capacitor Bank
  • Ring Spring Dampers
  • Act Like Shock Absorbers
  • Reduce Seismic Demand by 2 to 3x
    • Modified RRS per ASCE 41
Seismic Resiliency

- Damping Approach – Capacitor Bank
  - Ring Spring Damper Testing
  - Damping Characteristics
• Damping Approach – Capacitor Bank
  • Rack – Not Seismically Qualified
  • Modify Legs with Dampers
  • Construction/Design by City Light
Seismic Resiliency

• Damping Approach – Capacitor Bank
  • Install on Shims, Preload, Remove Shims
  • Damping Design Per ASCE
  • Construction/Design by City Light
Seismic Resiliency

• Building Upgrades
  • Least Cost – Structure Only - $50/SF
  • Highest Cost – Structure/Non-Structure/Occupied
    • Off Hours Construction
    • Architectural Finishes/Re-roof
    • Energy Requirement
    • Nonstructural
Seismic Resiliency

• Building Upgrades—Structural
  • Screen – ASCE 41 – 16 – Tier 1
  • Evaluate – ASCE 41 – 16 – Tier 2
  • Upgrade – IBC/ASCE 7 and/or 41
Seismic Resiliency

• Building Upgrades - Nonstructural
  • Standards
    • FEMA 74, ASCE 41, ASCE 7
  • Components
    • Partitions, Ceilings, Lighting
  • Component Bracing
    • Parapets, Cladding, Contents
    • Hazardous Material
  • Equipment – Mech/Elect
  • Equipment Supports
  • Connections/Attachments
  • Differential Displacement
Seismic Resiliency

• Building Upgrades – Construction
  • Mitigating Construction Noise and Dust
    • Working Off Hours
    • Protecting Equipment
Seismic Resiliency

• Building Upgrades – Seismic Standards and Resources
  • Design
    • ASCE 7 for New Buildings, Equipment Supports, Non-Structural
    • ASCE 41 for Existing Buildings, Equipment Supports, Non-Structural
    • ASCE Manual 113 – For Yard Equipment Supports and Foundations
    • IEEE 693 – For Ordering Substation Equipment
    • IEEE 1593 – Design of Flexible Buswork in Seismic Regions
    • FEMA – 74 for Design and Installation of Nonstructural Building Components
  • On Line Course
    • Oregon State University - Electrical Systems Resilience – 10-20 HR
    • https://pace.oregonstate.edu/catalog/electrical-systems-resilience
  • SERA
    • System Earthquake Risk Assessment
    • System Wide Evaluation
Seismic Resiliency

• Building Seismic Resilience of Utility
  • Specifications
  • Design
    • Strength
    • Stiffness
    • Displacement
    • Damping
  • Construction
Worried About the Big One?
  - Chances Are ...You Have Some Time.

Get Started
  - Seismic Policy
  - Specifications

Design Approaches
  - Strength
  - Stiffness
  - Displacement
  - Damping

The Easy Fix?
  - The Incremental Approach
Seismic Resiliency
What a Utility Should Know to Keep the Lights On

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