BC Hydro Strategy for Replacement of Equipment

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BC Hydro
The BC Hydro System
– Reliable Power, at low cost, for generations

• **Generation**
  – 41 Dam sites, 30 Hydro facilities and 9 Thermal units

• **Transmission**
  – 18,000 km of Transmission lines
  – 260 substations, 22,000 steel towers
  – Two Control Centers
  – Interconnect to Alberta and US

• **Distribution**
  – 56,000 km of Distribution lines
  – Approx. 900K poles, over 300K transformers
  – Non-integrated areas and DGs
  – Replacement Cost CAD$5.7B

• COMA/Customer ~US$120

• SAIDI = 5.2 hrs/yr (total); 4.1 hrs/yr (normalized)
The Challenge

• Provide an empirical evaluation of distribution system “health”, to gauge the effectiveness of asset maintenance and replacement investments.
  – Age is not an effective measure of “health”
  – System composed of many components of differing “value” (quantity, cost, impact on performance)
  – Definition of failure – functional versus conditional
  – Repair versus Replace, O&M versus Capital
Asset Health?

- On a scale of 1 to 10 how “healthy” is your transportation asset (car)?
Distribution Maintenance – Planning

1. Set Objectives
2. Define Asset Performance and Standards
3. Assess Condition
4. Build Plan
5. Execute Plan
6. Evaluate Performance
Set Objectives

There are two primary objectives of planning for maintenance and replacement capital:

– Ensuring that performance requirements are defined and met, both now and into the future
– Costs are minimized over the asset life-cycle.
Define Asset Performance and Standards

DM plans for maintenance and capital replacement programs from the ‘bottom-up’, based on the ability of each asset to meet its intended purpose. These purposes include:

1. Protecting workers and the public from electrical and other hazards;
2. Maintaining system capabilities such as delivering energy and lighting streets; and
3. Protecting equipment from catastrophic damage.
<table>
<thead>
<tr>
<th>Category</th>
<th>Activity</th>
<th>Cycle Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>O/H Public Safety</td>
<td>Inspection</td>
<td>Annual</td>
</tr>
<tr>
<td>O/H Infrared Thermography</td>
<td>Inspection</td>
<td>Urban(4 Yrs), Mixed(5 Yrs), Rural(DM PO)</td>
</tr>
<tr>
<td>O/H Air Break Disconnects</td>
<td>• Visual inspection</td>
<td>• Each time operated</td>
</tr>
<tr>
<td></td>
<td>• Infrequent operation, operate, lubricate</td>
<td>• 2 years</td>
</tr>
<tr>
<td></td>
<td>• Service and maintain (all)</td>
<td>• 7 years</td>
</tr>
<tr>
<td>Reclosers</td>
<td>• Oil, initial maintenance</td>
<td>3 years or 200 ops</td>
</tr>
<tr>
<td></td>
<td>• Vacuum, initial maintenance</td>
<td>5 years</td>
</tr>
<tr>
<td></td>
<td>• Electronic, initial maintenance</td>
<td>3 years, 1 year battery</td>
</tr>
<tr>
<td></td>
<td>• Subsequent cycle</td>
<td>Max. 5 years or 300 ops</td>
</tr>
<tr>
<td>Capacitors</td>
<td>• Visual inspection</td>
<td>Annual</td>
</tr>
<tr>
<td></td>
<td>• Oil switch, charge oil</td>
<td>5 years or 3,000 ops</td>
</tr>
<tr>
<td></td>
<td>• Vacuum switch</td>
<td>none</td>
</tr>
<tr>
<td>Step Voltage Regulators</td>
<td>• Inspection &amp; operation</td>
<td>Annual</td>
</tr>
<tr>
<td></td>
<td>• Oil sample, initial</td>
<td>1 year</td>
</tr>
<tr>
<td></td>
<td>• Subsequent sample</td>
<td>50,000 operations</td>
</tr>
<tr>
<td></td>
<td>• internal inspection</td>
<td>100,000 operations</td>
</tr>
<tr>
<td>Equipment Control Devices</td>
<td>• Inspection/Battery Changes</td>
<td>5 years</td>
</tr>
<tr>
<td>Poles</td>
<td>• FLT Cedar initial inspection</td>
<td>20-27 years</td>
</tr>
<tr>
<td></td>
<td>• FLT Non-Cedar initial inspection</td>
<td>14-21 years</td>
</tr>
<tr>
<td></td>
<td>• BT initial inspection</td>
<td>14-21 years</td>
</tr>
<tr>
<td></td>
<td>• UT &amp; HT in itial inspection</td>
<td>8-15 years</td>
</tr>
<tr>
<td></td>
<td>• All subsequent inspections</td>
<td>8 years</td>
</tr>
<tr>
<td>Street Lights</td>
<td>• Group relamping</td>
<td>4 years</td>
</tr>
<tr>
<td>URD, UD Public Safety</td>
<td>Inspection</td>
<td>Annual</td>
</tr>
<tr>
<td>Live Front Interior</td>
<td>Inspection</td>
<td>2 years</td>
</tr>
<tr>
<td>Dead Front Interior</td>
<td>Inspection</td>
<td>5 years</td>
</tr>
<tr>
<td>Vault and Padmount Thermography</td>
<td>Thermography network vaults, dual radial street</td>
<td>Annual</td>
</tr>
<tr>
<td></td>
<td>vaults, building vaults</td>
<td>Whenever padmount or vault opened</td>
</tr>
<tr>
<td></td>
<td>Thermography switchgear and transformers</td>
<td>Before switching done</td>
</tr>
<tr>
<td></td>
<td>Thermography switching kiosks, SICs</td>
<td></td>
</tr>
<tr>
<td>Network Transformers and Street Vaults</td>
<td>• Cleaning</td>
<td>Annual</td>
</tr>
<tr>
<td></td>
<td>• Visual</td>
<td>Annual</td>
</tr>
<tr>
<td></td>
<td>• Network protector functional test</td>
<td>Annual</td>
</tr>
<tr>
<td></td>
<td>• Oil dielectric test</td>
<td>Annual</td>
</tr>
<tr>
<td></td>
<td>• Transformer electrical tests</td>
<td>5 years</td>
</tr>
<tr>
<td></td>
<td>• Network protector internal inspection and calibration</td>
<td>5 years</td>
</tr>
<tr>
<td></td>
<td>• Switch compartment internal inspection and oil change</td>
<td>5 years</td>
</tr>
<tr>
<td></td>
<td>• Cleaning and lubrication of SICs</td>
<td>5 years</td>
</tr>
<tr>
<td></td>
<td>• Transformer oil sample for lab analysis</td>
<td>5 years</td>
</tr>
<tr>
<td>Building Vaults with Hydro Equipment</td>
<td>Visual inspection</td>
<td>Annual</td>
</tr>
</tbody>
</table>
Asset Condition
Traditional component failure models

- Hazard Rate “Bathtub” Curve

- Survivor Curve

92%
# Asset Health Index “Soccer Field”

<table>
<thead>
<tr>
<th>Asset Type</th>
<th>% of Asset F2006 (Units)</th>
<th>Areas of Concern</th>
</tr>
</thead>
<tbody>
<tr>
<td>OH Wires</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equip, Primary wire, svc, insulators</td>
<td></td>
<td>Automatic splices, Transformer reduced service life issue</td>
</tr>
<tr>
<td>Revenue Meters</td>
<td></td>
<td>2 T2 element, Schlumb. worm gear, A R-A demand display, PT/CT mtc, aging meters</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poles</td>
<td></td>
<td>Aging poles, Buprestid Beetle issue</td>
</tr>
<tr>
<td>Submarine &amp; UG Cables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feeder Cables</td>
<td></td>
<td>Aging Vancouver cables</td>
</tr>
<tr>
<td>Equipment</td>
<td></td>
<td>Transformer reduced service life issue</td>
</tr>
<tr>
<td>Civil Structures</td>
<td></td>
<td>Deteriorating manholes &amp; crushed ductbanks</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
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</tbody>
</table>

**FOR GENERATIONS**

- **Moderate to Good**
- **Fair (Attention within 10 years)**
- **Attention Now**
BC Hydro’s new Asset Replacement Index (ARI)

Asset Replacement Index is the ratio of:

\[ \text{NPV cost for O&M (until End of Life)} + \]
\[ \text{NPV cost Capital replacement (at End of Life)} + \]
\[ \text{NPV of all future O&M & Capital replacements} \]

And

\[ \text{Cost of Capital replacement Now} + \]
\[ \text{NPV cost of all future O&M & Capital replacements} \]

If Asset Replacement Index

\[ \geq 1 \text{ replace now!} \]
\[ >0.8 \text{ Red – plan for replacement within 4 years.} \]
\[ >0.5 \text{ Yellow – plan for replacement within 10 years.} \]
A Formula for Asset Replacement

\[
ARI = \sum_{t=0}^{n} (O & M + Rplace)_{t=n} + \sum_{t=n}^{\infty} (O & M + Rplace) \\
Rplace_{t=0} + \sum_{t=0}^{\infty} (O & M + Rplace)
\]

All Net Present Value (NPV)
ARI Considerations

• Data intensive, significant effort (e.g. ~900,000 poles).
• Age data not readily available for all assets (e.g. cables). Need to use proxies, or base on representative sample.
• Provides a long-term Maintenance capital plan for replacement based on established Maintenance and performance expectations.
• Does not provide direct indication of asset Maintenance “needs”. That is, an ARI that is green does not mean one can reduce Maintenance (O&M) spending.
• ARI related to health, but not equal to.
## Asset Replacement Index “Soccer Field”

<table>
<thead>
<tr>
<th>Asset Type</th>
<th>% of Assets F2007 (Units)</th>
<th>Areas of Concern</th>
<th>Replacement $M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeder, Submarine &amp; UD Cables</td>
<td>984</td>
<td>Aging Vancouver cables</td>
<td></td>
</tr>
<tr>
<td>Duct Banks</td>
<td>2,000</td>
<td>Deteriorating manholes &amp; crushed ductbanks</td>
<td></td>
</tr>
<tr>
<td>Equipment</td>
<td>1,038</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poles</td>
<td>2,964</td>
<td>Aging poles</td>
<td></td>
</tr>
<tr>
<td>Structure Attachments (Crossarms, Guys, Anchors)</td>
<td>1,061</td>
<td>Cutouts, crossarms, anchors, guy wires, Vancouver platforms</td>
<td></td>
</tr>
<tr>
<td>Equipment</td>
<td>407</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary and Secondary Wire</td>
<td>468</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Notes:
- **AHI** presents assets requiring attention, irrespective of cost.
- **ARI** is closely tied to LCA and represents the cost.

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### Definitions:
- **FOR GENERATIONS**: Addressing needs to ensure continued service.
- **Moderate to Good**: Assets in good condition.
- **Fair (Attention within 10 years)**: Assets requiring attention within 10 years.
- **Attention Now**: Assets requiring immediate attention.
- **Total**: Total number of assets requiring attention.
Example: Pole AHI versus ARI

- Based on BC Hydro poles 866,016
- Data on age available. Well established pole T&T program.
- “Health” of poles different if using AHI versus ARI
- BCH Test & Treats ~90,000 poles and renews ~5,500 poles annually.

<table>
<thead>
<tr>
<th></th>
<th>AHI</th>
<th>ARI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>87%</td>
<td>95%</td>
</tr>
<tr>
<td>Yellow</td>
<td>9%</td>
<td>4%</td>
</tr>
<tr>
<td>Red</td>
<td>4%</td>
<td>1%</td>
</tr>
</tbody>
</table>
BC Hydro Distribution Wood Pole
Age Spectrum

Average Age = 23.83
Next Steps

• ARI calculations recently completed for 8-10 asset types.
• Continue with BOTH expert judgement AHI represented in the soccer field and the new ARI calculation.
• Consider introducing a more rigorous AHI evaluation, to remove subjective judgement.
• Create and implement a plan to gather missing asset age & condition data to be able to accurately calculate ARI.
• Consider how to reduce the level of effort required to complete ARI calculations annually. Automate process.
Feeder Cable Background

- 1180 feeder cables, *approximately 2000 km* (1240 miles)
- ~55% PILC, ~45% XLPE
- PILC are three-phase (13 kV belted, 400 and 600 KCM)
- All feeder cable in concrete encased ducts
- Splices are in concrete manholes
- One feeder can have both PILC-UJ & J segments
- Large majority of failures in manholes or near terminations
Cable Testing at BC Hydro

- **Electrical**
  - Leakage Current pico-Ampere Test (LIpATEST©)
  - Time-domain Reflectometry (TDR)
  - Partial Discharge (Ultrasonic)

- **Physical**
  - Hardness test
  - Dye Penetrant Test
  - Visual Inspection Test
Cable Strategy Pre-2004

- Based on failure history and available condition tests
  - Most failures with PILC – unjacketed
  - Conclusion – reached burnout of “bathtub” curve
  - Strategy – blanket replacement of PILC – UJ
  - Result – some perfectly good cable being replaced!
Cable Asset Health Methodology

- Established Detailed Condition Assessment (DCA) ranking system
  - DCA Ranking 1&2: Severe Degradation
  - DCA Ranking 3: Moderate Degradation
  - DCA Ranking 4: Minor Degradation
  - DCA Ranking 5: No Degradation
- In average, 80% of the cable sections are in good condition.
- The average rate of severe degradation/defects of cables is 3%.
- PILC UJ cables have the highest severe degradation/defect.
In average, 85% of the splices are in good condition.
The average rate of degradation/defects of splices is 7.9%.
Transition splices have the highest severe degradation /defect rate.
Build Plan

"Unitized" Costs

- Public Safety Inspections
- Planned/Preventative Maintenance & Condition Assessments
- Forecast of Defects found during Condition Assessment (short-term)
- Forecast of End of Life Replacement (long-term)

10-Year Plan

"Discrete" Costs

- Funding for Studies and Failure Investigations
- Distribution Maintenance Departmental Costs
- Special Maintenance and Replacement Initiatives

*Work volumes adjusted to reflect asset demographic changes due to life-service 'allure' (equipment or other causes e.g., VAP) and land re-development initiatives (e.g., road widening, subdivision developments).*
Execute Plan

The processes used to execute the plan are also considered important aspects of the overall planning process:

– Obtaining budget approval;
– Implementing work plans;
– performance and modifying plans accordingly
Evaluate Performance
Analysis includes:

- Standard costs per unit work compared to actuals;
- DODW failure and trouble call information are analyzed for equipment failure causing outages;
- SAM defect data is reviewed to determine if process has desired affect over time;
- Safety incidents and near misses are reviewed to determine if design standards, work practices, or other factors should be changed;
- Environmental incidents and compliance are monitored.
Conclusions

• DM’s 10-Year plan provides a long-term forecast of OMA and capital replacement spending that is deemed necessary to maintain a high level of performance in BC Hydro’s distribution network.
• Continue with subjective and audited asset health evaluations to meet safety and due diligence requirements.
• Continue to expand condition assessment and build asset data profiles for various assets.
• Use ARI and LCA to improve the effectiveness of maintenance and replacement spending in delivering performance expectations.
• Include customer needs and expectations in managing asset health investments.
• Move to an investment perspective of asset health and demonstrate the opportunity to reduce investment while meeting performance expectations.
Thank you

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