Vision 2050 – An Asset Management Strategy

Jaclyn Cantler
Manager, Transmission Planning, PHI
Agenda

- Case for Change
- About Vision 2050
- Status
- Closing
Aging infrastructure, emergence of new technologies, change in customer expectations and traditional regulatory compact drive the need to implement a comprehensive asset management strategy for PHI.

**System Design**
- Cybersecurity
- Interface with distributed/dispersed generation (micro and macro)
- Substation siting issues, etc.
- High Side Bus configurations
- LVAC network renewal
- Criteria for adding new substations
- Selective / system Undergrounding

**Infrastructure Design**
- Aging transformer replacement
- Conversion of 4kV to 13kV
- General aging infrastructure replacement criteria
- Switchgear & breaker replacement
- Network protector & transformer replacement
- PILC replacement
- Transmission line upgrades
- 69 kV - 600 MCM MPOF cable replacement

**New Technology**
- Smart grid and distribution generation requirements
- EV growth
- Recloser application
- Distribution & sub-transmission automation
- Integrated volt-VAR control
- Distributed energy resources
- CVR
- Energy storage
- Innovation in design and dist equipment

**Reliability**
- Reliability centered maintenance (RCM)
- Distribution feeder, sub-transmission, transmission hardening
- Pole and padmounted transformer replacement
- SCADA control for substations in ACE & DPL
- Inspection programs

**Appropriate Business Models**
PHI must select the business models that best address widespread future requirements.
Vision 2050 Initiative Objectives

“Develop sound strategies that are practically based, can drive execution and the ability to make decisions based on solid research and background.”

Objective:
Determine what PHI’s electric system of the future will look like and what PHI needs to do through the development of a long-term asset management roadmap that aligns our regulatory and financial strategies with our asset management strategies to get us there

- Define and institute a governance process for asset management across PHI
- Create an asset strategy roadmap for the next 5, 10 and 40 years
- Develop a going forward process that facilitates meeting asset strategy goals and improves the transparency of PHI’s capital and O&M investments
- Implement a consistent framework/methodology for evaluating asset management based initiatives across PHI
- Adopt a set of models and tools that can be used to evaluate different initiative options
- Develop standards and system design for implementation across PHI

Reliability Enhancement Plan
Pepco, ACE, DPL

Power Delivery Vision 2050
Comprehensive Asset Management Strategy
Ongoing REP work
Vision 2050 Initiative Benefits

- Incorporation of long-term infrastructure renewal strategies with ongoing REP work
- Increased alignment of the asset management needs with customer and regulator expectations
- Identification of critical assets and programmatic approaches that focus on the renewal of transmission, substation and distribution infrastructure
- Standardization of asset management strategies across all jurisdictions
- Justification to pursue new technologies supported by thorough benefit to cost analysis
- Development of recognized thought and execution leadership in the area of system modernization and data analytics
- Achievement of optimized system performance objectives coupled with an understanding of asset utilization, losses and capacity constraints
- Understanding of future workforce requirements
- Enhanced decision making balancing cost, risk and performance
- Establishment of a clear and defensible path forward that can meet customer and shareholder expectations
Project Scope

• What’s in scope?
  – All assets of the transmission and distribution system used in the delivery of electric power
    • Transmission
    • Distribution
    • Substations
  – Distribution and transmission planning guidelines and criteria
  – Assets involved with dispersed generation, EV’s and storage

• Related initiatives
  – Maintenance and operations practices and standards
    • Assumption for development of asset replacement standards is that the current maintenance and operations will remain as defined albeit there is a capability of updating as necessary
    • Any changes that may be identified as part of this work will be referred to the appropriate standards group for review and action
Transmission System

Managing asset replacement based on multiple risk criteria was determined to be the most practical approach for the transmission system.

A novel approach has been developed for identifying, scoring and ranking transmission circuit risk:

• Plan is proactive and transparent
• Addresses transmission assets as an integrated system through defined risk assessment models
• The models are dynamic, do not rely on age only, and were designed to use relative comparisons
• Model output (risk scores) allows for situational awareness
• An asset replacement program can be derived from the models
• The results are a decision support tool that can be integrated with PHI capital investment prioritization software
Underground Risk Model

Underground risk model development began with physical asset data collection. A previous assessment of the UG oil filled transmission system in 2013 provided an excellent starting point for identifying multiple risk criteria and comprehensive risk models. The initial risk criteria included:

- Age
- Type
- Installation
- Water crossing
- Trenchless installation
- DB reservoirs
- Age of primary pumping plant
- Loading
- System impact
- Circuit availability
- Response time
- Availability of resources
- Accessibility
- Location
- Cable type
- Splices
- Terminations
- Accessories
- Alarms
- Leaks
- Repeat problem locations
- Sub 1 reservoirs
- Sub 1 terminations
- Sub 2 reservoirs
- Sub 2 terminations
- Duct line
Underground Risk Model (cont.)

Additional risk factors were added to account for:
- Hybrid construction
- Direct buried splices
- Redundancy
- SCFF cable systems – due to obsolescence
- Failures

<table>
<thead>
<tr>
<th>Feeder Number</th>
<th>Risk Value</th>
<th>Hybrid Construction</th>
<th>Buried Splices per Mile</th>
<th>Redundancy</th>
<th>SCFF</th>
<th>Failures</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>69xxx</td>
<td>240</td>
<td>3</td>
<td>0.00</td>
<td>2</td>
<td>3.00</td>
<td>2.50</td>
<td>265.50</td>
</tr>
<tr>
<td>69xxx</td>
<td>240</td>
<td>3</td>
<td>0.00</td>
<td>2</td>
<td>3.00</td>
<td>2.50</td>
<td>271.50</td>
</tr>
<tr>
<td>69xxx</td>
<td>232</td>
<td>3</td>
<td>0.12</td>
<td>2</td>
<td>3.00</td>
<td>0.00</td>
<td>256.36</td>
</tr>
<tr>
<td>69xxx</td>
<td>232</td>
<td>3</td>
<td>0.00</td>
<td>2</td>
<td>3.00</td>
<td>0.00</td>
<td>250.00</td>
</tr>
<tr>
<td>69xxx</td>
<td>232</td>
<td>3</td>
<td>0.00</td>
<td>2</td>
<td>3.00</td>
<td>0.00</td>
<td>198.62</td>
</tr>
<tr>
<td>69xxx</td>
<td>174</td>
<td>3</td>
<td>0.21</td>
<td>2</td>
<td>3.00</td>
<td>0.00</td>
<td>198.00</td>
</tr>
</tbody>
</table>
Overhead Risk Model

The starting point for the OH risk model was the UG model. All UG risk model criteria that could also be applied to the OH model were used in addition to criteria specific to OH facilities

- Age
- Type
- Water crossing
- Permitting
- Loading
- Future plans
- Customer criticality
- Circuit criticality
- Response rate
- Accessibility
- Redundancy
- Underbuild
- Materials
- Steel
- Wood
- Insulators
- Conductor
- OHGW
- Foundation and footings
- Grounding
- Arms
- Hardware

For the condition criteria (in blue) comprehensive inspection reports over the past 5 years were used to complete the condition scores. If no inspection was available, PHI personnel manually entered the scores.
## Overhead Transmission Line Risk Criteria

<table>
<thead>
<tr>
<th>Category</th>
<th>Variable</th>
<th>Score (higher score = higher risk)</th>
<th>Description</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line Characteristics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>Calculated</td>
<td>1-5</td>
<td>Current year minus installation year divided by 10. If replacements have been made use the average age.</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I-Beam</td>
<td>1</td>
<td>Based on the overall reliability of each tower/structure type. The higher the number the higher the probability of failure under various deterioration and weather conditions. If there are multiple tower types use the average (for example, if a line is 50% tubular steel and 50% lattice, the score would be 2.5 = 0.5<em>2+0.5</em>3)</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Tubular steel</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lattice tower</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>H-Frame wood</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Single pole wood</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Crossing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Not applicable</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Non-navigable lake or river</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Navigable lake or river</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Permitting</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>County or municipal permits only</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>State permitting agencies involved</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Federal permitting agencies involved</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loading</td>
<td>1</td>
<td>Average monthly peak load does not exceed 50% of normal rating SUMMER; or 50% of normal rating WINTER</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Average monthly peak load does not exceed 65% of normal rating SUMMER; or 65% of normal rating WINTER</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Average monthly peak load does not exceed 80% of normal rating SUMMER; or 80% of normal rating WINTER</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Average monthly peak load does not exceed 95% of normal rating SUMMER; or 95% of normal rating WINTER</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Average monthly peak exceeds normal rating SUMMER; or normal rating WINTER at least once per year.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Future plans</td>
<td>1</td>
<td>Circuit is planned for replacement or upgrading in the next 5 years.</td>
<td></td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Circuit is planned for replacement or upgrading in the next 10 years.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>No plans for any work in the foreseeable future.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Customer Criticality</td>
<td>1</td>
<td>Residential, light commercial, farming</td>
<td></td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Urban centers, schools high density residential</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Hospital, government center, large industrial customers</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Overhead Risk Model – Sample Output

The overhead risk model includes a forced pair ranking process to set the weighting factors for each individual risk criteria. The individual risk criteria scores are multiplied by their weighting and summed to obtain the overall risk score. A sample output is shown below.

<table>
<thead>
<tr>
<th>Asset Information</th>
<th>Overall Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Circuit Number</td>
</tr>
<tr>
<td>Pepco</td>
<td>11xxx</td>
</tr>
<tr>
<td>Pepco</td>
<td>11xxx</td>
</tr>
<tr>
<td>Pepco</td>
<td>23xxx</td>
</tr>
<tr>
<td>Pepco</td>
<td>11xxx</td>
</tr>
<tr>
<td>Pepco</td>
<td>11xxx</td>
</tr>
<tr>
<td>Pepco</td>
<td>23xxx</td>
</tr>
<tr>
<td>Pepco</td>
<td>5xxx</td>
</tr>
</tbody>
</table>
Substations and Equipment

Initial efforts used available data, industry knowledge, equipment condition assessment (ECA), age, and the Asset Health Index to understand the potential replacement and required capital spend

• Substation assets were broken down by high level equipment including:
  • Batteries, breakers, switchgear, and transformers
• General findings
  • Approach and methodology vary for each equipment type
  • Identified potential data gaps
  • Application of the novel risk model approach can be applied to substation assets to rank by risk and inform the capital budget
    – Factors such as equipment obsolescence, spare equipment programs, existing condition and assessment, and maintenance programs are several of the key criteria to be factored into assessing substation equipment risk
Initial Risk Factors and Data

Batteries
- Lifecycle is dependent on operating atmosphere
- Replacement programs primarily use age as trigger

Free standing T & D breakers
- Lifecycle is dependent on age, insulating medium, stored energy system, BIL, clearing capabilities, events, limited supplier support of assets, etc.
- Oil circuit breaker replacement project underway

Switchgear
- Lifecycle dependent on condition of the breakers including: number of operations and severity, moisture, building conditions, spare parts, deterioration of cubicles, etc.
- Two recent studies were completed on all PHI switchgear
Initial Risk Factors and Data (Cont.)

Substation transformers

• Lifecycle is dependent on many factors including load, temperature, design, moisture, quality of the build, etc.

• Transformer asset health index has been completed for nearly all existing fleet
  – 1964-1998 failures occurred predominantly in units 20-40 years old
  – Failures of late focus on the >50 year old units.
## Asset Health Index Weighting

### Weighting Summary
Higher score value = worse condition

<table>
<thead>
<tr>
<th>Factor</th>
<th>Total Weight</th>
<th>Score Range</th>
<th>Reasoning</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. LTC</td>
<td>10%</td>
<td>1-10</td>
<td>Issues with the LTC can cause the entire transformer to fail.</td>
<td>SAP, Field reports</td>
</tr>
<tr>
<td>1. Age</td>
<td>10%</td>
<td>1-10</td>
<td>Calculated based on in-service date.</td>
<td>SAP</td>
</tr>
<tr>
<td>1. Bushings</td>
<td>10%</td>
<td>1-10</td>
<td>Bushing tests reveal equipment trending towards failure.</td>
<td>Doble DTA Web, SAP</td>
</tr>
<tr>
<td>1. Main Tank Leaks</td>
<td>10%</td>
<td>1-10</td>
<td>Leaking tanks should be repaired as soon as possible, preferably without an outage.</td>
<td>Field reports</td>
</tr>
<tr>
<td>1. LTC Leaks</td>
<td>5%</td>
<td>1-10</td>
<td>Leaking tanks should be repaired as soon as possible, preferably without an outage.</td>
<td>Field reports</td>
</tr>
<tr>
<td>1. Manufacture</td>
<td>5%</td>
<td>1-10</td>
<td>Flawed designs can be prone to failure.</td>
<td>SAP, Industry Knowledge</td>
</tr>
<tr>
<td>1. Doble Tests</td>
<td>15%</td>
<td>1-10</td>
<td>Trending the power factor can identify units that may fail.</td>
<td>Doble DTA Web</td>
</tr>
<tr>
<td>1. Dissolved Gas Analysis</td>
<td>15%</td>
<td>1-10</td>
<td>Testing the oil provides vital knowledge regarding the state of the transformer windings and insulation.</td>
<td>PHI Chemistry Lab (TOA), SAP, TM View</td>
</tr>
<tr>
<td>1. Oil Quality and Estimated Paper Life</td>
<td>5%</td>
<td>1-10</td>
<td>Measuring characteristics of the oil in the transformer provides insight and can also be used to estimate paper life.</td>
<td>PHI Chemistry Lab (TOA)</td>
</tr>
<tr>
<td>1. Surface Rust</td>
<td>5%</td>
<td>1-10</td>
<td>Surface rust can be treated and sealed if caught early before it causes larger problems.</td>
<td>Field reports</td>
</tr>
<tr>
<td>1. History</td>
<td>5%</td>
<td>1-10</td>
<td>If a certain vintage model is known to fail, then our similar unit has a higher chance of failure.</td>
<td>eLogger, SAP</td>
</tr>
<tr>
<td>1. System Criticality</td>
<td>5%</td>
<td>1-10</td>
<td>N-1 and N-2 contingency analysis will determine how “critical” a transformer is.</td>
<td>System Planning</td>
</tr>
<tr>
<td>1. Loading</td>
<td>0%</td>
<td>-</td>
<td>Track this in the database to ensure that if a transformer is overloaded, planning knows to analyze it for a potential upgrade.</td>
<td>PI</td>
</tr>
<tr>
<td>1. Through faults</td>
<td>0%</td>
<td>-</td>
<td>Track this in the database for informational purposes.</td>
<td></td>
</tr>
</tbody>
</table>
### Table of Contents

1. **INTRODUCTION** ........................................................................................................... 2
2. **EXECUTIVE SUMMARY** ............................................................................................ 4
   2.1 Summary of the Plans ............................................................................................... 7
3. **SUBSTATION DC SYSTEMS – BATTERIES AND CHARGERS** .................................. 9
   3.1 Present Population ................................................................................................. 10
   3.2 Replacement Plans ............................................................................................... 11
   3.3 Cost and Replacement Plans .............................................................................. 13
   3.3.1 Cost ............................................................................................................... 13
4. **BREAKERS - OVERVIEW** ......................................................................................... 16
   4.1 Demographics of the Existing Equipment ............................................................... 19
   4.2 Alternatives/Options .............................................................................................. 21
   4.3 Present Population V. Age of the Assets ................................................................. 22
   4.4 Replacement Breaker Costs .................................................................................... 24
   4.5 Estimated Replacement Costs ............................................................................... 24
5. **SWITCHGEAR** ......................................................................................................... 26
   5.1 Present Population ............................................................................................... 27
   5.2 Equipment Evaluation - Switchgear ...................................................................... 28
   5.2.1 Equipment Assessments .................................................................................. 28
   5.3 PHI Switchgear Replacement Plans ...................................................................... 30
   5.3.1 AEP ............................................................................................................... 30
   5.3.2 DPL ............................................................................................................... 31
   5.3.3 PEPCO .......................................................................................................... 32
6. **TRANSFORMERS** ...................................................................................................... 37
   6.1 Present Population ............................................................................................... 38
   6.2 Development of a Risk Based Strategy .................................................................. 39
   6.2.1 PHI transformer failures – 1963 to 2013 ......................................................... 40
   6.2.2 Predicting Future Failure Probability .............................................................. 42
   6.2.3 Prioritizing the Replacements ......................................................................... 45
   6.3 Replacement Strategy ............................................................................................ 45
   6.3.1 Spare Transformer Strategy ............................................................................ 49
7. **LONG TERM STRATEGY AND PLAN UPDATES** ....................................................... 51

---

The output of this process is a comprehensive framework and documented, proactive, risk-based replacement standards.
Summary

Vision 2050 is an overall asset management strategy that incorporates:

• Programmatic, documented replacement of assets
• Management of risk
• Incorporation of industry as well as historical operating and maintenance asset data
• Balancing of capital funds to meet regulatory requirements
• Uses dynamic models to easily facilitate changes in a non-static environment