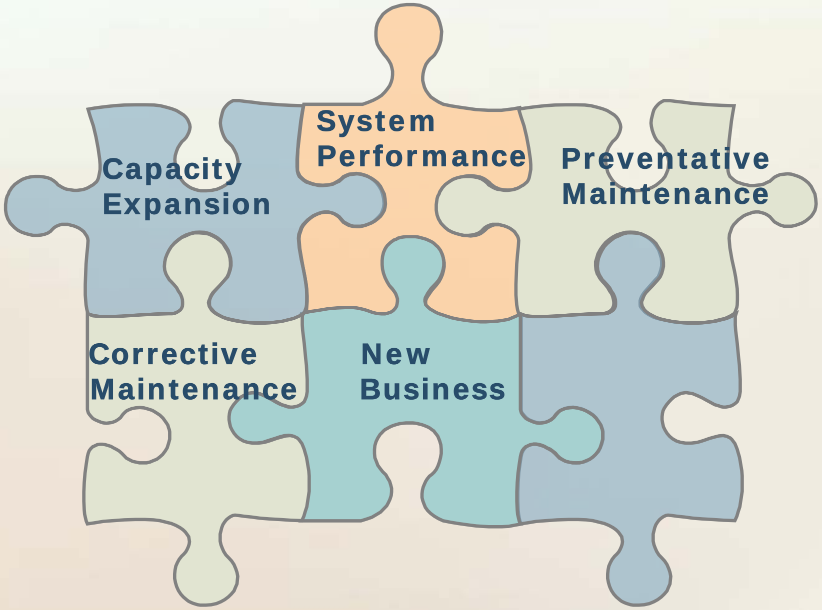
Transmission Owner Asset Management

Pieces of Asset Management

- New customers, load growth, repairs, maintenance, operational issues, etc.
- All the pieces make up the asset management plan for repair or replacement



Vocabulary

- Asset Replacement
  - Point at which infrastructure:
    - Will fail or has failed– Normal consequence of aging infrastructure
    - Uneconomical or impractical to repair
    - Outdated technology and equipment that is no longer supported or lack of spare parts
  - Determined by:
    - Infrastructure condition – Either from aging or premature deterioration
    - Performance history
    - Maintenance history
    - Assessment
    - Health monitoring

Asset Replacement Factors

- Aging infrastructure needing repair/replacement
- Environmental conditions and loading can shorten life while maintenance can extend life
  - Winter ice loading and wind that stress insulators or thermal overloads that anneal conductor
  - Cleaning current carrying contacts reduces heat and thermal damage

Asset Replacement Necessity Consequences

- Reliability impact resulting from failed infrastructure
  - Substations single serviced
  - Equipment overloads or system voltage violations that will degrade or stress equipment
  - Loss of service to customers
  - Transmission congestion

PECO Asset Replacement Strategy

- Three components are evaluated
  - Obsolescence of Equipment
  - Condition – Health/Risk
  - Engineering Recommendations
- Proprietary tool for evaluation is Component Health Indicator Program (CHIP) Report
  - Created using CASCADE Database Data
  - Provides Condition – Health/Risk ranking for each asset
  - Displays if an asset has been identified as Obsolescence

Obsolescence of Equipment

- Equipment that although is in working order, is reaching end of technology life cycle or requiring repairs or upgrades that cannot be cost justified given the remaining useful technology life
- Make/model or specific type of equipment known as bad actors, some examples:
  - Solenoid operated oil CBs
  - Si Gapped Surge Arrestors
  - Pin and Cap insulators
  - Allis Chalmers FZOs
  - GE type FX-339s

Obsolescence of Equipment

- Parameters used for identifying Obsolescence
  - **Make/Model Parameters**: Age, parts availability, manufacturer support, knowledge availability, equipment bulletins, known equipment problems
  - **Operating Parameters**: Operating constraints, no try-back rule, maintenance constraints, design functionality
  - **Recurring Problems:** Reliability impact, cost impact, image impact, safety impact, risk to public and workforce
  - **Environmental risk:** Large SF6 quantity, oil, PCB, corporate Green house gas reduction goals and the location of equipment near navigable water

Obsolescence of Equipment

- Equipment identified as obsolete does not automatically lead to immediate replacement
- Equipment Condition (Health/Risk) is looked at for the identified equipment and also for all equipment
  - CHIP report is ran against all equipment and also just the subset of equipment identified as obsolete so comparisons/decisions can be made versus budget to determine optimum solution

Condition - Health/Risk

- The CHIP report ranks equipment based on overall Risk
- Risk = Value for "Probability of Failure" X Value for "Consequences of failure"
  - **The value for the probability of failure** is approximated by using the health of the equipment
  - **The value for the consequence of failure** is defined as the equipment criticality based on a system review and input from Transmission system operations and Distribution systems operations

Factors of Probability of Failure

- The CHIP Report uses a variety of Cascade equipment collected database data to develop a health score
  - Age
  - Preventative maintenance history and status
  - Corrective maintenance history
  - Top Oil temperature
  - % loaded
  - Open corrective maintenance and severity
    - Oil leaks, SF6 leaks, Bushing replace, hot spots
  - Oil results
    - Gases, moisture, Fluid Condition and Gas Condition codes

Factors of Consequence of Failure

- A Criticality Ranking is assigned to equipment relative to the electrical position of the equipment on the system and considering factors such as
  - Major transmission substations
  - Customer count and critical customer count
  - Associated with critical transmission lines
  - Associated with generation or tie between generation stations
  - Associated with transmission tie to other utilities or offsite power source

Engineering recommendations

- The Chip report is ran against obsolescence equipment
- The Chip report is ran against all equipment
- Engineering evaluates the Risk from each report
- Replacement candidates are selected versus allotted budget
  - Some programs may be initiated for obsolete identified equipment i.e. replace X amount every Y years

ComEd Transformer Replacement Strategy

- No ongoing obsolesce program in place to replace the asset based upon age
  - Case by case determination to take action if DGA or other indicators point to an issue with a transformer but it is case by case.
- High value on excessive gassing seen through DGA, acoustical/electrical testing, and thermal aging (not transformer age)
- Known industry design defects, excessive corrective maintenance intervals, defective or problematic LTC's and OEM support/parts availability
- Difficulty of replacement
- Actual age of a transformer is a very low value in terms of replacement need
  - Operational history (faults and loading age a transformer, not necessarily years of service
- Transformer monitoring on all new medium and large power units
  - Allows response to a transformer in danger of failing
    - Probability and consequence of failure to go down
    - Transformer can be removed from service prior to failure

BGE Substation Asset Management & Equipment Replacement Philosophy

- Asset Management & Asset Health Verification is a process driven approach
  - Asset management via Asset Suite 8: Main Database for all substation equipment information
  - Review of data, performance history (reliability, failures, costs, corrective work, preventive planned work)
  - Continuously seeking improvements such as on-line type monitoring systems as “real-time” wear and degradation indication
  - Robust maintenance program with defined maintenance intervals
  - Focused response on equipment failures with significant extent of condition impacts to safety & reliability
- Age is a factor but alone is not the single most influential criteria supporting *repair* or *replace* decisions
- Equipment is typically *managed* in-service for general 30 - 40 year life
  - 30 year life expectancy is a general rule of thumb and can be different for different equipment
  - Technical assessment of health:
    - Visual Inspections – Monthly
    - Thermographic Checks – Yearly
    - Partial Discharge – As Necessary
    - Testing & PM Work – 3Y, 5Y, 8Y depending upon specific equipment type
    - Variations to above depends upon specific substation equipment

BGE Substation Asset Management & Equipment Replacement Philosophy

  - Replacement decision based upon age, above results (*asset health*), maintenance cost, design / manufacturing flaws (if applicable), improved technology to safety / maintenance cost / reliability
  - Evaluate a Corrective Maintenance (CM) Rate: [#CM Jobs / (# Elements * # Years of data)]
    - Approach most effective when targeting a poor performing model or deciding upon a manufacturer purchase decision
    - Cumulative CM Dollars, Cumulative CM Hours, and CM Rate are all assessed for guidance in decision making
  - Spare equipment available for emergent, unpredictable, failures

- Proactive Replacement Programs for Known Poor Performance – Technology / Safety / Reliability:
  - Porcelain Housed SiC – Gap Type Lightning / Surge Arresters
  - Coupling Capacitor Voltage Transformers
  - Oil Circuit Breakers, Air Thrust Circuit Breakers, Tank Type Capacitors, PCB Oil, Insulators, etc.
- Robust and Re-Vitalized PM Program Leads to Finding Problems early allowing for required maintenance and / or planned replacement.

BGE Transformer Replacement Strategy

- Based on BGE transformer failure history. Age is a factor, but not the only indicator of transformer health.
- Transformers are typically allowed to remain in-service until failure.
  - Stored system spare transformers and mobile transformer fleet provide backup
- Transformers are proactively replaced based upon:
  - Diagnostic testing results that indicate imminent failure.
  - Asset health study which analyzed cross section of existing fleet to determine probability of failure. Factors included in-service age, design, diagnostic tests, insulation aging, and through-fault risk.
  - Capacity upgrades based on system planning criteria.
- Increased maintenance frequencies and online monitoring allows for proactive response to incipient failure modes.

Pepco Holding Asset Replacement Strategy

Problem description

Industry background

Approach and methodology

Methodology application

PPM integration

Maintenance of the model,

Problem description

- PHI's OH and UG transmission system is aging with some of the lines beyond their expected life.
- A sound asset management strategy dictates balanced cost, risk and performance based decisions.
- For this reason a new approach for identifying, scoring, and ranking transmission line risk was developed.
  - A proactive plan has been developed to enable a long term look at asset replacement strategies for transmission.
  - The plan addresses transmission assets as an integrated system through defined risk assessment model(s).
  - The plan is a decision support tool, not a decision making tool.
  - Model output (risk scores) allows for situational awareness of risk, including but not limited to replacement (via risk drivers), and the development of risk mitigating contingencies.
  - Outputs from the model can be directly loaded into PPM.

Industry background

Pepco has more underground oil filled cable than any other utility and most utilities installed PILC or composite cable.

- Underground, oil filled, pipe type cable systems were designed for an expected life of 30 – 40 years, primarily driven by the life span of the oil circulating and pumping equipment.
- These types of transmission line systems were replaced due to auxiliary equipment problems and replacement material obsolescence, and not problems directly associated with the cable itself.

Industry information from several sources that indicated the following

- Steel: 100 years
- Wood: 50 years (heavily dependent on pole test and treat programs, can be up to 75 years)
- Concrete: 50 years (depending on moisture and salt contamination)
- Conductor: 50 – 60 years
- Insulators: 40 – 50 years
- Splices: 40 years

This variety of ageing profiles for overhead lines makes using asset age as the key factor for replacement a complex issue.

Approach and methodology

It was determined that managing asset replacement strategies based on multiple risk criteria was the most practical approach for the transmission system.

- A previous assessment of the UG oil filled transmission system by PHI (summer 2013) provided an excellent starting point for identifying multiple risk criteria and comprehensive risk models:
  - The models do not rely on age only, as a risk factor,
  - The models are dynamic and risk scenarios can be run at any time to update the risk profile as conditions change, and
  - The results can be integrated with other PHI analysis models such as PPM.
  - The algorithms were designed to use relative comparisons (as opposed to absolute) so that feeder risk profiles could be compared to each other.
  - Condition is included as one of the risk factors

Approach and methodology

- The models are designed to provide transparency.
  - Users can see what was driving the risk profile for each feeder. High risk did not necessarily mean faster replacement. It could mean addressing the risk factors themselves or providing an alternative work around.
  - Weight factors were developed based on the concept of forced pair ranking, a process used to rank criteria by comparing each risk criteria against all the others(allowing for each criteria for both the OH and UG models to be weighted individually in terms of importance).
  - Individual criteria are multiplied by their weight factor and then summed to get the overall rick score.

Methodology application

Underground risk model development began with physical asset data collection. Most of the data came from a previous PHI initiative completed in 2013. The original 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

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Methodology application

Additional risk factors were added to account for:

- Hybrid construction – where multiple hydraulic systems were used in a single feeder (low pressure and high pressure).
- Direct buried splices – increased possibility of failure.
- Redundancy – the N-x design criteria for each feeder.
- SCFF cable systems – additional weighting for low pressure cable systems due to obsolescence.

Algorithms

The numerical calculations for the UG and OH models are different, but the algorithms are the same:

Risk Criteria Score x Risk Criteria Weight = Weighted Risk Score

$$\sum(RS_1*RW_1 + RS_2*RW_2 + \ldots)$$

Methodology application

The model output is a summary of the risk calculations that can be sorted to suit individual analysis needs.

Feeder Information					Scores		PPM Values					
Feeder Number	Installation Date	Operating Company	Voltage Class	Type of Cable	Weighted Risk Score	Rank	Failures	MVA at risk	Collateral Damage	Failures Rank	MVA at risk Rank	Collateral Damage Rank
[redacted]	[redacted]	Pepco	69	Medium pressure oil	288	1	0.74	15	$10	1	83	1
[redacted]	[redacted]	Pepco	69	Medium pressure oil	286	2	0.74	14	$10	2	98	1
[redacted]	[redacted]	Pepco	69	Low pressure oil	264	3	0.68	17	$7	3	74	15
[redacted]	[redacted]	Pepco	69	Medium pressure oil	259	4	0.67	15	$7	4	97	15
[redacted]	[redacted]	Pepco	69	Low pressure oil	259	4	0.67	14	$3	4	99	101
[redacted]	[redacted]	Pepco	69	Low pressure oil	256	6	0.66	18	$7	6	72	15
[redacted]	[redacted]	Pepco	69	Medium pressure oil	256	6	0.66	20	$10	6	69	1
[redacted]	[redacted]	Pepco	69	Medium pressure oil	255	8	0.66	30	$10	8	59	1
[redacted]	[redacted]	Pepco	69	Medium pressure oil	255	8	0.66	15	$10	8	83	1
[redacted]	[redacted]	Pepco	69	Medium pressure oil	249	10	0.64	15	$10	10	83	1
[redacted]	[redacted]	Pepco	69	Medium pressure oil	239	11	0.61	37	$6	11	51	18
[redacted]	[redacted]	DPL	69	Low pressure oil	236	12	0.61	0	$3	12	112	101
[redacted]	[redacted]	Pepco	69	Medium pressure oil	232	13	0.60	15	$6	13	83	18
[redacted]	[redacted]	Pepco	69	Medium pressure oil	230	14	0.59	15	$6	14	83	18
[redacted]	[redacted]	Pepco	69	Low pressure oil	224	15	0.58	14	$6	15	99	18
[redacted]	[redacted]	Pepco	69	Low pressure oil	217	16	0.56	16	$3	16	78	101
[redacted]	[redacted]	Pepco	69	Low pressure oil	217	16	0.56	16	$3	16	78	101

Methodology application

The OH risk model started with the risk criteria developed for the UG model. All the UG risk model criteria that could also be applied to the OH model were used and additional ones were selected.

- Age
- Type
- Water Crossing
- Permitting
- Loading
- Future plans
- Customer Criticality
- Circuit Criticality
- Response rate
- Accessibility
- Redundancy
- Failures

- Underbuild
- Materials
- Steel
- Wood
- Insulators
- Conductor
- OHGW
- Foundation and footings
- Grounding
- Arms
- Hardware

Condition criteria

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.

Methodology application

The model output is a summary of the risk calculations that can be sorted to suit individual analysis needs. This version uses overall weighted risk score.

Asset Information				Overall Score	PPM Scores					
Company	Circuit Number	Companion Circuit	Voltage (kV)	Weighted Risk Score	Failures	MVA at Risk	Collateral Damage	Failures Rank	MVA at risk Rank	Collateral Damage Rank
Pepco				183.47	0.63	120.00	$6	1	12	22
Pepco				183.47	0.63	120.00	$6	1	12	22
Pepco				171.64	0.59	297.90	$0	3	4	85
Pepco				170.84	0.58	321.30	$12	4	3	1
Pepco				169.30	0.58	30.40	$9	5	82	5
Pepco				167.45	0.57	20.40	$9	6	86	5
Pepco				167.45	0.57	30.00	$9	6	84	5
Pepco				165.78	0.57	356.70	$10	8	1	3
Pepco				165.42	0.57	85.20	$6	9	22	22
Pepco				165.07	0.56	83.30	$6	10	34	22
Pepco				165.07	0.56	83.30	$6	10	34	22
Pepco				164.70	0.56	30.40	$9	12	82	5
Pepco				163.78	0.56	350.80	$10	13	2	3
Pepco				163.07	0.56	83.30	$6	14	34	22
Pepco				163.07	0.56	83.30	$6	14	34	22
Pepco				162.95	0.56	20.40	$9	16	86	5
Pepco				162.95	0.56	24.00	$9	16	85	5
Pepco				161.97	0.55	83.30	$6	18	34	22

Methodology application

The model output is a summary of the risk calculations that can be sorted to suit individual analysis needs. This version uses the age and condition risk factors to calculate the weighted risk score.

Asset Information				Overall Score		PPM Scores					
Company	Circuit Number	Companion Circuit	Voltage (kV)	A&C Risk Score	Quadrille Positioning	Failures	MVA at Risk	Collateral Damage	Failures Rank	MVA at risk Rank	Collateral Damage Rank
Pepco				101.47	1	0.74	120.00	$6	1	12	22
Pepco				101.47	1	0.74	120.00	$6	1	12	22
Pepco				88.27	1	0.61	85.20	$6	3	22	22
Pepco				81.11	1	0.61	120.00	$6	3	12	22
Pepco				87.12	1	0.59	65.40	$6	5	78	22
Pepco				87.12	1	0.59	65.40	$6	5	78	22
Pepco				83.42	1	0.56	85.20	$6	7	22	22
Pepco				81.07	1	0.54	83.30	$6	8	34	22
Pepco				81.07	1	0.54	83.30	$6	8	34	22
Pepco				81.07	1	0.54	83.30	$6	8	34	22
Pepco				81.07	1	0.54	83.30	$6	8	34	22
Pepco				79.97	1	0.53	83.30	$6	12	34	22
Pepco				79.97	1	0.53	83.30	$6	12	34	22
Pepco				79.07	1	0.51	65.40	$6	14	78	22
Pepco				79.07	1	0.51	65.40	$6	14	78	22
Pepco				76.11	1	0.51	120.00	$6	14	12	22
Pepco				75.96	2	0.51	83.30	$6	17	34	22
Pepco				75.96	2	0.51	83.30	$3	17	34	84
Pepco				65.03	2	0.50	85.20	$6	19	22	22
Pepco				65.03	2	0.50	85.20	$6	19	22	22

PPM integration

The risk models developed for OH and UG circuits contain numerous factors that can impact the risk value of a given circuit. These numbers are intended to serve as guidelines for replacement decisions and to provide inputs to the Project Portfolio Management (PPM) tool. The PPM inputs are:

- Number of failures – using the age and condition risk score normalized on a 0 – 1 scale. This then becomes the probability of future failures based on risk
- MVA at risk – using 10% of the maximum rating of the line (winter/summer, normal/emergency) multiplied by the redundancy factor.

PPM integration

- Collateral damage – for overhead circuits, using the repair cost equal to the labor and material cost of a new/replacement structure/tower for each line type and voltage normalized by the sum of the unweighted operational risk scores for circuit criticality, response rate, and accessibility.
- Collateral damage – for underground circuits, using the labor and material historic cost for repairing a failed underground cable by hydraulic system, normalized by the operational risk scores for water crossing, response time, availability of resources, and accessibility.

Maintenance of the risk models

Risk models are dynamic evaluation tools to integrate risk into the asset decision making process. Rely on real time data (such as annual inspection updates for condition), so must be updated on a regular basis to maintain the appropriate risk profiles in line with the ASAP (Asset Strategy And Planning) process:

- An assessment cross references high risk circuits to the current 5 Year Plan to determine if age/condition projects need to be initiated; and to validate that the age and condition projects (referenced to circuit number) in the Plan are valid, and in fact should be built;
- All transmission circuits (except pepco 69kV distribution) rescoring is conducted. The re-scoring will account for any circuit replacements or improvements during the year and will result in a revised risk score ranking that is used for the next annual program assessment,

Asset Replacement Criteria

- Transmission facility replacement is an asset management decision made by utility executives based on the corporate risk and prioritization model, maintenance program, reliability impact and customer concerns
  - TO is accountable to customer and public impact (reliability and safety) for asset replacement decision, not PJM

Summary

- Asset management replacement decisions are driven by geography, maintenance, design, manufacturer, age, parts, condition, environment, safety and other factors
  - Not necessarily known well in advance
  - Drivers may change asset decision over time
- Asset replacement decision transparency into the PJM RTEP