PPL Electric Utilities

PPL Asset Management

PJM TRPSTF

May 23rd, 2016

PPL Asset Management

PPL Examples of Asset Management

- Transmission Line Reliability Analysis Tool
- Cellon Wood Poles
- SF6 Gas Circuit Breakers – Mortality Analysis
- CCVT – Mortality Analysis

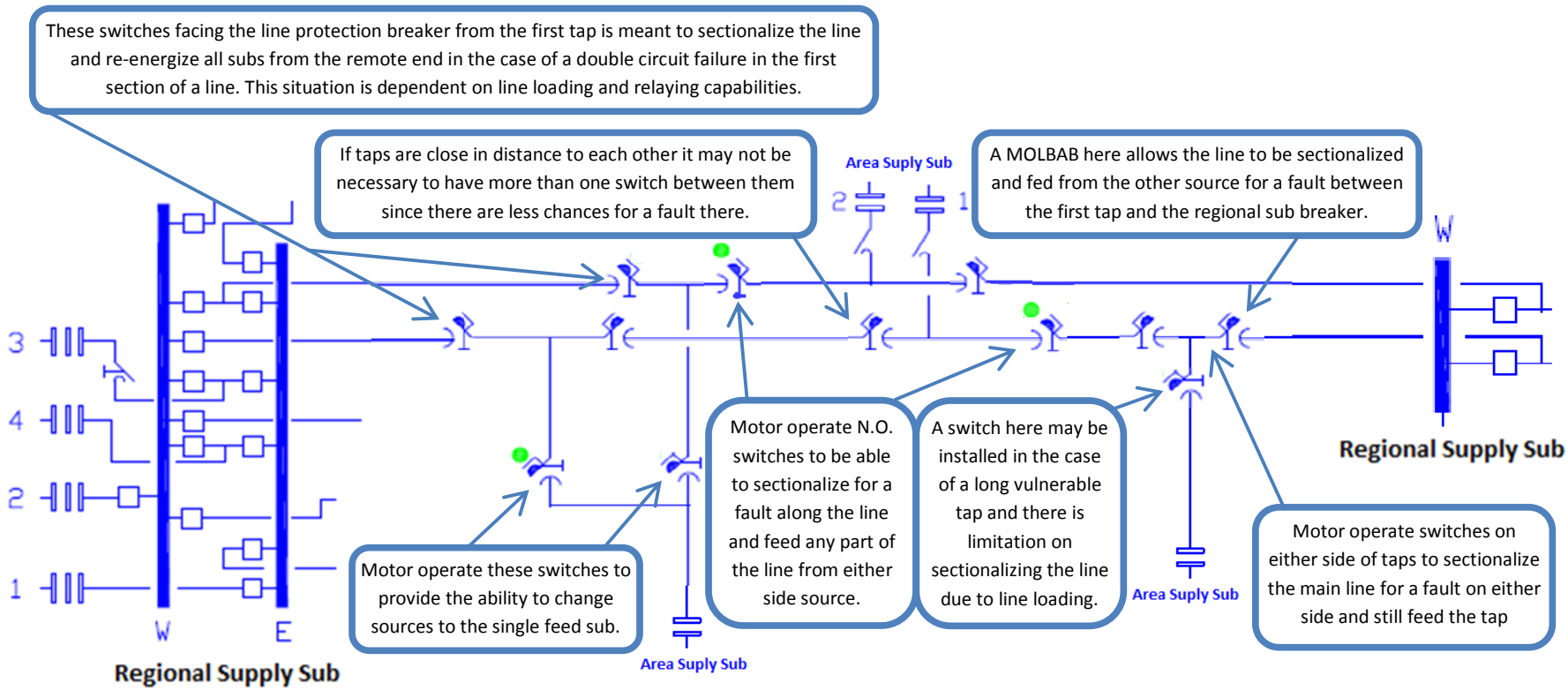
PPL Asset Management – Transmission Lines

PPL Transmission System Highlights

- 500kv, 230kV, 138kV and 69kV
- 1.4M Customers fed from 138kV and 69kV Lines
- 69kV and 138kV lines “Designed for Network, Operated Radially”
- Aging Infrastructure – lines constructed as early as 1910’s
- About half of the ~50,000 Transmission Structures are Wood Poles

PPL Asset Management – Transmission Lines

Typical PPL 69kV Topology



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PPL Asset Management – Transmission Lines

Transmission Line Reliability Analysis Tool

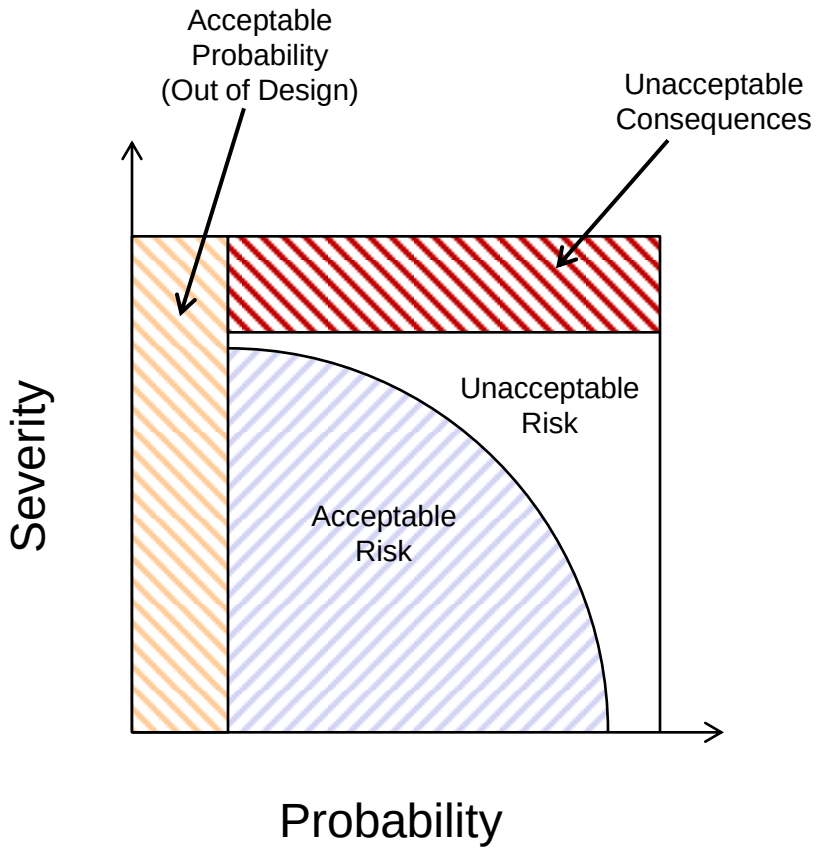
- Proprietary Asset Management Tool that *supports* a reliability focused, cost effective and well coordinated asset investment and condition-based maintenance program
- *Dynamic* Asset Health, Criticality and Risk Scores along with *predictive* SAIFI and MAIFI measurements
- Risk scores and probability of failure should be scalable from component level up to system level
- Condition-based maintenance algorithms to trigger alerts and warnings and to initiate work orders
- System-wide Asset Inventory to capture relevant information
- Digitizing of inspection forms and trouble reports to feed field data directly into Asset Database

PPL Asset Management – Transmission Lines

Use Cases for Transmission Line Tool:

- Maintenance – condition-based inspections and maintenance
- Rehabilitate versus Rebuild – better understand impact and analysis around decision
- Project Prioritization – compare lines based on overall Risk (Health, Criticality, and Performance)
- Reliability Improvements – understand performance impact when addressing known reliability issues
- Asset Optimization – optimize line performance through component-level analysis
- Transmission Operations – provide information to make operational decisions based on Risk
- Life-cycle management – ability to project health of line into the future

PPL Asset Management – Transmission Lines



Risk Matrix

Main Line Risk Matrix		Health				
		A	B	C	D	F
Criticality	1					
	2					
	3					
	4					

Risk = Criticality x Health
(Severity x Probability)

Example: Line A = B3
Line B = C1

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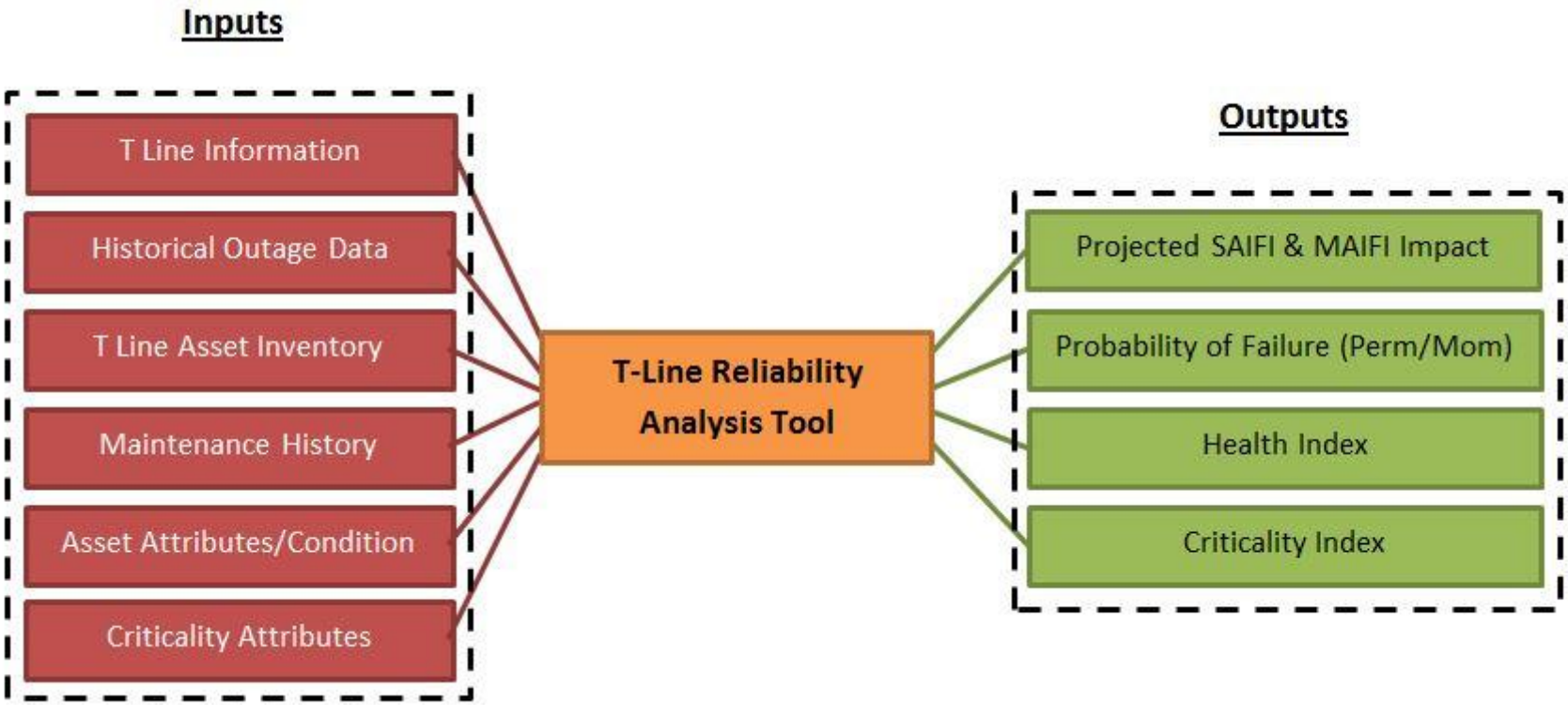
Transmission Line Reliability Analysis Tool Structure



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Transmission Line Reliability Analysis Tool

- Assessment is based on 3 key areas: **Performance**, **Asset Health**, and **Criticality**

- Assessment is completed at the component, structure and line level to provide an aggregate score at the Line, Region or System level

- MicroStrategy reporting interface is used to analyze the asset data

- Standard Reporting Capabilities:
  - Projected MAIFI & SAIFI Performance
  - Current Health & Criticality
  - Risk Score (Rating)

- Scenario Forecast Reporting Capabilities:
  - Future Status (aged assets)
  - Idealized Status (rebuilt/replaced assets)

Transmission Line Reliability Analysis Tool

- **Performance (MAIFI & SAIFI)**
  - Baseline uses MAIFI/SAIFI impact per outage event (customer dependent)
  - Probability of Failure (Momentary & Permanent)
    - Evaluated at the structure level and compiled at the line level
    - Factors in historical outage history and performance
    - Asset specific attributes positively/negatively impact Pf
  - Projected MAIFI & SAIFI is a function of Pf and MAIFI/SAIFI per event

- **Asset Health**
  - Baseline score is based on the aggregate of all the structures on the line
  - Health score is calculated using modeled life curves
  - Additional attributes are weighted against the health score for various attributes that impact structures positively/negatively

- **Criticality Score**
  - Based on various factors specific to the transmission line
    - Topology (Voltage Class, Single Circuit, Double Circuit, etc.)
    - Loading (Average, Peak)
    - Operability (switches, transfer capability, etc.)
    - Critical Customers

Transmission Line Reliability Analysis Tool

- **Assessment Methodology for T-Line Assets**
  - Utilize Condition Parameters (CP) and Weights (W) assigned to given assets for both permanent and momentary impacts
  - All attributes specific to a structure are weighted against the health and projected MAIFI & SAIFI metrics
  - Common Attributes
    - Structure Material
    - Structure Type & Configuration
    - Cross Arms
    - Guying
    - Type & Level of Insulation
    - Environmental (Wooded, Fields, Mountainous, Wetland, etc.)
    - Crossing (Line, River, Structure, etc.)
    - Underbuilt Assets

Transmission Line Reliability Analysis Tool

T & S Transmission Lines Reliability
System Overview

Total System

Projected Impact				
Customers	SAIFI (Total)	MAIFI (Total)	Health (Avg)	Criticality (Avg)
1,396,372	0.04105	0.33539	84%	2

		Projected Impact					
T Line	Region	Customers	SAIFI	MAIFI	Health	Criticality	Rating
[redacted]	Central	5,176	0.00024	0.00024	85%	2	2A
	Central	9,506	0.00003	0.00003	85%	2	2A
	Central	9,253	0.00068	0.00267	85%	2	2A
	Lehigh	16,811	0.00002	0.01481	86%	3	3A
	Central	4,376	0.00064	0.00659	82%	2	2B
	Central	3,259	0.00047	0.00491	85%	1	1A
	Central	7,266	0.00027	0.00612	84%	2	2B
	Central	13,712	0.00090	0.00971	85%	2	2A
	Susquehanna	0	0.00000	0.00000	82%	2	2B
	Central	6,143	0.00073	0.02387	85%	2	2A
	Central	4,157	0.00001	0.00001	81%	2	2B

**Click on the T-Line/Region to view the T-Line overview/Region Overview*

Click here to return to Main Menu

Main Line Risk Matrix		Health				
		A	B	C	D	F
Criticality	1					
	2					
	3					
	4					

SAIFI	MAIFI
0 - 0.005	0 - 0.05
> 0.005 - 0.05	> 0.05 - 0.1
> 0.05 - 0.3	> 0.1 - 0.5
> 0.3	> 0.5

Criticality	
1	Low
2	Med - Low
3	Med - High
4	High

Health	
A (Very Good)	HI > 85 %
B (Good)	70 <= HI < 85 %
C (Fair)	50 <= HI < 70 %
D (Poor)	25 <= HI < 50 %
F (Very Poor)	HI < 25 %

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Transmission Line Reliability Analysis Tool

T & S Transmission Lines Reliability

T-Line Overview

[redacted]

Total System Customers	1,396,372

Click here for Excel Export

			Projected Impact			
TLine	Customers	MAIFI/SAIFI (Per event)	SAIFI	MAIFI	Health	Criticality
[redacted]	6,143	0.00440	0.000735	0.023869	83%	2
	5,047	0.00361	0.000733	0.023867	84%	
	0	0.00000	0.000000	0.000000	79%	
	1,096	0.00078	0.000002	0.000003	83%	
	0	0.00000	0.000000	0.000000	86%	

Click here to view the Detail Report

Main Line Risk Matrix		Health				
		A	B	C	D	F
Criticality	1					
	2					
	3					
	4					

SAIFI	MAIFI
0 - 0.005	0 - 0.05
> 0.005 - 0.05	> 0.05 - 0.1
> 0.05 - 0.3	> 0.1 - 0.5
> 0.3	> 0.5

Criticality	
1	Low
2	Med - Low
3	Med - High
4	High

Health	
A (Very Good)	HI > 85 %
B (Good)	70 <= HI < 85 %
C (Fair)	50 <= HI < 70 %
D (Poor)	25 <= HI < 50 %
F (Very Poor)	HI < 25 %

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Transmission Line Reliability Analysis Tool

As of 02-Feb-2016 : 2:37:12 PM

T & S Transmission Lines Reliability

T-Line Detail

System Total	1,396,372
Line Total	6,143
MAIFI/SAIFI (Per event)	0.00440
SAIFI (Contribution)	0.000735
MAIFI (Contribution)	0.023869
Health	83%
Criticality	2

Line Name	Mileage
66	27.00
81	4.00
77	0.00
223	3.00
Total	34.00

Line Name	Substation Name	Customer Count
66		3,397
		1,650
	Total	5,047
77		1,096
		1,096
Total		6,143

----------OUTAGE----------

Outage History

Year	Failure Type: Momentary	Failure Type: Permanent
2007	12	0
2008	3	0
2009	15	0
2010	4	1
2011	8	1
2012	4	0
2013	13	0
2014	4	0
2015	3	0
2016	0	0

In-Service Year 2007

Click here for excel export

T-Line	Customers	MAIFI/SAIFI	SAIFI	MAIFI	Health	Criticality
	6,143	0.00440	0.000735	0.023869	83%	2
	5,047	0.00361	0.000733	0.023867	84%	
	0	0.00000	0.000000	0.000000	79%	
	1,096	0.00078	0.000002	0.000003	83%	
	0	0.00000	0.000000	0.000000	86%	

Historical Momentary Outage Interruption Event Contributors

History	Total Outages	Projected: Pf (Mom)	Projected: MAIFI
10	66	6.60	0.02904

Historical Permanent Outage Interruption Event Contributors

History	Total Outages	Projected: Pf (Perm)	Projected: SAIFI
10	2	0.20	0.00088

T-Line Section	Grid	Seq #	Health Index	Pf (Perm)	Pf (Mom)	Perm Structure Type CP	Perm Structure Type Pf	Perm Structure Type W	Perm Structure Material CP	Perm Structure Material Pf	Perm Structure Material W	Perm Structur Configuratior CP
MAIN LINE		NA	84%	0.00333	0.00400	0.70	0.005	2.00	1.00	0	3.00	0.8

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Cellon Wood Poles

- Cellon Wood Pole Highlights
  - 2010 – 1st Failure of Cellon Wood Pole
  - Root Cause Analysis identified correlation between Cellon-treated Douglas Fir Wood with high probability for excessive internal decay
  - “Rotted” poles are structurally compromised and at risk of failure
  - Failure is a risk to public Safety and Reliability
  - Wood Pole inspections are ineffective at identifying “rotted” poles
  - Cellon Pole Program developed to systematically replace at-risk poles on the system with Steel
  - Targeted high Criticality lines, Critical crossings, Roadways and public locations first
  - Condition Parameters in Transmission Line Reliability Analysis Tool reflect the poor condition of these structure types
  - Over 2/3 of Cellons replaced since 2010

Cellon Wood Poles

Cellon Wood Poles

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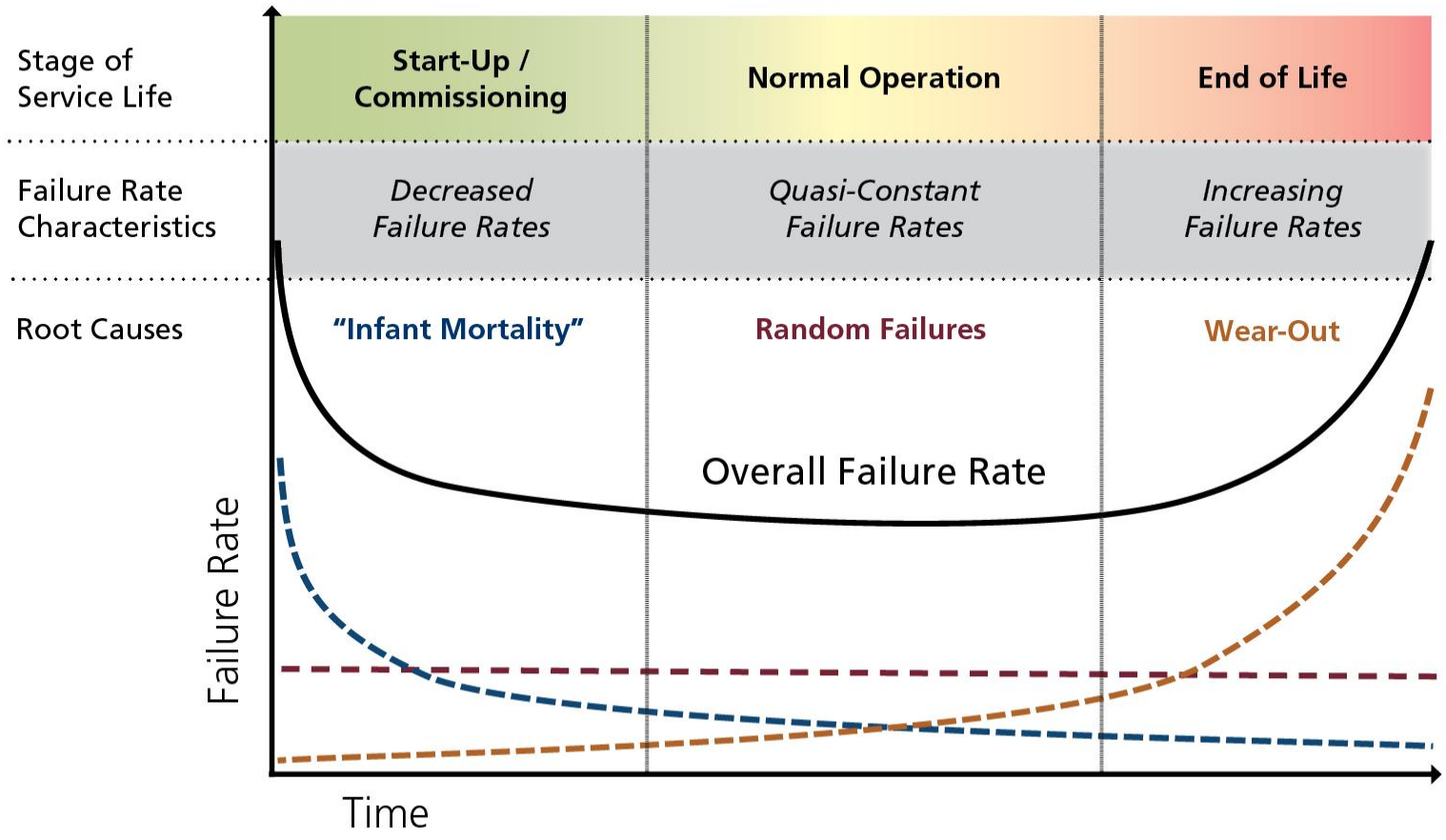
Reliability "Bathtub" Curve



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SF6 Circuit Breakers – Mortality Analysis

Situation

- SF6 Breaker failures are increasing 33% year over year
- SF6 breakers leak and alarm creating emergency work
- Breakers are repeatedly filled unplanned
- Breakers are repaired after several alarms

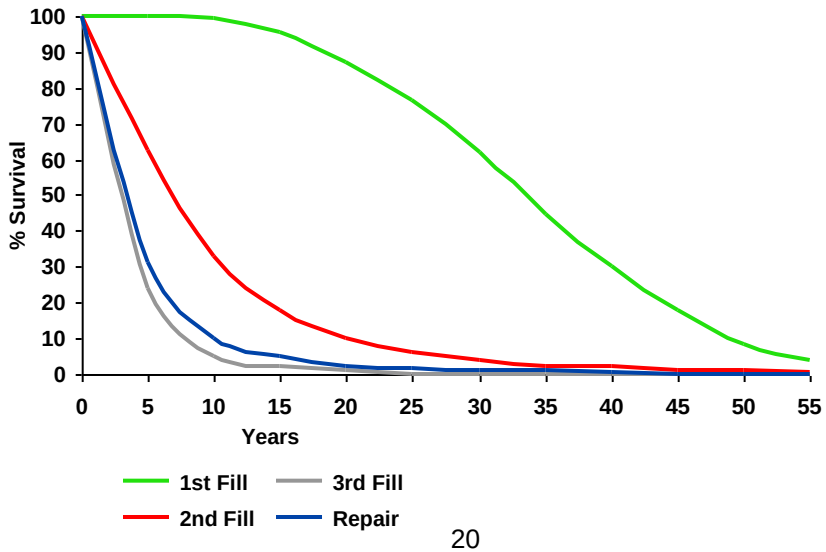
Findings

- Model and vintage drives survival rate
- Repairing breaker mitigates issue for ~12 months
- Once a breaker begins to leak it will repeatedly leak more often
- Cost/Benefit Analysis shows leaking breaker should be planned for replacement in lieu of repeated repairs

Results

- **46** SF6 breakers added to Capital Replacement Plan over 5 years
- Proactive replacement will reduce maintenance costs on SF6 fills, leak repairs and alarm call-outs
- Less SF6 will be lost to the environment
- Less unplanned line outages for SF6 fills/leaks will occur

Expected Survival Rate (Vendor A)



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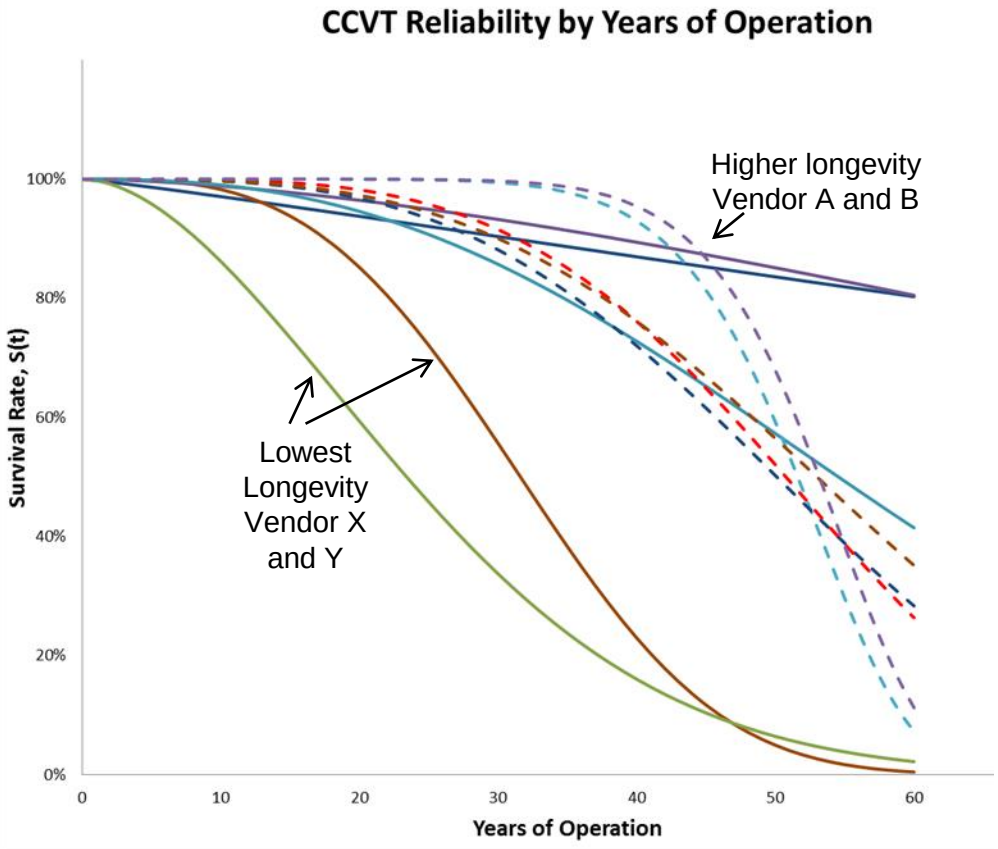
CCVT – Mortality Analysis

- Develop a statistical model for Time-to-Failure maintenance data
- Forecast expected CCVT Failures and Replacements
- Reduce Doble-testing (currently every 4 years)
- Optimize O&M Spending
- Improve Reliability Performance of the Fleet
- Ensure Safe Operation of CCVT Fleet (no catastrophic failures)

CCVT – Mortality Analysis

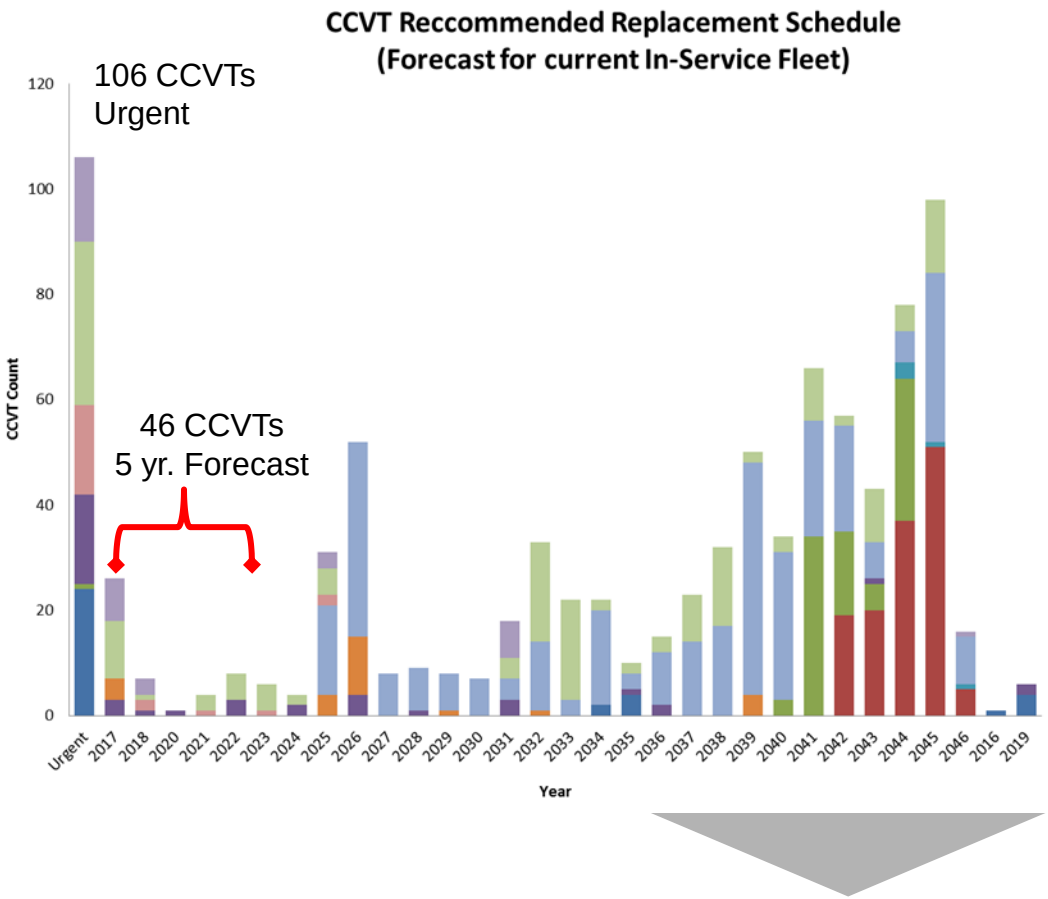


- Statistical model proved life expectancy based on Test Criteria
- Learning from statistical models can help shape the Testing program
- Risk is measured as a function of Survival Probability

Bigger Reliability drop expected for Vendor X and Y

Behavior due to faster mean-time-to-failure as compared with other OEMs

CCVT – Mortality Analysis



- Plan asset replacement at recommended age to minimize risk of failure and reduce maintenance costs of future Doble-testing
- Manage risk based on Failure probability model

Revise CCVT Replacement program to reduce operating Cost and improve Reliability of System.

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CCVT – Mortality Analysis

Recommended Test and Replacement Program

Manufacturer	First Test Criteria (years)	Continuous Testing (years)	Replacement Age (Years)
Vendor A	16	8	30
Vendor B	14	8	30
Vendor C	5	6	20
Vendor D	24	8	44
Vendor E	19	8	42
Vendor F	14	8	30
Vendor G	14	8	30
Vendor H	24	6	30
Vendor I	14	8	30

- Findings based on over 20 years of Doble-Testing, Failure and Maintenance Data
- Identified several high risk CCVTs that required immediate Doble testing
- Implemented reduced testing cycles for future tests
- Developed revised Capital Replacement program based on results

Testing Program can be significantly reduced by implementing a Condition-based program vs. a Time-based 4 year cycle