Validating Reliability Improvements of New Cable Designs

Chris Fletcher\textsuperscript{1}, Joe McAuliffe\textsuperscript{2}, Nigel Hampton\textsuperscript{3}, & Josh Perkel\textsuperscript{3}

\textsuperscript{1}Duke Energy, \textsuperscript{2}Southwire, & \textsuperscript{3}NEETRAC
Outline

• Verifying Performance Improvements on a Utility System
• Method
• Adjustments for the Utility Environment
• Example
  – Background of Self Healing Solutions
  – Duke Pilot Study
  – Performance Evaluation
  – Projections
• Conclusions
Introduction

• New materials, installation methods, operational issues and cable designs are under constant refinement

• These are generally claimed to offer better performance than past iterations

• How can we verify that the performances are improved??
Introduction

• Pilot studies are often used

• BUT we need
  – control population – a basis for comparison
  – method to “scale up” projections
  – often forgotten

• Difficult to construct a “traditional control population”

• Trials carried out on “live” systems thus need to deal with:
  – Climate / weather issues
  – Different sizes
  – Multiple failure modes
  – Coarse data
Crow-AMSAA Basics

- Crow AMSAA plots cumulative number of failures against cumulative time
- Log / Log scales linearize the data
- The gradients/slopes show the Failure Rates
- Decreasing gradients show decreasing Failure Rates

The difference in slope between the two lines quantifies the improvement in reliability
Aero Engine Example

Data comes from Monthly Reports & includes:
1) Unscheduled Engine Removals
2) Unscheduled Line Replaceable Units

Cumulative Flight Hours vs. Cumulative Unscheduled Maintenance Events
Con Ed DC vs VLF Hipots

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Changing / Inconsistent Sizes

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Crow-AMSAA

Regression Fit

Cumulative Failures [#]

FR Increase

FR Unchanged

FR Decrease

Data

Prediction

Experience [ft * yr]

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Duke 600V Pilot Study
Why do 600 V cables fail?

There are many potential reasons for 600 V cable to fail

– Dig-ins and damage caused by other utilities
– Lightning
– Improper installation
– Rodent Damage
– Incidental damage caused by property Owners
  • Landscaping
  • Installing shrubs & bushes
Why do 600 V cables fail?

- Installation Damage
- Rodent Damage
- Corrosion Failures
- Lightning Failure
Standard 600 V Cable

- There are 3 standard cable constructions used today for underground residential 600 V Cables
  - Standard single layer construction
    - Typically low density XLP
  - Abuse resistant
    - Medium Density and High Density XLP
      - Single layer
      - 2 Layer
  - Self Sealing cable constructions
Self-Sealing Designs

Many different designs have been tried through the years

- Mastic in combination with XLP or PE insulation
  - Shrink back issues

- Thick fluid in combination with XLP or PE insulation
  - Fluid flow control issues

- Visco-Elastic sealant in channels within insulation
  - Material flow is controlled
  - Sealing is quick (30 min +/-)
2/0 Pilot Program

Anderson
Duke Secondary Cable System

Anderson Op Area
Failure Rate Changes

Experience [ft * yrs]

Cumulative Failures [#]

Area
- Anderson
- Carolinas
- Southern

Failure rate decrease

Est. Adoption of Self-Sealing Cable - 2006
Control Populations ???

Was the change just luck or self sealing?
Duke Secondary Cable System - Areas
Gradients – Split at 2006

No changes

Significant decrease

Experience [ft²*yr]

Cumulative Failures [#]

Area
Anderson
Carolinas
Southern

2003-2006

2006-2009

0.477
0.530
0.634
0.459
0.372

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Impact Avoided Failures - 2010

- Standard Design
- Self Sealing + Standard Design
- Actual

Cumulative Failures [#]

Experience [ft*Age]

Pre-Self Sealing
Self Sealing
Prediction/Estimate

69 Avoided Failures by 2010

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Avoided Failures - 2020

216 Avoided Failures by 2020

Cumulative Failures [#]

Experience [ft*Age]

Pre-Self Sealing
Self Sealing
Prediction/Estimate

Variable
- Standard Design
- Self Sealing + Standard Design
- Actual

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Summary

• Crow-AMSAA method is useful for spotting improvements or reductions in reliability
  – Can be used to predict future performance
  – Can be used to predict “do nothing” performance
  – Does not require “age” information on population
  – Effective for economic decisions to be made

• Widely applicable
  – Field Testing
  – Overhead Connector Failures
  – Outage Prediction
  – Network Fires / Manhole Events
  – Secondary Cable Design Enhancements