HV & EHV Extruded Cable System Service Performance

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Project Purpose / Scope

- Underground Transmission Systems are viewed by some utilities as “New Technologies” and by others as “Established Technologies”.

- Utilities and standardization bodies are very interested in understanding industry-wide performance surveys.

- The most recent document, which takes an international perspective is:

  CIGRE TB 379 “UPDATE OF SERVICE EXPERIENCE OF HV UNDERGROUND AND SUBMARINE CABLE SYSTEMS” issued in 2009.

- Reading this document led to some questions / confusion.
Selected CIGRE 379 Analyses

Voltage Range (kV) 315 - 500
220 - 314
110 - 219

Length (cct km)
4000
3000
2000
1000
0

Voltage (kV)
220 - 500
60 - 219
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00

Failure Rate (fail/yr/100cctkm)
Terminations
Joint
Cable

Sheath
- Laminated
- Extruded / Welded
- None
Approach

- Include both Manufacturers and Utilities

- Focus on extruded cable systems installed since 2000

- Components failing in service, excluding third party damage

- Simultaneously collect & verify data (where possible) on failures and installed lengths

- Consider HV (69 – 150 kV) & EHV (230 – 400 kV)

- Obtain disbursement of component failures

- Estimate most likely failure rate and most likely range

- Provide reliability perspective on “bathtub curve”
What has Failed?

Collated in 2014
Decisions when estimating Failure Rates

- Select the data
  1. Only include the failures that come with lengths?
  2. Include those without length info (20%) and estimate lengths

- Count the data
  i. Place all the numbers into two pots and divide: $\Sigma$fails/$\Sigma$miles
  ii. Maintain integrity of failures / lengths: 1/10, 1/100
  iii. Add Engineering Knowledge to calculate a failure rate range for zero data: 0/2, 0/97

- All approaches have merit

- Decided to adopt all data (2) and count (3) methods separately, use results to get “Uncertainty of Measurement”
Estimating Failure Rates
Range of Failure Rates

Collated in 2014
Range of Failure Rates

No adjustment made for “Under Reporting”

An adjustment would likely skew the peak to higher rates

Collated in 2014
Estimates of Component Rates

Collated in 2014

Reported HV lengths >4 times EHV lengths

Collated in 2014
Comparison with CIGRE

Uncertainty in NEETRAC Estimates is of the order of +/- 25% at least
Bathtub Curve

• Although not requested, some (but not all) of the data were provided with specific times in service before failure or a range of times before failure.
• There was sufficient data to be able to:
  – Identify if there were different failure modes:
      ➢ Early / Infant, Middle, Late / End of Life
  – See relative differences in rate
  – Understand when they initiate
Bathtub Curve - Times of Failure

Hazard Plot
Multiple Distributions
Arbitrary Censoring - ML Estimates

Failure Rate (arb)
Time in Service (yrs)
Bathtub Curve - Times of Failure

Hazard Plot
Multiple Distributions
Arbitrary Censoring - ML Estimates

Shape Parameter = 0.3
Infant Mortality

Shape Parameter = 1
Random
Information not requested on:

- Accessory construction
- Age at failure (some was provided / inferred)
- Cable construction
- Conditions
- Location
- Manufacturer (generally not provided)
- Numbers of components
- Style of accessory
Conclusions

- North American HV & EHV Service Performance data for modern extruded systems do differ from CIGRE data
  - Failure rates are lower
  - Disbursement differs (lower component failure rates)
- Difference could be due to
  - Differing data sets – this project used data for systems after installed after 2000
  - Larger NA participation – 44 entities
  - Reduced confirmation bias – data for both failed & non-failed
  - Increased data verification
- Failures likely to follow the Bathtub Curve but can only discern the Early and Middle portions
- Infant Mortality failure mode inactive by 1 to 4 yrs in service
- Results are not static: failures & installations occur