**AMPCO-1**

**Reference: Exhibit 2, Tab 1, Schedule 1, p.10, Table 4**

**Please provide the Threshold Capital Expenditure Calculation for the PowerStream RZ using the OEB-approved 2024 inflation factor.**

**Response:**

Alectra Utilities has provided the Threshold Capital Expenditure Calculation for the PowerStream RZ using the OEB-approved 2024 inflation factor in Table 1 below.

**Table 1 – Threshold Capital Expenditure Calculation – PowerStream RZ**

| Description | PRZ |
|---|---|
| Inflation | 4.80% |
| Less: Productivity Factor | 0.00% |
| Less: Stretch Factor | 0.30% |
| Price Cap Index | 4.50% |
| | |
| Growth Factor | 0.50% |
| | |
| Rebasing Year | 2017 |
| # Years since rebasing | 7 |
| Price Cap Index | 4.50% |
| Growth Factor | 0.50% |
| Dead Band | 10% |
| Rate Base | $1,082,805,162 |
| Depreciation | $52,272,173 |
| **Threshold Value** | |
| Price Cap IR Year 2024 | **250%** |
| **Threshold CAPEX** | |
| Price Cap IR Year 2024 | **$130,502,043** |

**AMPCO-2**

**Reference: Exhibit 2, Tab 1, Schedule 1, p. 19, Table 11**

**Please provide the Threshold Capital Expenditure Calculation for the Enersource RZ using the OEB-approved 2024 inflation factor.**

**Response:**

Alectra Utilities has provided the Threshold Capital Expenditure Calculation for the Enersource RZ using the OEB-approved 2024 inflation factor in Table 1 below.

**Table 1 – Threshold Capital Expenditure Calculation – Enersource RZ**

| Description | ERZ |
|---|---|
| Inflation | 4.80% |
| Less: Productivity Factor | 0.00% |
| Less: Stretch Factor | 0.30% |
| Price Cap Index | 4.50% |
| | |
| Growth Factor | -0.28% |
| | |
| Rebasing Year | 2013 |
| # Years since rebasing | 11 |
| Price Cap Index | 4.50% |
| Growth Factor | -0.28% |
| Dead Band | 10% |
| Rate Base | $623,497,832 |
| Depreciation | $25,461,389 |
| **Threshold Value** | |
| Price Cap IR Year 2024 | **266%** |
| **Threshold CAPEX** | |
| Price Cap IR Year 2024 | **$67,665,866** |

**AMPCO-3**

**Reference: EB-2022-0013, Decision and Order, November 17, 2022, p. 9**

**At page 11, the Decision states:**

**"The OEB applied the 3.7% inflation factor to calculate the 2023 ICM materiality thresholds. The OEB will not change the inflationary input to the ICM calculations as outlined by OEB staff. OEB staff's suggestion could be considered as part of a review of the OEB's ICM policy but should not be considered in this proceeding given that it was only raised by OEB staff in its submission and calculations were not provided to the other parties to allow for a thorough consideration of this issue."**

**In the absence of a review of the OEB's ICM policy, please explain why Alectra believes it is appropriate to change the inflation calculation as an input to its 2024 ICM calculations.**

**Response:**

Please see Alectra Utilities' response to 1-Staff-2.

**AMPCO-4**

**Reference: EB-2022-0013, Decision and Order, November 17, 2022, p. 14, Table 4**

**Table 4: Enersource RZ Capital Expenditure Funding 2017 to 2023**

| | Cable Renewal Funding Supported Through Distribution Rates | | | | | | | | ICM Request |
|---|---|---|---|---|---|---|---|---|---|
| **Annual Cable Renewal Spending ($ millions)** | **Actual 2017** | **Actual 2018[31]** | **Actual 2019** | **Actual 2020** | **Actual 2021** | **Actual & Budgeted 2022** | **Average 2017-2022** | **Budget 2023** | **Budget 2023** |
| **Cable Replacement** | $18.7 | $16.1 | $13.8 | $15.2 | $9.7 | $7.6 | $13.5 | $5.1 | $5.8 |
| **Cable Injection** | N/A | N/A | $0.0 | $0.0 | $0.0 | $1.7 | $0.4 | $1.6 | $2.9 |
| **Emerging Underground Projects** | N/A | N/A | $0.7 | $1.0 | $2.8 | $0.0 | $1.5 | $1.1 | N/A |
| **Total** | $18.7 | $16.1 | $14.5 | $16.2 | $12.6 | $9.3 | $14.6 | $7.8 | $8.7 |
| **Total 2023 Cable Renewal Budget** | | | | | | | | **$16.5** | |

**Please update Table 4 to include: 2022 actuals, update the 2023 and 2024 budget for cable renewal funded through distribution rates, update the 2023 ICM Budget and add the ICM budget request for 2024.**

**Response:**

Please see Alectra Utilities' response to 1-Staff-4 a).

## AMPCO-5

**Reference:** **EB-2022-0013, Decision and Order, November 17, 2022, p. 14, Table 5**

**Table 5: PowerStream RZ Capital Expenditure Funding 2017 to 2023**

| | Cable Renewal Funding Supported Through Distribution Rates | | | | | | | | ICM Request |
|---|---|---|---|---|---|---|---|---|---|
| **Annual Cable Renewal Spending ($ millions)** | **Actual 2017** | **Actual 2018** | **Actual 2019** | **Actual 2020** | **Actual 2021** | **Actual & Budgeted 2022** | **Average 2017-2022** | **Budget 2023** | **Budget 2023** |
| **Cable Replacement** | $8.3 | $9.9 | $6.7 | $11.9 | $6.3 | $9.5 | $8.8 | $7.4 | $10.7 |
| **Cable Injection** | $3.7 | $3.6 | $3.8 | $7.9 | $7.4 | $9.7 | $6.0 | $8.8 | $5.9 |
| **Emerging Underground Projects** | $0.0 | $0.0 | $1.9 | $1.9 | $3.0 | $2.3 | $2.3 | $1.4 | N/A |
| **Total** | $12.0 | $13.5 | $12.4 | $21.7 | $16.7 | $21.5 | $16.3 | $17.6 | $16.6 |
| **Total 2023 Cable Renewal Budget** | | | | | | | | **$34.2** | |

**Please update Table 5 to include: 2022 actuals, update the 2023 and 2024 budget for cable renewal funded through distribution rates, update the 2023 ICM Budget and add the ICM budget request for 2024.**

**Response:**

Please see Alectra Utilities' response to 1-Staff-4 a).

**AMPCO-6**

**Reference: Exhibit 3, Tab 1, Schedule 2, p. 3, Figure 4**

**Please provide the number of Customer Hours of Interruption and number of Customer Interruptions for Cable XLPE and Accessories by rate zone for 2022.**

**Response:**

Alectra Utilities has provided Table 1 providing the Customer Hours of Interruption and number of Customer Interruptions for Cable XLPE and Accessories by rate zone for 2022. Due to a greater volume of automation in PRZ compared to HRZ, restoration and fault finding occurs faster in PRZ. However, over a five-year period (2018 to 2022), both the number of Customer Interruptions and Customer Hours of Interruption is higher in PRZ compared to HRZ as provided in Table 2.

**Table 1 – Cable XLPE and Accessories by rate zone for 2022**

| Rate Zone | # of Customer Interruptions | Customer Hour Interruptions |
|---|---|---|
| Alectra | 171,432 | 210,929 |
| ERZ | 75,779 | 88,309.32 |
| BRZ | 10,201 | 14,081.67 |
| HRZ | 52,321 | 60,089.38 |
| PRZ | 32,846 | 47,573.75 |
| GRZ | 285 | 875.13 |

**Table 2 - Cable XLPE and Accessories by rate zone 5 year total (2018-2022)**

| Rate Zone | # of Customer Interruptions | Customer Hour Interruptions |
|---|---|---|
| Alectra | 927,962 | 1,125,733 |
| ERZ | 402,599 | 370,944.55 |
| BRZ | 113,999 | 129,359.77 |
| HRZ | 191,564 | 262,948.62 |
| PRZ | 208,175 | 356,532.15 |
| GRZ | 11,625 | 5,948.02 |

**AMPCO-7**

**Reference: Exhibit 3, Tab 1, Schedule 2, p. 5**

**From 2018 to 2022, the backlog of deteriorated underground cable has increased from 3,173 km (14% of the population) to 4,766 km (21% of the population).**

**a) Please explain in detail how Alectra determined that an additional 1,593 km of underground cable is deteriorating and failing.**

**b) Please provide a breakdown of the incremental 1,593 km of underground cable by rate zone.**

**Response:**

a) As provided in Exhibit 1, Tab 1, Schedule 4, page 5, deteriorated underground cable refers to the cables with a Health Index of Poor or Very Poor condition as identified by the Asset Condition Assessment report. The additional 1,593 km was determined based on the difference in cable population deterioration rates between 2018 and 2022. Further details on the methodology used to assess the condition of cables are provided in Alectra Utilities' 2018 Asset Condition Assessment included as Appendix D in Alectra Utilities' 2020-2024 DSP.

b) Table 1 below provides a breakdown of the incremental 1,593 km of deteriorated cables by rate zone.

**Table 1 – Deteriorated Cable Population Change (2018 vs. 2022) by Rate Zone**

| Rate Zones | Deteriorated Cables (km) 2018 | Deteriorated Cables (km) 2022 | Difference (km) |
|---|---|---|---|
| PRZ | 710 | 1,662 | 952 |
| ERZ | 1,028 | 1,587 | 559 |
| HRZ | 894 | 833 | (61) |
| BRZ | 430 | 493 | 63 |
| GRZ | 111 | 191 | 80 |
| **Total** | **3,173** | **4,766** | **1,593** |

**AMPCO-8**

**Reference: Exhibit 3, Tab 1, Schedule 2, p.11, Table 21**

**a) Please add the 2024 forecast to Table 21.**

**b) Please provide the Table in part (a) on the basis of ICM funded cable renewal investments.**

**Response:**

a) Alectra Utilities has added 2024 Budget to Table 21 in Table 1 below.

**Table 1 – UG Cable Renewal Investments 2018-2024 ($MM)**

| Investment | Actual 2018 | Actual 2019 | Actual 2020 | Actual 2021 | Actual 2022 | Forecast 2023 | Budget 2024 |
|---|---|---|---|---|---|---|---|
| Cable Renewal – Replacement | $37.2 | $31.2 | $35.4 | $25.3 | $20.1 | $38.5 | $36.9 |
| Cable Renewal – Injection | $3.6 | $4.9 | $11.5 | $13.7 | $12.8 | $17.0 | $23.8 |
| Emerging Underground Projects | $2.3 | $5.9 | $8.0 | $10.1 | $6.1 | $6.3 | $6.7 |
| **Total** | **$43.1** | **$42.0** | **$54.9** | **$49.1** | **$39.0** | **$61.8** | **$67.4** |

b) Alectra Utilities has only received ICM funding for cable renewal investments in 2023. Table 2 below provides the 2023 forecast for the 2023 approved ICM projects and the proposed budget for the 2024 ICM projects included in this application.

**Table 2 – ICM Funded Cable Renewal Investments ($MM)**

| Investment | Forecast 2023 | Budget 2024 |
|---|---|---|
| Cable Remediation –Replacement | 10.3 | 13.9 |
| Cable Remediation – Injection | 5.8 | 11.3 |
| **Total** | **16.1** | **25.1** |

**AMPCO-9**

**Reference: EB-2022-0013, AMPCO-13 (a)**

**a) Please update Table 1 in part (a) to include 2022 actuals and the forecast for 2023 and 2024.**

**b) Please provide Table 1 in part (a) on the basis of ICM funded cable renewal investments.**

**Response:**

a) Table 1 below provides Underground Cable Renewal on a km basis

**Table 1 – UG Cable Renewal (Table 21 from EB-2022-0013, AMPCO-13) km**

| Investment | Base + ICM | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Actual 2018 | Actual 2019 | Actual 2020 | Actual 2021 | Actual 2022 | Forecast 2023 | Forecast 2024 | Total |
| Cable Replacement | 96 | 45 | 74 | 43 | 55 | 44 | 72 | 429 |
| Cable Injection | 56 | 78 | 118 | 105 | 157 | 169 | 272 | 955 |
| Emerging Underground Projects | 6 | 9 | 17 | 17 | 16 | 4 | 3 | 72 |
| Total | 158 | 132 | 209 | 165 | 228 | 217 | 347 | 1456 |

b) Alectra Utilities has provided Table 2 below, which includes the kms of cable for the ICM projects.

**Table 2 – UG Cable Renewal – ICM projects only**

| Investment | Base + ICM | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Actual 2018 | Actual 2019 | Actual 2020 | Actual 2021 | Actual 2022 | Forecast 2023 | Forecast 2024 | Total |
| Cable Replacement | 0 | 0 | 0 | 0 | 0 | 25 | 23 | 48 |
| Cable Injection | 0 | 0 | 0 | 0 | 0 | 71 | 117 | 188 |
| Emerging Underground Projects | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 0 | 0 | 0 | 0 | 0 | 96 | 140 | 236 |

**AMPCO-10**

**Reference: Exhibit 3, Tab 1, Schedule 2, p. 14**

**Alectra Utilities combined reliability statistics by grid against the 2020 ACA as part of an enhanced overlay methodology. Reliability heat maps illustrate the most recent (2016–2021) outages due to cable failures, including the location of recently (2016-2021) completed projects, planned projects in base rates and the proposed incremental cable renewal projects.**

**a) Please provide copies of any ACAs completed beyond 2020.**

**b) Please explain if Alectra combined reliability statistics by grid against the most recent ACA. If not, why not?**

**c) Please discuss how the results of the overlay methodology impact the 2024 project priorities if the latest ACA and 2022 cable failures are used in the analysis.**

**Response:**

a) Alectra Utilities has attached the 2021 and 2022 Asset Condition Assessment reports as AMPCO-10_Attach 1_Alectra 2021 ACA Report and AMPCO-10_Attach 2_Alectra 2022 ACA Report.

b) and c)

Yes, Alectra Utilities combined reliability statistics by grid against the most recent ACA in a manner consistent with that conducted in 2022. As provided in Exhibit 3, Tab 1, Schedule 4, page 7, lines 8-11, the engineering assessment of cable failures was completed utilizing the most recent reliability results as of year-end 2022. The assessment conducted in 2021-2022 was reviewed during the 2022-2023 period. Based on the engineering assessment there was no change to the 2024 priority projects identified in this application. Although additional priority projects were identified as part of this review, those projects will be completed in later years.

# AMPCO-10

# Attachment 1
# Alectra 2021 ACA Report

2021

alectra
Discover the possibilities

# Asset Condition Assessment - 2021

## ASSET MANAGEMENT

2021 ACA REPORT
MAY 2022

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# Executive Summary

In 2018, Alectra Utilities harmonized its Asset Condition Assessment (ACA) practices. Alectra Utilities compiles an annual report based on the latest inputs to the ACA. This report presents the 2021 ACA using input data as of December 2021.

Alectra's service territories extend from the city of St. Catharines, located on the shores of Lake Ontario, to the town of Penetanguishene, located along the southeastern shores of Georgian Bay. The service territories span over 1,800 square kilometers, providing electricity to approximately one million customers. Alectra owns, operates, and maintains distribution assets in these territories. Asset condition assessments are used to assist in developing asset sustainment strategies and guiding investments.

Asset condition assessment involves monitoring and inspecting assets and analyzing the collected data to determine their condition. Assessment is performed using Health Index (HI) models. The HI model is an analytical one that quantifies the condition of an asset in a consistent manner. Models reflect asset degradation, industry guidelines, and Alectra's experience. HI model formulas, parameters, inputs, and results are stored in a Relational Database, enabling a unified source for performing HI computations and providing the agility for future enhancements.

Health Index is calculated for the distribution asset classes listed below:

- Pad-mounted transformers
- Pole-mounted transformers
- Vault type transformers
- Pad-mounted switchgear
- Pole-mounted load interrupting switches
- Overhead primary conductors
- Wood poles
- Concrete poles
- Underground medium-voltage power cables

A summary of distribution asset HI results is presented in Figure 1.

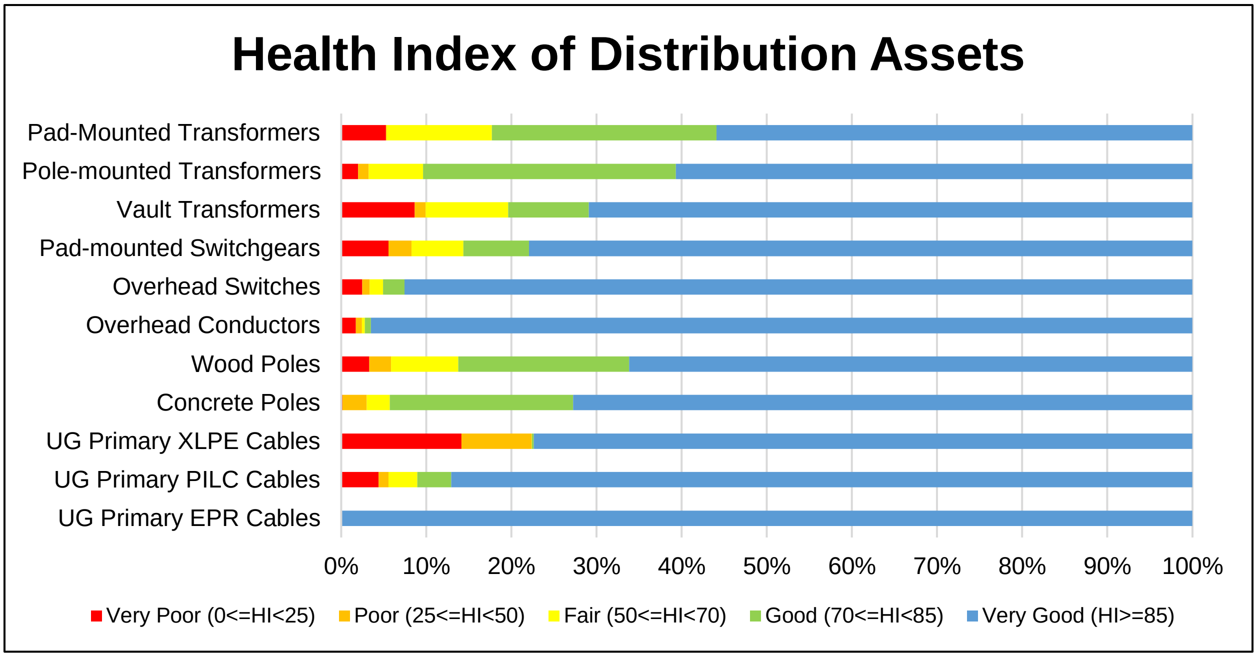


*Figure 1 Distribution Asset Health Index Results Summary for 2021*

Distribution asset HI results and sustainment pacing recommendations are provided to subject matter experts (SME) for each asset class. SMEs determine system sustainment needs and develop business cases based on a recommended number of assets that require attention. Business cases are submitted for optimization using Alectra's Capital Investment Portfolio application (Copperleaf C55).

HI is calculated for the station asset classes listed below:

- Station power transformers
- Station class switchgear
- Station circuit breakers

A summary of station asset HI results is presented in Figure 2.

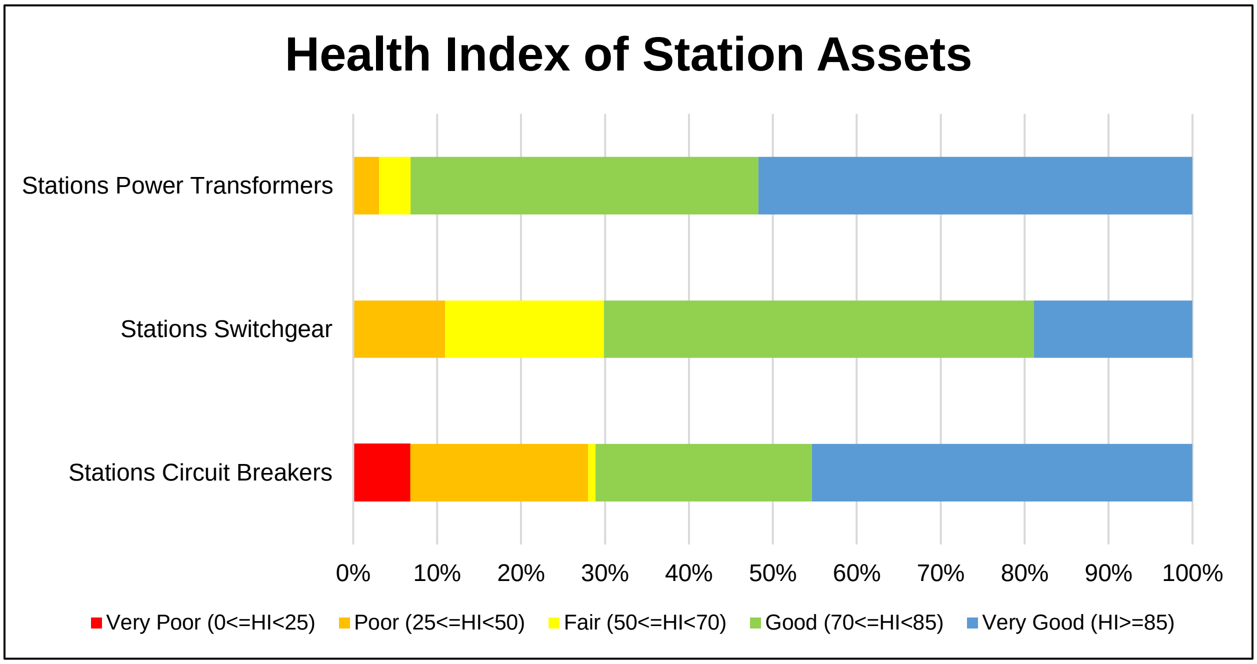


*Figure 2 Station Asset Health Index Results Summary for 2021*

Station assets HI results are compiled on a per-station basis and published to SMEs for evaluation. Grouping assets by station facilitates a station-centric approach, enabling a thorough review process involving SMEs in multiple departments. SMEs leverage the HI results, along with other considerations that include the following: station decommissioning schedules associated with voltage conversion projects, expansion requirements, magnitude and criticality of the load that is supplied, type of customers supplied, potential stranded load conditions, distribution system load transfer capabilities, obsolescence, availability of parts, maintainability, safety and environmental concerns, and available budget. SMEs prepare business cases for station needs and opportunities identified through this exercise and submit them into Copperleaf C55 for optimization.

# 1 Introduction

This Asset Condition Assessment (ACA) report is prepared to address system renewal, and sustainment investment needs drivers as part of Alectra's Asset Management practices. The report also addresses specific elements of the Asset Management Process as noted in Chapter 5.3.3 of the Ontario Energy Board's "Filing Requirements for Electricity Distribution Rate Applications - 2020 Edition for 2021 Rate Applications".

The 2021 ACA represents an update, incorporating condition and inventory information available as of December 2021 using the same practices that were harmonized in 2018 after Alectra's formation.

This report describes an analytical approach to asset condition assessment using Health Indices for Alectra's distribution and station assets. Health Index (HI) is an input for SMEs when they derive system sustainment and asset management strategies.

ACA is an internal process used by Alectra as part of the overall asset management process. Outputs from the ACA are evaluated for sustainment needs. Figure 3 shows the needs drivers in Alectra's asset management process and identifies the alignment of the ACA in the process.

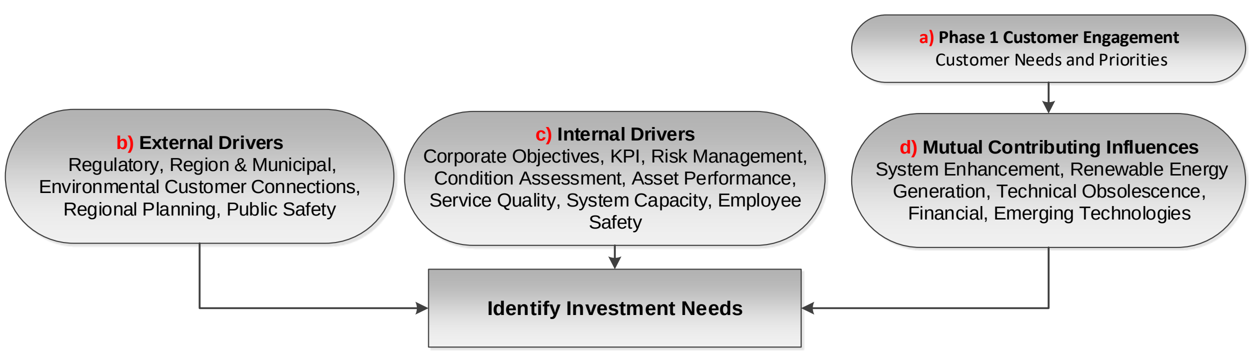


*Figure 3 Asset Management Process Investment Drivers and Considerations*

Distribution assets ACA results are provided to SMEs for evaluation to determine system sustainment needs and for business case development. SMEs incorporate the outcome of the ACA to build business cases for assets that warrant action. Distribution assets' business cases are based on a recommended number of assets that require attention. Business cases are documented in Alectra's Capital Investment Portfolio system (Copperleaf C55). Figure 4 illustrates the process of identifying investment needs for distribution assets.


Figure 4 Distribution Assets Condition Process

Station assets' HI results for multiple asset classes are grouped for each station and provided to SMEs for evaluation. Grouping multiple assets classes by the station facilitates a station-centric approach, enabling a thorough review process with SMEs in multiple departments. SMEs determine the system sustainment needs, where HI is one of several considerations considered in determining the needs.

In addition to the HI data, decisions on sustainment for station assets include considerations related to: station decommissioning schedules associated with voltage conversion projects, expansion requirements, magnitude and criticality of the load that is supplied, number of customers that are supplied, potential stranded load conditions, distribution system load transfer capabilities, obsolescence, availability of parts, maintainability, safety and environmental concerns, and available budget. Where station needs warrant sustainment activities, business cases are documented in Copperleaf C55, integrating all applicable cross-functional drivers as part of Alectra's integrated planning. Figure 5 shows the process identifying investment needs for station assets.

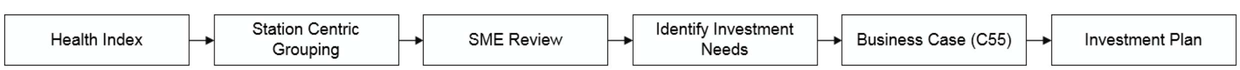


*Figure 5 Station Assets Condition Assessment Drivers*

Capital investment portfolio optimization is completed in Copperleaf C55, where investments are optimized across all Alectra investment categories. The optimization provides the prioritized allocation and pacing of investments. The optimization considers the risk and benefit in conjunction with financial attributes, such as weighted average cost of capital, and factors in inflation.

# 2 Health Index Methodology

The Health Index (HI) model quantifies the condition of an asset in a consistent manner. Each asset class has different inputs to inform the HI model. The input weights are based on the asset's characteristics, the extent to which the input reflects asset degradation, industry guidelines, and Alectra Utilities' experience. Health Index model formulas, parameters, inputs, and results are stored in a Relational Database, enabling a unified source for performing HI computations and providing the agility for future enhancements. Figure 6 shows a flowchart summarizing the HI methodology.

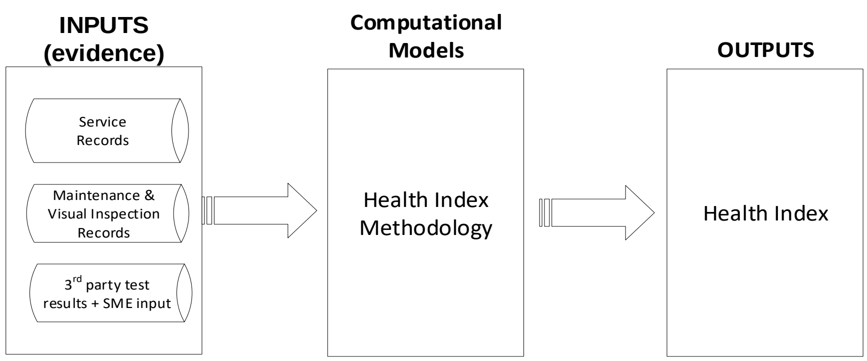


*Figure 6 Health Index Methodology: Inputs, Computation, & Outputs*

The advantage of using an evidence-based HI is having a practical and consistent method to gauge the condition of assets analytically in a quantified manner. Having a standardized model for assets across Alectra ensures that all assets are being measured in a consistent manner to guide asset management strategies and policies. The generic equation below shows the calculation of the Health Index:

$$\boldsymbol{Health\ Index} = \frac{\sum_{i=1}^{n}(Input\ Weight_i \times Input\ Score_i)}{\sum_{i=1}^{n}(Input\ Weight_i)} * Condition\ Multiplier \qquad (\mathbf{1}), \quad where$$

$$\boldsymbol{n}: number\ of\ available\ inputs\ for\ an\ asset\ class,$$

$$\boldsymbol{Input\ Score}: percentage\ (0-100\%),$$

$$\boldsymbol{Health\ Index}: percentage\ (0-100\%),$$

$$\boldsymbol{Input\ Weight}: percentage, where \sum_{i=1}^{n} Input\ Weight_i = 100\%$$

$$\boldsymbol{Condition\ Multiplier}: maximum\ allowable\ HI\ given\ asset\ specific\ metrics$$

$$described\ further\ in\ this\ report$$

## 2.1 Input Score

Inputs to the HI are scored in one of two ways: a step score, or a percentage score. Each input that makes up the Health Index is scored accordingly.

### 2.1.1 Step Score

Step score is a points-based scoring method used for inputs of the HI calculation that are non-continuous. Field inspections are an example. Step scoring is reserved for inputs with distinct levels measured against defined criteria.

Station assets and distribution assets are inspected and monitored through different processes and criteria. Field inspections and HI components that use step scoring for distribution assets have a six-point scoring system (0-5). Table 1 shows the distribution asset step scoring criteria and associated scores in percentage.

*Table 1 Distribution Asset Step Scoring*

| Inspection Score | Criteria | HI Input Score |
|---|---|---|
| 5 | Excellent condition | 100% |
| 4 | Relatively good condition | 80% |
| 3 | Fair condition | 60% |
| 2 | Moderate degradation | 40% |
| 1 | Major degradation/not fit for service | 20% |
| 0 | Imminent failure | 0% |

Field inspections and HI components that use step scoring for station assets have a five-point scoring system (0-4). Table 2 shows the station asset step scoring criteria and associated scores in percentage.

*Table 2 Station Asset step Scoring*

| Inspection Score | Criteria | HI Input Score |
|---|---|---|
| 4 | Excellent - Like new | 100% |
| 3 | Good - Within operating context | 75% |
| 2 | Fair - Not failed but watching | 50% |
| 1 | Poor - Not within operating context | 25% |
| 0 | Very Poor - Imminent failure | 0% |

### 2.1.2 Percentage Score

Percentage scoring is the continuous (i.e., graduated) scoring of an input. Percentage scoring is used when more granular data are available and where step scoring is not accurately representative of an input's impact. This representation is used for certain measurements, such as pole residual remaining strength, as well as for other data, such as age.

For example, age is represented as a percentage score based on a continuous function given by the Gompertz-Makeham Model described by the following set of equations:

$$Age\ score = e^{\frac{-(f(t)-e^{-\alpha\beta})}{\beta}} \qquad \mathbf{(2)} \quad ,where$$

$$f(t) = e^{\beta(t-\alpha)}, where$$

$$t: age\ (years)$$

$$\alpha, \beta: \text{constants}$$

The constants α, β are calculated so as to yield an age score of 80% at the Typical Useful Life (TUL), and 1% at the End of Useful Life (EUL) of an asset. Use of the Gompertz-Makeham Model is a widely accepted industry practice for assessing asset condition.

Asset TUL is based on the "Asset Depreciation Study for the Ontario Energy Board Kinectrics Inc. Report No: K-418033-RA-001-R000 July 8, 2010" report. Similarly, asset EUL is based on the Maximum Useful Life (Max UL) from the same report.

## 2.2 Condition Multiplier

To adequately represent the health of an asset using the HI, conditions that determine major degradation or imminent failure of an asset are accounted for by limiting the HI to a maximum value, using the condition multiplier. Once certain conditions are triggered, the HI of an asset is limited to a maximum score, regardless of the status of other inputs.

Condition multipliers are based on dominant HI inputs that significantly impact the asset's health. For example, pole residual strength is a dominant input and indicator of a wood pole's health.

Examples of condition multipliers are as follows:

- **Field inspection multiplier** is applied to assets that exhibit major degradation or imminent failure as determined by field inspection.
- **Measurement multiplier** is applied to assets that exhibit major degradation or imminent failure as determined by a measurement.
- **Safety hazard multiplier** is applied to assets that pose a safety hazard or in a condition that is below the acceptable industry safety standards, guidelines, and practices.
- **Obsolescence multiplier** is applied to assets that are no longer supported by vendors, have limited or no parts availability and/or no longer meet current safety or performance standards. Obsolescence is largely driven by specification changes, compatibility, and/or manufacturer/supplier.

Where two or more condition multipliers are applicable, the smallest multiplier (by value) is applied.

## 2.3 Health Index Categorization

The HI of assets is expressed as a percentage. Categorization based on percentage ranges enables the identification of groups within an asset class that exhibit similar characteristics from an overall condition perspective. The HI is classified into one of five categories, as shown in Table 3.

*Table 3 Health Index Categories*

| Category | Criteria | Range |
|---|---|---|
| **Very Good** | Asset is in excellent condition. | $HI \geq 85\%$ |
| **Good** | Asset is still relatively in excellent condition. | $70\% \leq HI < 85\%$ |
| **Fair** | Asset is functional but showing signs of deterioration. | $50\% \leq HI < 70\%$ |
| **Poor** | Asset is exhibiting degraded condition. | $25\% \leq HI < 50\%$ |
| **Very Poor** | Asset is showing major degradation / imminent failure. | $HI < 25\%$ |

A bar chart displaying the five asset Health Index categories as a function of HI score is presented in Figure 7.

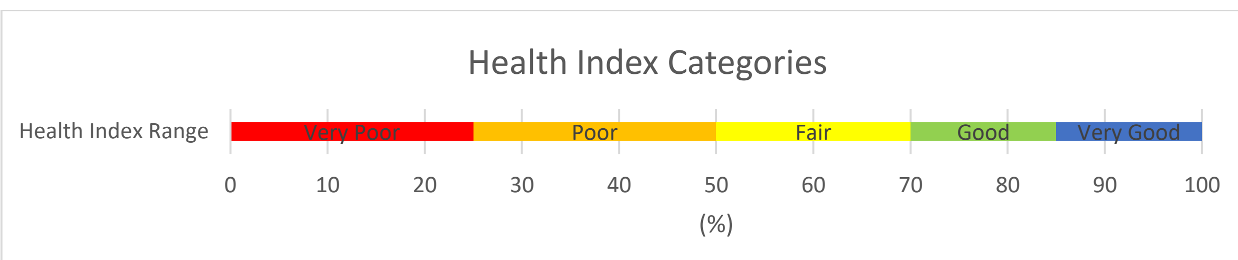


*Figure 7 Health Index Categories*

## 2.4 Data Availability

To assess the data completeness required by the computational model, a Data Availability Index (DAI) is calculated for each asset evaluated in this report.

The main function of DAI is to represent the amount of information, in percentage by input data weight, that went into calculating the HI of an asset. DAI only represents the completeness and not the quality of data.

$$DAI = \sum_{i=1}^{m} (Input\ Weight_i \times\ Input\ Data\ Available_i) \qquad (\mathbf{3})$$

$$, where$$

$$\boldsymbol{m}: number\ of\ inputs\ required\ in\ the\ Health\ Index\ model\ of\ an\ asset\ class$$

$$\boldsymbol{Input\ Weight}: percentage, where \sum_{i=1}^{n} Input\ Weight_i = 100\%$$

$$\boldsymbol{Input\ Data\ Available}:\ True = 1\ or\ False = 0$$

$$\boldsymbol{DAI}: percentage\ (0 - 100\%)$$

The average DAI is provided in the Health Index results section for each asset class. SMEs use the average DAI in decision-making for assessing overall data availability. However, it is sensitive to model improvements. For example, when the model is enhanced by adding a new input parameter, the average DAI may initially be reduced until new data has been collected.

As Alectra harmonizes its inspection, maintenance, testing and data collection practices over time, asset DAI is expected to increase.

# 3 System Sustainment Strategies

The ACA identifies assets within each asset class that require action. System sustainment strategies are dependent on the type of asset, consequences of failure and asset management practices. These strategies are:

- **Further assessment** (detailed risk assessment, inspection, testing)
- **Planned replacements** (like-for-like or right sizing)
- **Maintenance or rehabilitation**
- **Continue to monitor**
- **Run to failure**

**Further assessment** is required to ensure the prudent selection of a strategy. This is applicable to assets that can be maintained to extend their service life. For example, poles can be rehabilitated in some cases to restore them to acceptable operational and safety parameters. Such further assessments determine the viability of maintenance (versus replacement) on a case-by-case basis.

**Planned replacement** approach applies to critical assets that carry significant risk to the safe and reliable operation of the distribution system and protection of the environment. This strategy is also applicable to assets that have undergone further investigation and were determined unmaintainable. Safety considerations include safety of both the public and distribution system workers (Alectra's staff and contractors). For example, failure of wood poles carries significant safety risk to the public; therefore, a planned replacement strategy is prudent. In the case of concrete poles, if maintenance is not an option, a planned replacement strategy is applicable.

**Maintenance or rehabilitation** strategy applies to assets where only certain components of the asset are exhibiting degradation that can be corrected by cleaning or washing, repairing, replacing or re-tightening of components, or utilizing technologies such as cable rejuvenation or concrete bracing. For example, dirty insulators in air-insulated switchgear may be remedied by dry-ice cleaning.

**Continue to monitor** applies to assets where condition is approaching what is typically considered to be at its end of life. Monitoring strategies may involve increasing asset inspection cycles and/or installing on-line monitoring, such as on power transformers. Transformer on-line monitoring, in conjunction with analytical tools, can provide an indication of the condition of the transformer's insulation, which is a primary indication of the transformer's health. Adoption of on-line monitoring and associated analytical tools, in conjunction with the development of a modified condition-based maintenance protocol, is a strategy for prolonging the operational life of a transformer.

**Run to failure** applies to assets having minimal impact on reliability, on public or employee safety, and on the environment. Such assets are run to failure and are replaced reactively when they no longer perform their intended function. The decision to run to failure considers redundancy, contingencies, and availability of spare units or components.

From a system sustainment perspective, Alectra has aligned its sustainment outlook horizons to match the Ontario Energy Board's Distribution System Plan cycles, where one cycle is five years, as shown below.

- **Short-term** outlook is based on one DSP cycle (**5 years**)
- **Long-term** outlook is based on two DSP cycles (**10 years**)
- **Medium-term** outlook is between short-term and long-term outlooks (**7.5 years**).

Distribution asset SMEs use quantities of Very Poor and Poor assets as the needs-driver for business cases. To assist SMEs and ensure smooth transitions between DSP cycles so that sudden increases in rates and resource requirements are avoided, work is strategically paced. A pacing guideline using three scenarios based on the planning outlooks is shown in Table 4.

*Table 4 Distribution Asset Sustainment Pacing Scenarios*

| Pace | Description | Quantity per year |
|---|---|---|
| Baseline pace | Sustainment strategy targeting Very Poor & Poor assets over the **short-term** | $\frac{(Very\ Poor + Poor)}{5\ years}$ |
| Moderate pace | Sustainment strategy targeting Very Poor & Poor assets over the **medium-term** | $\frac{(Very\ Poor + Poor)}{7.5\ years}$ |
| Slow pace | Sustainment strategy targeting Very Poor & Poor assets over the **long-term** | $\frac{(Very\ Poor + Poor)}{10\ years}$ |

**Station asset** investments follow a risk-based approach incorporating a station-centric approach to identify specific asset sustainment initiatives. SMEs consider multiple factors along with the HI results for individual components. The sustainment strategies for station assets are primarily guided by risk mitigation and not pacing/timing.

# 4 ACA Data & Implementation

The implementation of this ACA used a Microsoft Structured Query Language (SQL) database. This implementation enabled the following:

- **Integrating multiple data sources**, which enables the integration of multiple static data sources, while maintaining data integrity and consistency in the transfer process
- **Centralized storage**, which provides a common repository for the required ACA data and calculations
- **Multiple user access,** which allows for simultaneous access by multiple users, thus providing significant contribution to productivity
- **Version control**, which enables future assessments while maintaining a high level of productivity, data accuracy and benchmarking functionality
- **Development agility**, which enables fast and accurate future improvements/development to the ACA data, models, and computations

Using this new process methodology for data collection, storage, harmonization, and computation of HI through an SQL database has provided better data management, version control, development agility, and productivity improvements. In 2021, Alectra adopted Alteryx software to assist in data analytics and asset information.

# 5 Distribution Asset Class Details and Results

Alectra's distribution asset details are described in terms of asset degradation, demographics, HI results categorization, and sustainment pacing. The assets covered as part of distribution are:

- Distribution transformers
- Distribution switchgear
- Overhead switches
- Overhead conductors
- Wood poles
- Concrete poles
- Underground primary cables

## 5.1 Distribution Transformers

Distribution transformers are a vital component to servicing the end users from the distribution system with utilization voltages. Distribution transformers include three types: Overhead, Underground, and Vault. Distribution transformers are moderately complex assets with a varying price per unit.

### 5.1.1 Summary of Asset Class

Underground transformers, also referred to as pad-mounted transformers, connect customers to the distribution system where service laterals are underground. Pad-mounted transformers typically employ sealed tank construction and are liquid filled, with mineral oil being the predominant insulating medium.

Overhead transformers, also known as pole-top transformers, convert primary distribution voltages from overhead conductors to secondary voltages (utilization voltages) for use in residential and commercial applications. Typically, overhead transformers connect customers to the distribution system where service laterals are overhead. This type of transformer is mounted on wood or concrete poles. Overhead transformers include single-phase transformers, banked single-phase transformers, and three-phase (polyphase) transformers.

Vault transformers are similar to overhead transformers in construction, but are designed to be placed in chambers, ether below or above grade, or in rooms inside buildings. Vault transformers connect customers to the distribution system where service laterals are underground.

### 5.1.2 Asset Degradation

Distribution-class transformer life is affected by a number of factors including, but not limited to: voltage impulses from lightning and switching, current surges resulting from secondary cable faults, mechanical damage from vehicle contact and corrosive salts, loading, and ambient temperature. Therefore, a combination of field inspection attributes and age criteria are commonly used to determine the health of the asset.

Field inspections provide considerable information on transformer asset condition. Presence and magnitude of oil leaks and structural corrosion are quantified during field inspections.

The failure of a distribution transformer has a relatively minor impact on reliability. However, if a transformer is in a condition that poses risk to the safety of the public or to the environment, a proactive replacement strategy is executed.

### 5.1.3 Asset Class Demographics

Alectra's distribution system has 121,785 distribution transformers, comprising 79,725 pad-mounted transformers, 31,153 pole-mounted transformers, and 10,907 vault transformers. Figure 8, Figure 9 and Figure 10 show the age demographics of distribution transformers, by type, in Alectra's distribution system.

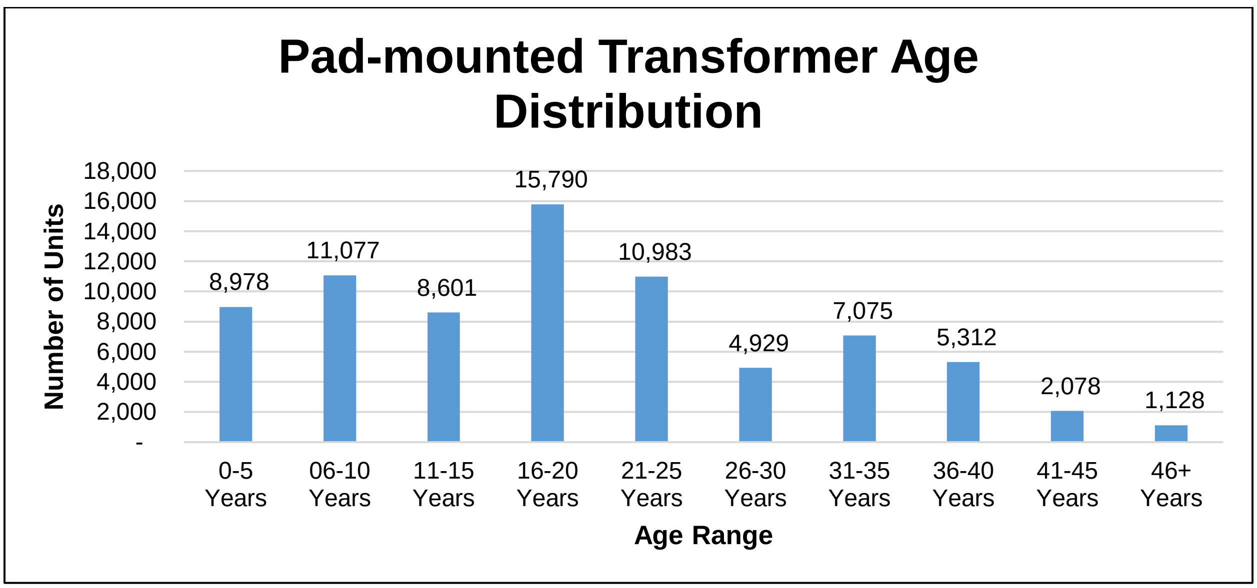


*Figure 8 Pad-mounted Transformer Age Distribution for 2021*

The pad-mounted transformers have a Typical Useful Life (TUL) of 40 years and are deemed to have reached End of Useful Life (EUL) at 45 years of age.

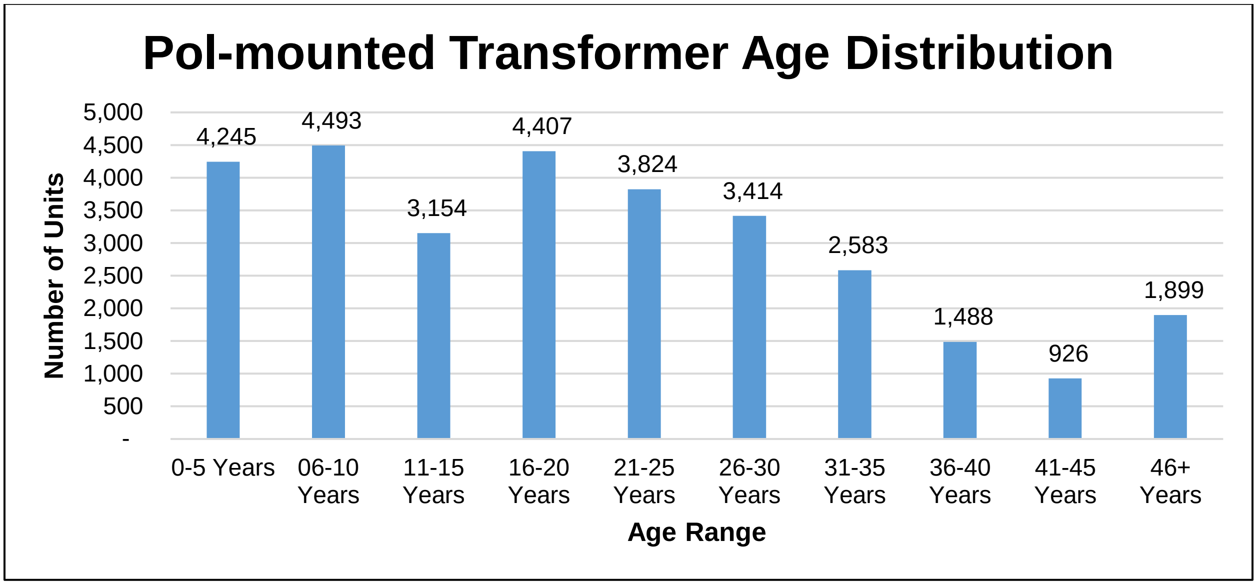


*Figure 9 Pole-mounted Transformer Age Distribution for 2021*

A pole-mounted transformer, also known as overhead transformer, has a TUL of 40 years and is deemed to have reached EUL at 60 years of age.

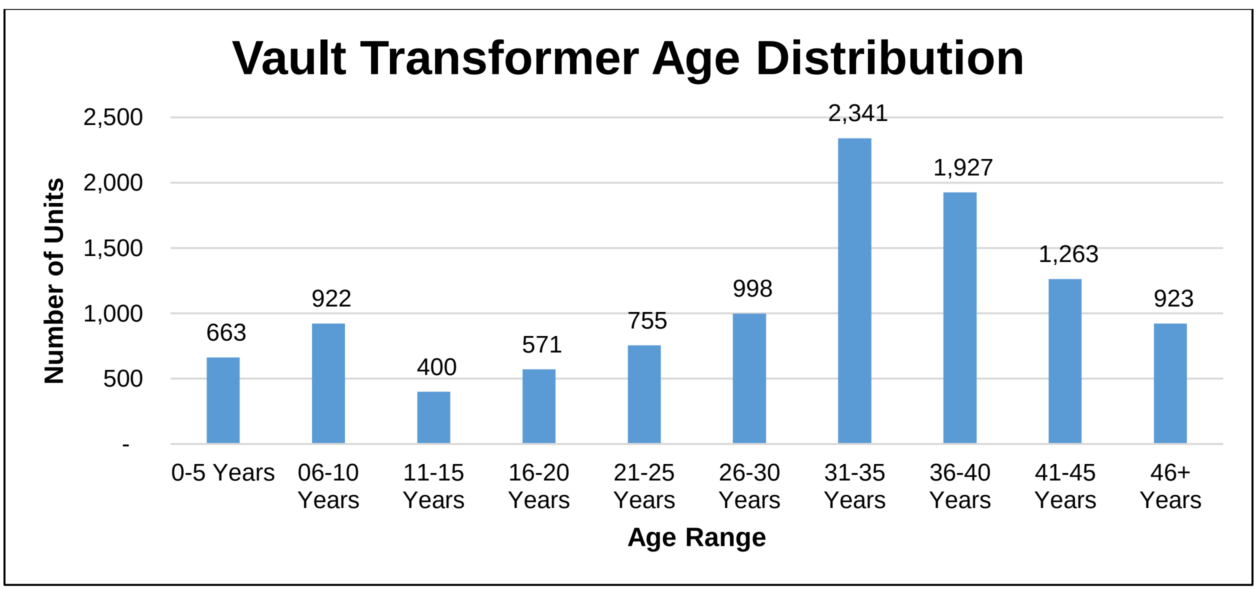


*Figure 10 Vault Transformer Age Distribution for 2021*

Vault transformers have a TUL of 35 years and are deemed to have reached EUL at 45 years of age.

### 5.1.4 Health Index Formula and Results

Health index of distribution transformers assesses the condition according to three components: Corrosion, Oil leak, and Age. Severity of corrosion and oil leak are determined through inspections and are scored as a step score.

Age represents deterioration due to factors not captured by the other components of the model. The scoring method for age is described in *Section 2.1.2 Percentage Score*.

The Health Index is computed by adding the weighted inputs of corrosion, oil leak and age, as shown in Table 5.

*Table 5 Distribution Transformer Health Index Parameters and Weights*

| # | Input | Input Weight for Pad-mounted Transformer | Input Weight for Pole-mounted Transformer | Input Weight for Vault Transformer | Scoring Method |
|---|---|---|---|---|---|
| 1 | Corrosion | 44% | 35% | 25% | Step Score |
| 2 | Oil Leak | 44% | 35% | 61% | Step Score |
| 3 | Age | 12% | 30% | 14% | Percentage Score |

**Field Inspection Multiplier**

If a distribution transformer exhibits major degradation or imminent failure, as determined by field inspection, it is considered to be of very poor health. The physical conditions considered in this criterion are major corrosion or major oil leak.

$$Field\ inspection\ multiplier = 25\%$$

Figure 11 shows the distribution of Health Index values of pad-mounted transformers, classified from Very Poor to Very Good. The average DAI is 84%.

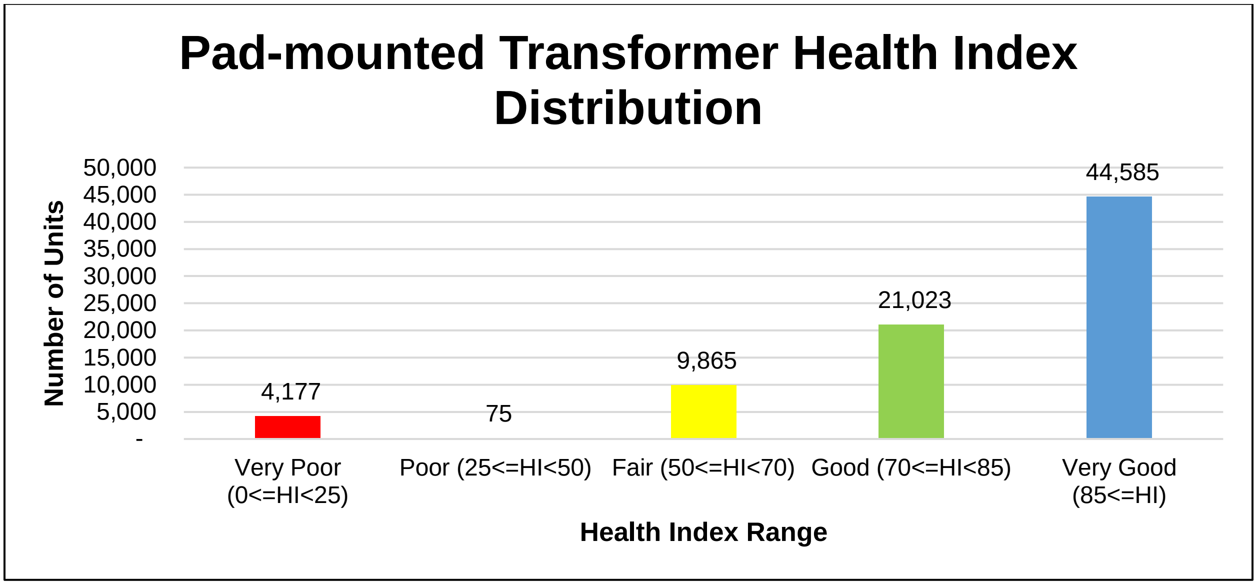


*Figure 11 Pad-mounted Transformer Health Index Distribution for 2021*

Figure 12 shows the distribution of Health Index values for pole-mounted transformers, classified from Very Poor to Very Good. The average DAI is 76%.

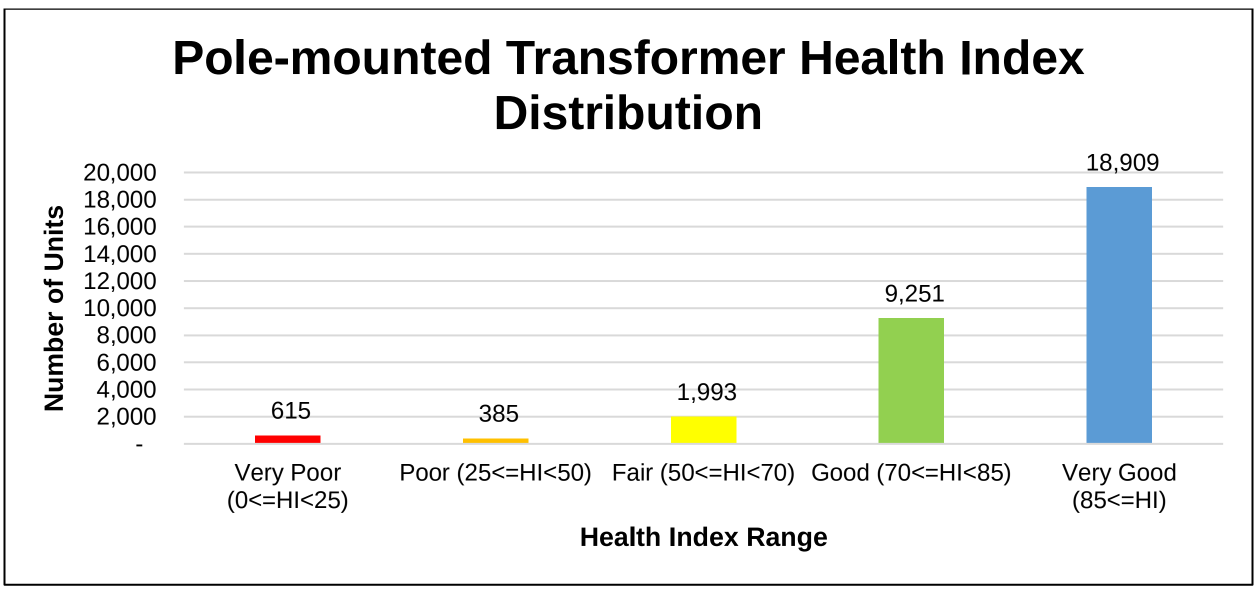


*Figure 12 Pole-mounted Transformer Health Index Distribution for 2021*

Figure 13 shows the distribution of Health Index values of vault transformers, classified from Very Poor to Very Good. The average DAI is 48%.

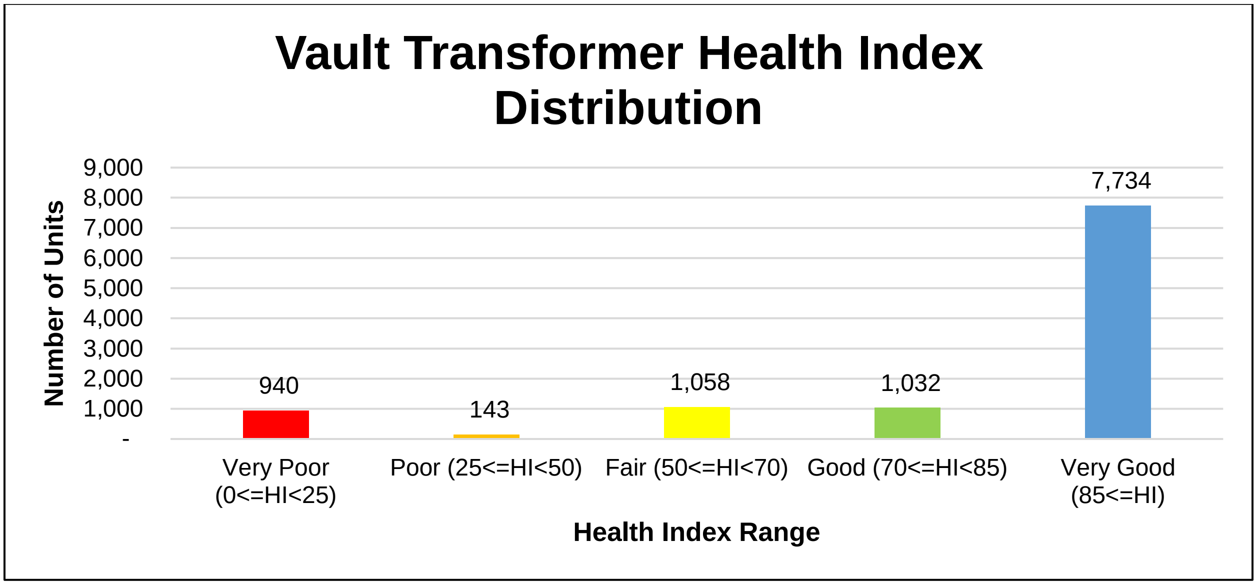


*Figure 13 Vault Transformer Health Index Distribution for 2021*

### 5.1.5 Sustainment Pacing

The total quantity in the Very Poor & Poor categories of all distribution transformers presented in Figure 11, Figure 12 and Figure 13 is 6,335 units.

Table 6 shows the pacing scenarios, namely, Baseline, Moderate, or Slow, that correspond to sustainment quantities over 5, 7.5, and 10-year intervals, respectively.

*Table 6 Distribution Transformer Pacing Scenarios*

| Pace | Description | Quantity per year |
|---|---|---|
| Baseline | Sustainment strategy targeting Very Poor & Poor assets over the **short-term** | $\frac{(Very\ Poor + Poor)}{5\ years} = 1267\ units$ |
| Moderate | Sustainment strategy targeting Very Poor & Poor assets over the **medium-term** | $\frac{(Very\ Poor + Poor)}{7.5\ years} = 845\ units$ |
| Slow | Sustainment strategy targeting Very Poor & Poor assets over the **long-term** | $\frac{(Very\ Poor + Poor)}{10\ years} = 634\ units$ |

## 5.2 Distribution Switchgear

### 5.2.1 Summary of Asset Class

Pad-mounted switchgear units are used in the underground distribution system to facilitate the connection of local distribution circuits from main-line underground feeder cable systems, as well as to interconnect main-line feeder circuits. Switchgear provides fused connection points for residential subdivisions and commercial/industrial customers. Switchgear units are used for isolating, sectionalizing, fusing for laterals, and reconfiguring cable loops for maintenance, restoration, and other operating requirements. Single switchgear can impact as many as 5,000 customers.

### 5.2.2 Asset Degradation

Switchgear aging and eventual end of life is often established by mechanical failures, such as rusting of the enclosures or ingress of moisture and dirt into the switchgear, causing corrosion of operating mechanism and degradation of insulation.

To extend the life of these assets and to minimize in-service failures, a number of strategies are employed on a regular basis, including inspection with thermographic analysis and cleaning with $CO_2$ for air insulated pad-mounted switchgear.

Failures of switchgear are most often not directly related to the age of the equipment but are associated instead with outside influences. For example, pad-mounted switchgear is most likely to fail due to dirt/contamination, vehicle accidents, rusting of the enclosure, rodents, and broken insulators caused by misalignment during switching. Failures caused by fuse malfunctions can result in a catastrophic switchgear failure.

Automated switchgear has the same construction as pad-mounted switchgear, but with the addition of motorized remote switch controls.

Automated switchgear has the same degradation mechanism as pad-mounted switchgear. In addition, failure of motor and/or its control may contribute to the end of life of the switchgear.

### 5.2.3 Asset Class Demographics

Alectra's distribution system has 3,250 pad-mounted switchgear, with varying insulation types, namely, air, solid dielectric, $SF_6$, and oil. According to industry averages, pad-mounted switchgear have a Typical Useful Life (TUL) of 30 years and are deemed to have reached End of Useful Life (EUL) at 45 years of age.

Air-insulted switchgear operating on the 27.6 kV system have different life characteristics. Based on Alectra's and industry experience, the TUL for these units is 20 years and EUL is 35 years.

Figure 14 shows the age demographics of all pad-mounted switchgear in Alectra's distribution system.

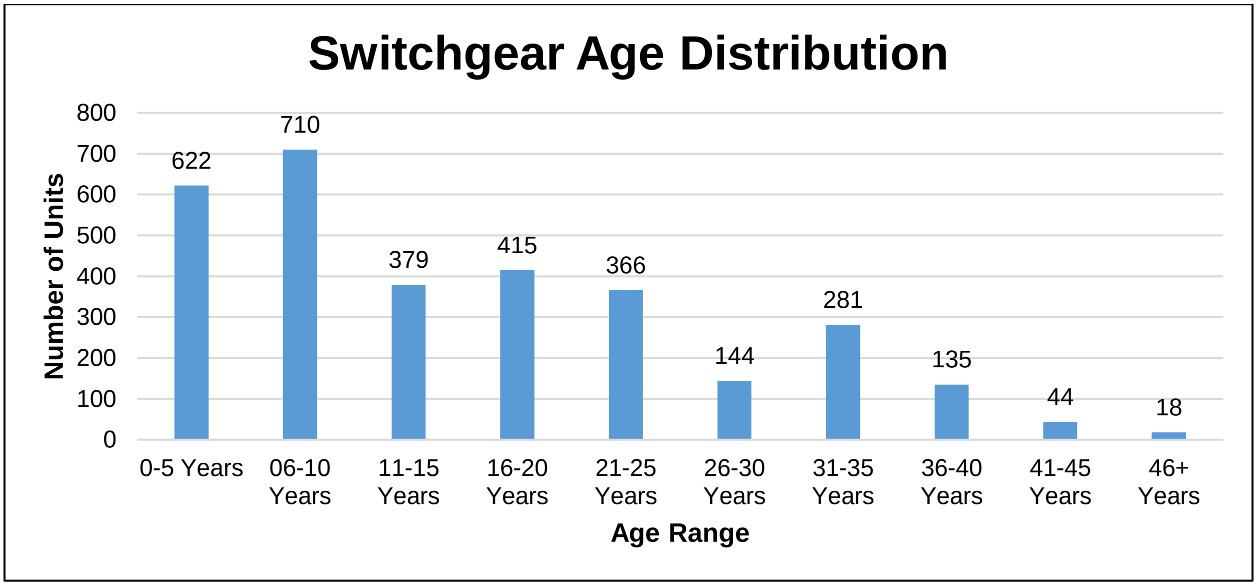


*Figure 14 Pad-mounted Switchgear Age Distribution for 2021*

### 5.2.4 Health Index Formula and Results

Health Index of pad-mounted switchgear assesses the condition according to five components: Corrosion, Component Failure, Insulation, Oil Leak (for oil types), and Age. Presence and magnitude of oil leaks (for oil insulated switchgear), and structural corrosion are quantified during field inspections and are scored as a step score.

Age represents deterioration due to factors not captured by the other components of the model. The scoring method for age is described in *Section 2.1.2 Percentage Score*.

The Health Index for Air, Solid Dielectric and $SF_6$ type switchgear is computed by adding the weighted components of: Corrosion, Component Failure (such as signs of damage to mechanical springs, motors in motorized units, and fuse supports), Insulation, and Age, as shown in Table 7.

*Table 7 Pad-mounted Air, Solid Dielectric and $SF_6$ Switchgear Health Index Parameters and Weights*

| # | Input | Input Weight (AIR, $SF_6$, SD) | Scoring Method |
|---|---|---|---|
| 1 | Corrosion | 21% | Step Score |
| 2 | Component Failure | 21% | Step Score |
| 3 | Insulation | 43% | Step Score |
| 4 | Age | 15% | Percentage Score |

The Health Index for Oil type switchgear is computed by adding the weighted components of: Corrosion, Component Failure (such as signs of damage to mechanical springs, motors in motorized units, and fuse supports), Insulation, Oil Leak, and Age, as shown in Table 8.

*Table 8 Pad-mounted Oil-type Switchgear Health Index Parameters and Weights*

| # | Input | Input Weight (OIL) | Scoring Method |
|---|---|---|---|
| 1 | Corrosion | 15% | Step Score |
| 2 | Component Failure | 15% | Step Score |
| 3 | Insulation | 40% | Step Score |
| 4 | Oil Leak | 15% | Step Score |
| 5 | Age | 15% | Percentage Score |

### Field Inspection Multiplier

If a pad-mounted switchgear exhibits major degradation or imminent failure, as determined by field inspection, it is considered to be of very poor health. The physical conditions considered in this criterion are major corrosion, major oil leak, major component failure, and major insulation failure.

$$Field\ inspection\ multiplier = 25\%$$

### Accelerated Degradation Multiplier

Air-insulated switchgear are highly susceptible to flashover due to contamination from dust particles that breach the enclosure. Their continuous nominal operating voltage rating is 25 kV with a maximum operating rating of 29.2 kV. These units function relatively well when new; however, during their normal duty, they are exposed to multiple voltage stresses that reduce their insulating performance, particularly when installed on the 27.6 kV distribution system. The 25 kV nominal voltage rating has been an inherent flaw in the equipment since it was first introduced to the Ontario market. This lower nominal voltage contributes to the reduced life of the switchgear and reduces the ability of the switchgear to perform under abnormal conditions, leading to premature failures.

$$Aceelerated\ degradation\ multiplier = 50\%$$

Figure 15 shows the distribution of Health Index values of pad-mounted switchgear, classified from Very Poor to Very Good. The average DAI is 84%.

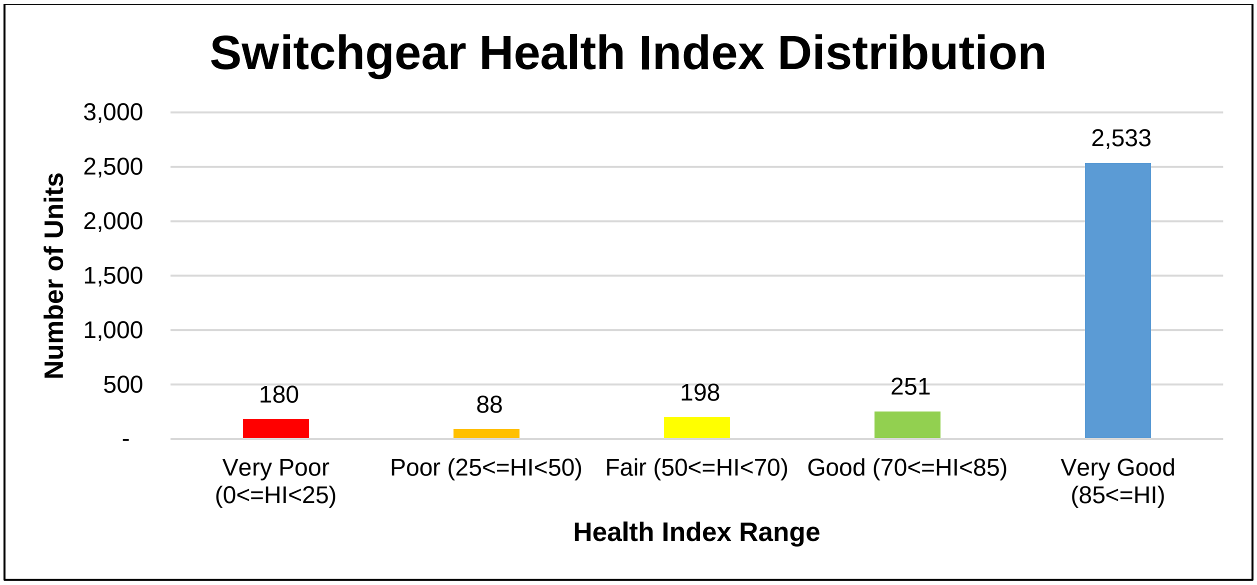


*Figure 15 Pad-mounted Switchgear Health Index Distribution for 2021*

### 5.2.5 Sustainment Pacing

The total quantity in the Very Poor & Poor categories of all pad-mounted switchgear is 268 units.

Table 9 shows the pacing scenarios, namely, Baseline, Moderate, or Slow, that correspond to sustainment quantities over 5, 7.5, and 10-year intervals, respectively.

*Table 9 Pad-mounted Switchgear Pacing Scenarios*

| Pace | Description | Quantity per year |
|---|---|---|
| Baseline | Sustainment strategy targeting Very Poor & Poor assets over the **short-term** | $\frac{(Very\ Poor + Poor)}{5\ years} = 54\ units$ |
| Moderate | Sustainment strategy targeting Very Poor & Poor assets over the **medium-term** | $\frac{(Very\ Poor + Poor)}{7.5\ years} = 36\ units$ |
| Slow | Sustainment strategy targeting Very Poor & Poor assets over the **long-term** | $\frac{(Very\ Poor + Poor)}{10\ years} = 27\ units$ |

## 5.3 Overhead Switches

### 5.3.1 Summary of Asset Class

The primary function of overhead switches is to facilitate transfer of loads between feeders and to allow isolation of line sections or equipment for maintenance, safety, or other operating requirements. This class of switch is also known as a Load-Break Distribution Switch (LBDS), or a Load Interrupting Switch (LIS), and can break load current.

### 5.3.2 Asset Degradation

The main degradation processes associated with switches include:

- Corrosion of steel hardware or operating rod
- Mechanical deterioration of linkages
- Switch blades falling out of alignment, which may result in excessive arcing during operation
- Loose connections
- Damaged insulators

The rate and severity of these degradation processes depend on several inter-related factors, including the operating duties and the environment in which the equipment is installed. In most cases, corrosion or rust represents a critical degradation process.

Consequences of overhead line switch failure may include customer interruption and safety concerns for operators.

### 5.3.3 Asset Class Demographics

Alectra's distribution system has 3,352 overhead switches. According to industry averages, overhead switches have a Typical Useful Life (TUL) of 40 years and are deemed to have reached End of Useful Life (EUL) at 55 years of age.

Figure 16 shows the age demographics of overhead switches in Alectra's distribution system.

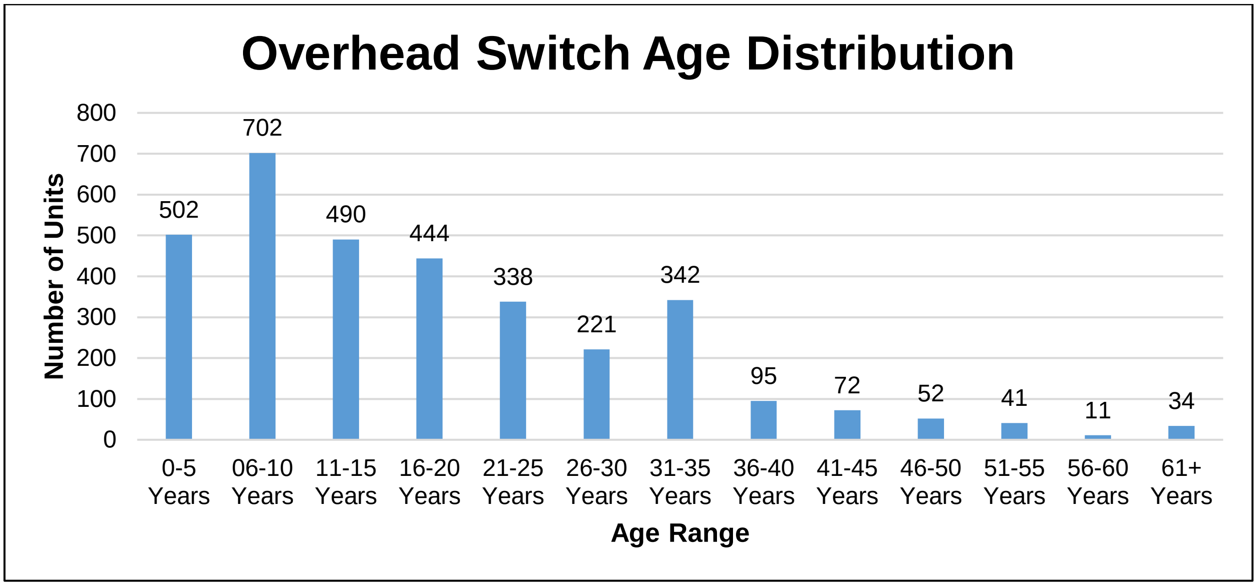


*Figure 16 Overhead Switch Age Distribution for 2021*

### 5.3.4 Health Index Formula and Results

Health index of overhead switches assesses the condition according to two components: Age, and Field Inspection. Age represents a proxy measure for switch deterioration over time. Field Inspection is assessed to determine the degree of degradation due to environmental and operational factors. Health Index is computed as a function of Age (i.e., percentage score) and Field Inspection (i.e., step score), as shown in Table 10.

*Table 10 Overhead Switch Health Index Parameters and Weights*

| Input | Input Weight | Scoring Method |
|---|---|---|
| Age | 31% | Percentage Score |
| Field Inspection | 69% | Step Score |

Age represents deterioration due to factors not captured by the other components of the model. The scoring method for age is described in *Section 2.1.2 Percentage Score*.

Figure 17 shows the distribution of Health Index values of overhead switches, classified from Very Poor to Very Good.  The average DAI is 43%.

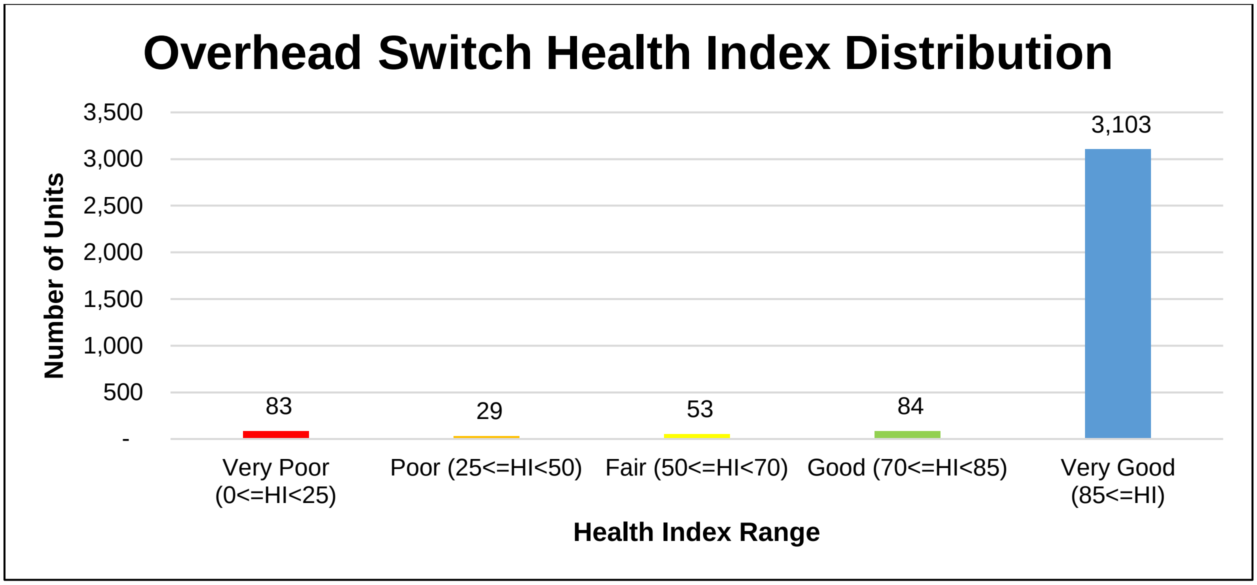


*Figure 17 Overhead Switch Health Index Distribution for 2021*

### 5.3.5 Sustainment Pacing

The total quantity in the Very Poor & Poor categories of overhead switches is 112 units.

Table 11 shows the pacing scenarios, namely, Baseline, Moderate, or Slow, that correspond to sustainment quantities over 5, 7.5, and 10-year intervals, respectively.

*Table 11 Overhead Switch Pacing Scenarios*

| Pace | Description | Quantity per year |
|---|---|---|
| Baseline | Sustainment strategy targeting Very Poor & Poor assets over the **short-term** | $\frac{(Very\ Poor + Poor)}{5\ years} = 22\ units$ |
| Moderate | Sustainment strategy targeting Very Poor & Poor assets over the **medium-term** | $\frac{(Very\ Poor + Poor)}{7.5\ years} = 15\ units$ |
| Slow | Sustainment strategy targeting Very Poor & Poor assets over the **long-term** | $\frac{(Very\ Poor + Poor)}{10\ years} = 11\ units$ |

## 5.4 Overhead Conductors

### 5.4.1 Summary of Asset Class

Electrical current flows through distribution line conductors, facilitating the movement of power throughout the distribution system. These conductors are supported by metal, wood, or concrete structures to which they are attached by insulator strings selected based on operating voltage. The conductors are sized for the maximum amount of current to be carried, as well as other design requirements. Conductors hold mechanical tension in conjunction with electrical properties that facilitate flow of electricity.

### 5.4.2 Asset Degradation

The flow of electrical current causes the conductors' temperature to increase. As a result, the conductors expand. Fluctuations of current flow cause the conductors to expand and contract in a cyclical manner, which contributes to conductor deterioration over time. Mechanical processes, such as fatigue, creep, and corrosion, are accelerated by the expansion and contraction. The rate of degradation depends on several factors including the size of conductor, metal/alloy component(s) of the conductor, type of conductor (e.g., solid or stranded), ambient temperature, the flow of current, the variation in the flow of current, and ambient temperature.

Overloading conductors accelerates the deterioration process and can cause serious safety concerns, as well as excessive fault currents. Conductor failure is a safety hazard to the public and can cause significant power interruptions.

### 5.4.3 Asset Class Demographics

Alectra's distribution system has 17,146 km of overhead conductors with various sizes and ages. According to industry averages, an overhead conductor has a Typical Useful Life (TUL) of 60 years and is deemed to have reached End of Useful Life (EUL) at 75 years of age.

Figure 18 shows the age demographics of overhead conductors in Alectra's distribution system.

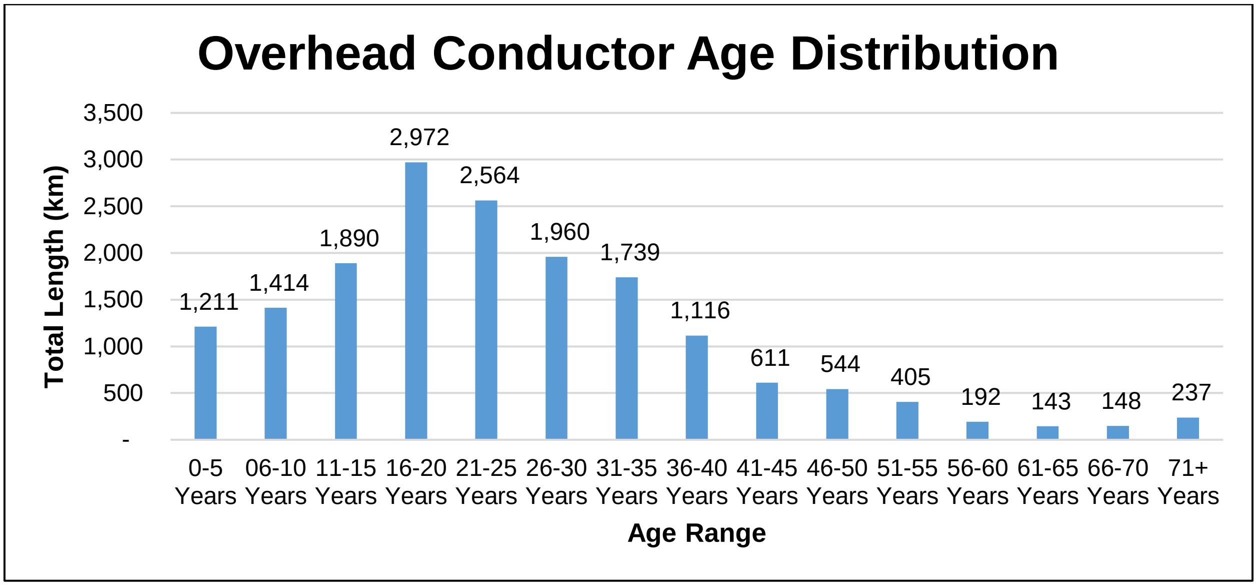


*Figure 18 Overhead Conductor Age Distribution for 2021*

### 5.4.4 Health Index Formula and Results

Health Index of overhead conductors assesses the condition based on Age (i.e., percentage score), as shown in Table 12.

*Table 12 Overhead Conductor Health Index Parameters and Weights*

| Input | Input Weight | Scoring Method |
|---|---|---|
| Age | 100% | Percentage Score |

Age represents a proxy measure for conductor deterioration over time due to environmental and operational factors. The scoring method for age is described in *Section 2.1.2 Percentage Score.*

**Restricted Conductors Multiplier**

Certain conductors fall below the acceptable size for the safe and reliable operation of the system. Any conductor below wire AWG (American Wire Gauge) size #6 is considered restricted and undersized according to current utility practices. Such conductors represent a major safety risk.

$$Restricted\ conductor\ multiplier = 25\%$$

Figure 19 shows the distribution of Health Index values of overhead conductors, classified from Very Poor to Very Good.  The average DAI is 100%.

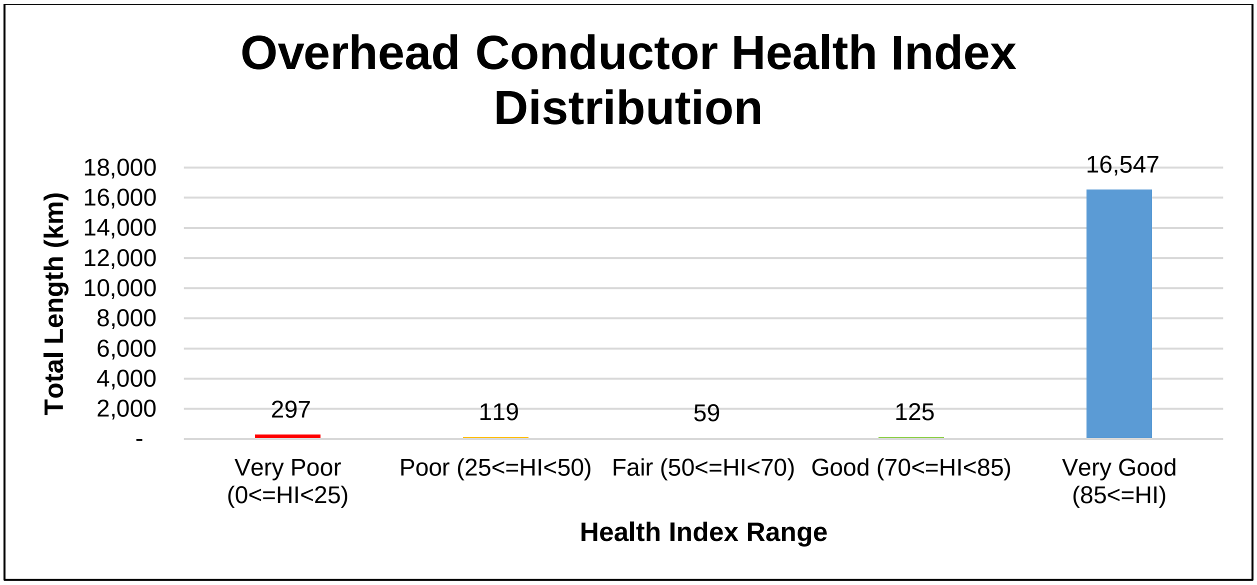


*Figure 19 Overhead Conductor Health Index Distribution for 2021*

### 5.4.5 Sustainment Pacing

The total quantity in the Very Poor & Poor categories of overhead conductors is 416 kilometers.

Table 13 shows the pacing scenarios, namely, Baseline, Moderate, or Slow, that correspond to sustainment quantities over 5, 7.5, and 10-year intervals, respectively.

*Table 13 Overhead Conductor Pacing Scenarios*

| Pace | Description | Quantity per year |
|---|---|---|
| Baseline | Sustainment strategy targeting Very Poor & Poor assets over the **short-term** | $\frac{(Very\ Poor + Poor)}{5\ years} = 83\ km$ |
| Moderate | Sustainment strategy targeting Very Poor & Poor assets over the **medium-term** | $\frac{(Very\ Poor + Poor)}{7.5\ years} = 55\ km$ |
| Slow | Sustainment strategy targeting Very Poor & Poor assets over the **long-term** | $\frac{(Very\ Poor + Poor)}{10\ years} = 42\ km$ |

## 5.5 Wood Poles

### 5.5.1 Summary of Asset Class

Wood poles support overhead primary & secondary distribution lines. Any deterioration in structural strength of poles impacts the safe and reliable operation of the distribution system. Poles are a critical component of the distribution system and support many assets including conductors, transformers, switches, streetlights, telecommunication attachments, and other items, as well as providing physical separation between ground level and energized conductors. As a pole's physical condition and structural strength deteriorate, the pole may become inadequate for its intended function, and should be replaced to maintain the integrity of the distribution system and to protect public safety. A regular field inspection is conducted on wood poles to assess their condition. In addition to the field inspection, a remaining strength measurement is conducted using third party testing to provide evidence-based measurement that reflects the integrity of the pole. The wood species commonly used for distribution wood poles include Red Pine, Jack Pine, and Western Red Cedar (WRC).

### 5.5.2 Asset Degradation

Since wood is a natural material, the degradation processes are different from those which affect other physical assets on electricity distribution systems. The degradation processes result in decay of the wood fibers, thus reducing the structural strength of the pole. The nature and severity of the degradation depends both on the type of wood, treatment preservatives, and the environment.

As a structural asset, assessing the condition of a wood pole is based on measuring the remaining structural strength and inspecting for signs of deterioration, such as cracks. Field inspection checks for indicators of decay, such as hollowing, pole top feathering, structural cracks, and other field indications of degradation. Pole residual strength testing is a test performed by drilling a small probe through the pole to measure quantitatively the remaining structural strength of the wood fibers.

Consequences of a pole failure are quite serious. Poles with reduced strength present a significant risk to the public, Alectra staff, and contractors, and also have reliability impacts to the distribution system. The combination of severe weather, along with reduced strength, can lead to end-of-life failure scenarios where multiple poles lose their structural integrity and fail, possibly falling to the ground. The risk is mitigated through the regular inspection and field-testing to identify candidates for replacement prior to their failure.

### 5.5.3 Asset Class Demographics

Alectra's distribution system has 103,426 wood poles.  According to industry averages, a wood pole has a Typical Useful Life (TUL) of 45 years and is deemed to have reached End of Useful Life (EUL) at 75 years of age.  Figure 20 shows the age demographics of wood poles in Alectra's distribution system.

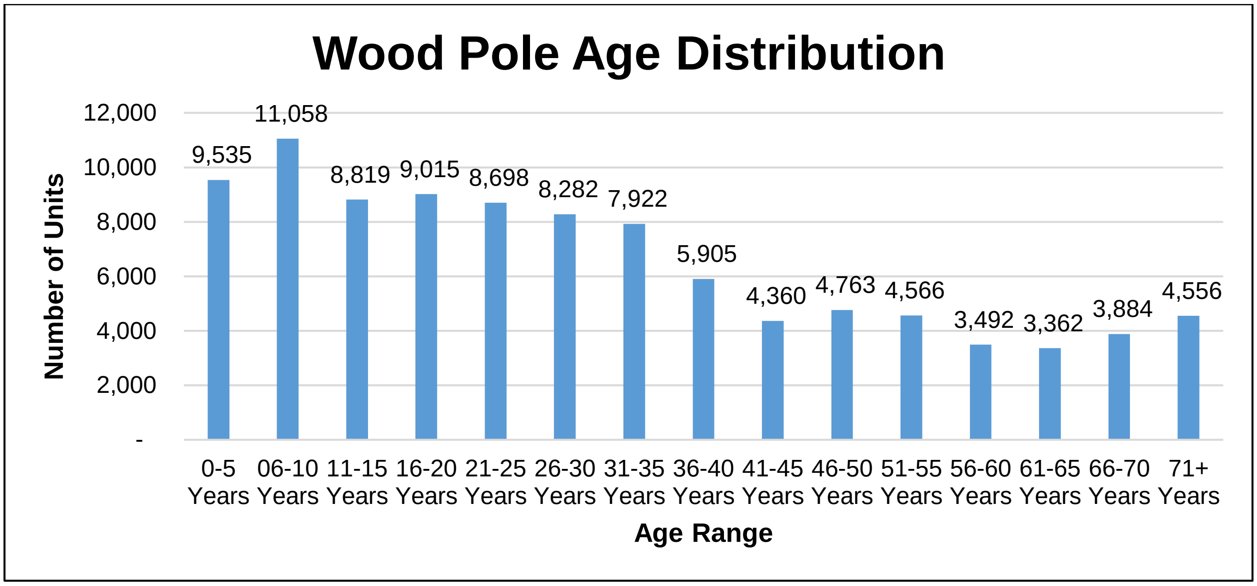


*Figure 20 Wood Pole Age Distribution for 2021*

### 5.5.4 Health Index Formula and Results

Health Index of poles assesses the condition of the pole according to three components: Pole Remaining Strength, Overall Condition, and Age.  Pole Remaining Strength is a vital component to the Health Index of wood poles and is a specialized test that is performed by a third party. Remaining strength measurement is an evidence-based measurement of physical condition and it is scored using percentage scoring.

Overall Condition is captured during the field inspection cycle of the wood poles and includes, but is not limited to, signs of mechanical damage, cracks, and feathering.  Overall Condition of a wood pole is scored using step scoring.

Age represents deterioration due to other factors not captured by the other components of the model.  The scoring method for age is described in *Section 2.1.2 Percentage Score*.

The Health Index is computed by adding the weighted inputs of Pole Remaining Strength, Overall Condition, and Age, as shown in Table 14.

*Table 14 Wood Pole Health Index Parameters and Weights*

| # | Input | Input Weight | Scoring Method |
|---|---|---|---|
| 1 | Pole Strength | 49% | Percentage Score |
| 2 | Overall Condition (Field Inspection) | 36% | Step Score |
| 3 | Age | 15% | Percentage Score |

**Pole Residual Strength Multiplier**

If a wood pole is measured to have 60% or less in remaining strength, it is considered to be of very poor health.

The Canadian Safety Association (CSA) defines the standards for overhead distribution system construction and the use of wood poles. Among other factors, Alectra is guided in its pole assessment process by Clause 8.3.1.3 of CSA Standard C22.3 No. 1-10, which states that:

> *"when the strength of a structure has deteriorated to 60% of the required capacity, the structure shall be reinforced or replaced".*

$$Pole\ residual\ multiplier = 25\%$$

**Field Inspection Multiplier**

A score of 20% or less on Overall Condition based on field inspection is an indication that a wood pole is exhibiting major degradation or failure is imminent and is of very poor health. The physical conditions considered in this criterion are major rotting, decay, splitting, insect infestation, bending and leaning.

$$Field\ inspection\ multiplier = 25\%$$

Figure 21 shows the distribution of Health Index values of wood poles, classified from Very Poor to Very Good. The average DAI is 56%.

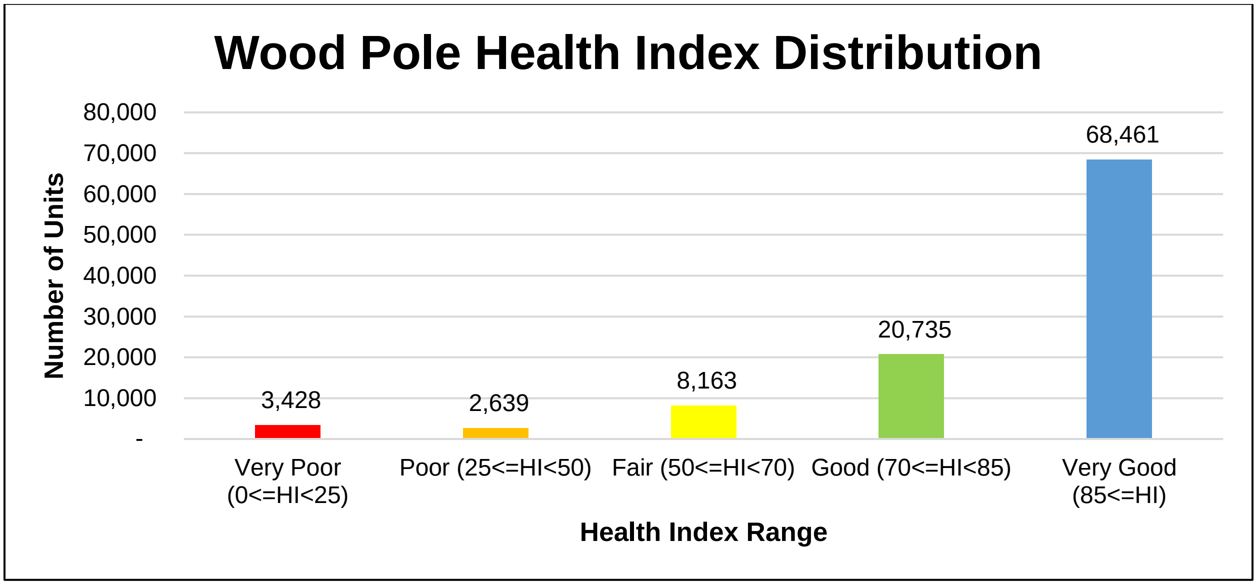


*Figure 21 Wood Pole Health Index Distribution for 2021*

### 5.5.5 Sustainment Pacing

The total quantity in the Very Poor & Poor categories of wood poles is 6,067.

Table 15 shows the pacing scenarios, namely, Baseline, Moderate, or Slow, that correspond to sustainment quantities over 5, 7.5, and 10-year intervals, respectively.

*Table 15 Wood Pole Pacing Scenarios*

| Pace | Description | Quantity per year |
|---|---|---|
| Baseline | Sustainment strategy targeting Very Poor & Poor assets over the **short-term** | $\frac{(Very\ Poor + Poor)}{5\ years} = 1{,}213\ poles$ |
| Moderate | Sustainment strategy targeting Very Poor & Poor assets over the **medium-term** | $\frac{(Very\ Poor + Poor)}{7.5\ years} = 809\ poles$ |
| Slow | Sustainment strategy targeting Very Poor & Poor assets over the **long-term** | $\frac{(Very\ Poor + Poor)}{10\ years} = 607\ poles$ |

## 5.6 Concrete Poles

### 5.6.1 Summary of Asset Class

Concrete poles support primary & secondary distribution lines. Any deterioration in structural strength of poles impacts the safe and reliable operation of the distribution system. Poles are a critical component of the distribution system and support many appurtenances, including conductors, transformers, switches, streetlights, telecommunication attachments and other items. Poles also provide physical separation between ground level and energized conductors. As a pole's physical condition and structural strength deteriorate, the pole may become inadequate for its intended function, and should be replaced to maintain the integrity of the distribution system and to protect public safety. A regular field inspection is conducted on concrete poles to assess their condition.

In some cases, concrete poles can be rehabilitated from mechanical damage, such as that caused by snowplows or other vehicular accidents, or by deterioration over time. Each case requires a specialized assessment by a subject matter expert to recommend the appropriate intervention.

### 5.6.2 Asset Degradation

Concrete poles age in the same manner as any other concrete structure. Any moisture ingress inside the concrete pores results in freezing during the winter and damage to the concrete surface. Road salt spray can further accelerate the degradation process and lead to concrete spalling (piece of concrete flaking off the pole). Cracks develop over time from stretching or bending forces. These cracks propagate over time resulting in structural cracks and spalling of the concrete.

Concrete poles contain metal rebar for reinforcement, water ingress and contaminants lead to corrosion of the rebar thus reducing the structural integrity of the concrete pole. Rebar corrosion can lead to the accelerated deterioration resulting in a reduced lifespan of a concrete pole.

Consequences of a pole failure are quite serious. Poles with reduced strength present a significant risk to the public, Alectra staff, and contractors, and also have reliability impacts to the distribution system. The combination of severe weather along with reduced strength can lead to end-of-life failure scenarios where multiple poles lose their structural integrity and fail, possibly falling to the ground. The risk is mitigated through the regular inspection and field-testing to identify candidates for replacement prior to their failure.

### 5.6.3 Asset Class Demographics

Alectra's distribution system has 26,882 concrete poles. According to industry averages, concrete pole has a Typical Useful Life (TUL) of 60 years and is deemed to have reached End of Useful Life (EUL) at 80 years of age. Figure 22 shows the age demographics of concrete poles in Alectra's distribution system.

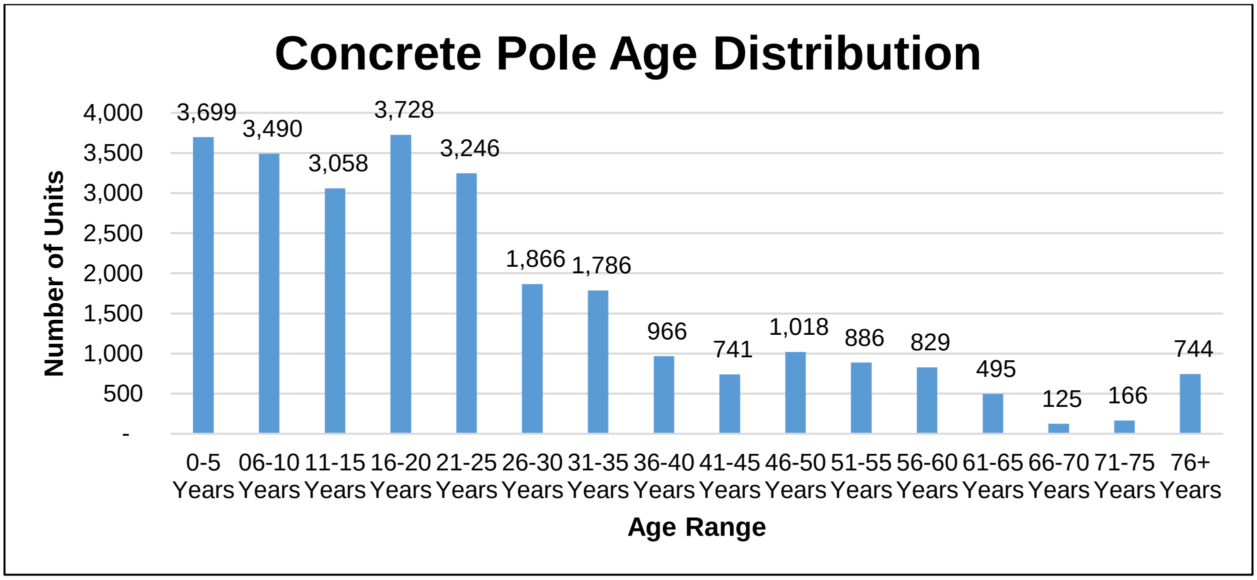


*Figure 22 Concrete Pole Age Distribution for 2021*

### 5.6.4 Health Index Formula and Results

Health Index of poles assesses the condition of the pole according to two inputs: Overall Condition and Age.

Overall Condition is captured during the field inspection cycle of the concrete poles and includes, but is not limited to, signs of mechanical damage and cracks. Age represents deterioration due to factors not captured by the other inputs of the model. The scoring method for age is described in *Section 2.1.2 Percentage Score.*

The Health Index is computed by adding the weighted inputs of Overall Condition from field inspection and Age, as shown in Table 16.

*Table 16 Concrete Pole Health Index Parameters and Weights*

| # | Input | Input Weight | Scoring Method |
|---|---|---|---|
| 1 | Overall Condition (Field Inspection) | 69% | Step Score |
| 2 | Age | 31% | Percentage Score |

**Field Inspection Multiplier**

If a concrete pole exhibits major degradation or imminent failure as determined by field inspection, it is considered to be of very poor health. The physical conditions considered in this criterion are major cracking, exposed rebar, or rusted rebar.

$$Field\ inspection\ multiplier = 25\%$$

Figure 23 shows the distribution of Health Index values of concrete poles, classified from Very Poor to Very Good. The average DAI is 64%.

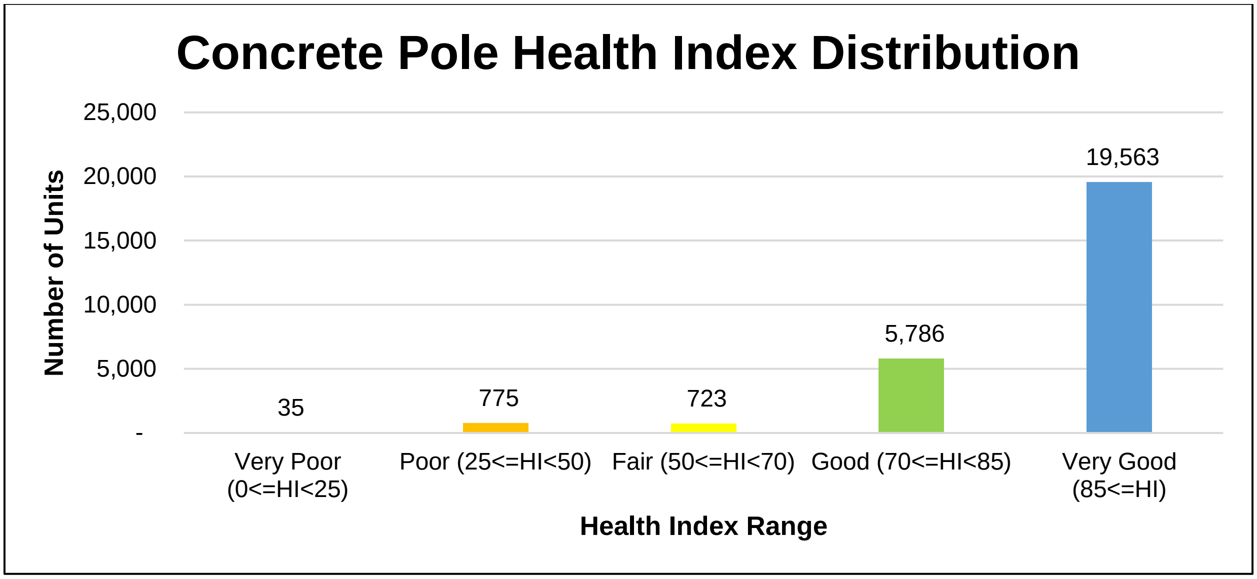


*Figure 23 Concrete Pole Health Index Distribution for 2021*

### 5.6.5 Sustainment Pacing

The total quantity in the Very Poor & Poor categories of concrete poles is 810.

Table 17 shows the pacing scenarios, namely, Baseline, Moderate, or Slow, that correspond to sustainment quantities over 5, 7.5, and 10-year intervals, respectively.

*Table 17 Concrete Pole Pacing Scenarios*

| Pace | Description | Quantity per year |
|---|---|---|
| Baseline | Sustainment strategy targeting Very Poor & Poor assets over the **short-term** | $\frac{(Very\ Poor + Poor)}{5\ years} = 162\ poles$ |
| Moderate | Sustainment strategy targeting Very Poor & Poor assets over the **medium-term** | $\frac{(Very\ Poor + Poor)}{7.5\ years} = 108\ poles$ |
| Slow | Sustainment strategy targeting Very Poor & Poor assets over the **long-term** | $\frac{(Very\ Poor + Poor)}{10\ years} = 81\ poles$ |

## 5.7 Underground Primary Cables

Underground distribution cables are mainly used in urban areas where obstacles to pole line construction are encountered. These can include aesthetic, legal, political, and physical constraints.

### 5.7.1 Summary of Asset Class

The asset categories of distribution system underground cables include underground cross-link-polyethylene (XLPE) cables, paper insulated lead covered (PILC) cables, and ethylene-propylene rubber (EPR) cables, all at voltage levels of 44 kV or below. Included are direct-buried and installed-in-duct feeder cables, underground cable sections running from stations to overhead lines, and from overhead lines to customer stations and switches.

### 5.7.2 Asset Degradation

Faults on primary underground cables are usually caused by insulation failure within a localized area.

Polymeric insulation is very sensitive to discharge activity. It is therefore very important that the cable, joints, and accessories are discharge-free when installed. Older-vintage cables are susceptible to moisture ingress (i.e., water treeing), especially if installed direct buried, or with terminations and splices susceptible to insulation breakdown that can result in localized failures.

Manufacturing improvements and development of tree-retardant XLPE cables have reduced the rate of deterioration and insulation breakdown from water treeing.

For PILC cables, the two significant long-term degradation processes are corrosion of the lead sheath, and dielectric degradation of the oil-impregnated paper insulation. Isolated sites of corrosion resulting in moisture penetration or isolated sites of dielectric deterioration resulting in insulation breakdown can result in localized failures. However, if either of these conditions becomes widespread, there will be frequent cable failures, and the cable can be deemed to be at end-of-life.

For EPR cables, long term degradation can occur due to mechanical damage, overheating, or the impact of moisture ingress and chemical deterioration.

### 5.7.3 Cross-Linked Polyethylene (XLPE) Cables

#### *5.7.3.1 Asset Class Demographics*

Alectra's distribution system has 22,462 km of primary underground XLPE cable. XLPE cables are categorized by type, as described below. Each type has a different expected useful life, based on industry averages and Alectra's experience.

- **Non-Tree-Retardant cables (NON-TR)**:
  Vintage 1988 or older; TUL 30 years; EUL 40 years
- **Tree-Retardant Direct-Buried cables (TR-DB)**:
  Vintage 1989-1993; TUL 35 years; EUL 45 years
- **Tree-Retardant or Strand-Blocked In-Duct cables (TR-ID):**
  Vintage 1994 or newer; TUL 40 years; EUL 55 years

Figure 24 shows the age demographics of XLPE cables in Alectra's distribution system.

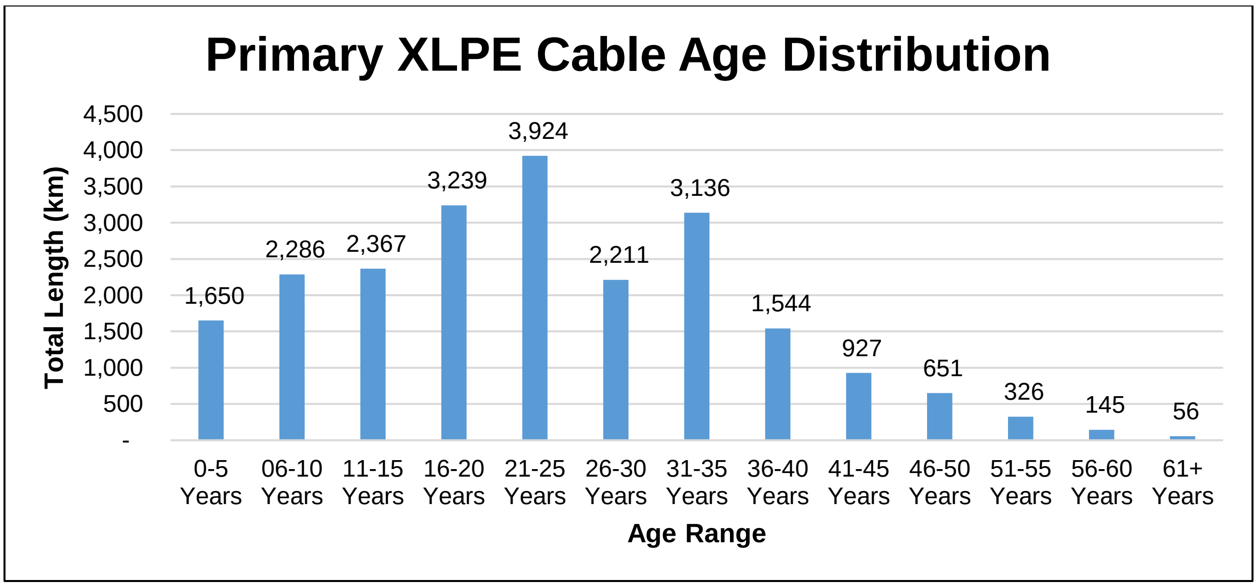


*Figure 24 Primary XLPE Cable Age Distribution for 2021*

#### *5.7.3.2 Health Index Formula and Results*

Health index of primary XLPE cables is calculated using Age. The scoring method for age is described in *Section 2.1.2 Percentage Score.*

Health index is scored according to the curves shown in Figure 25.

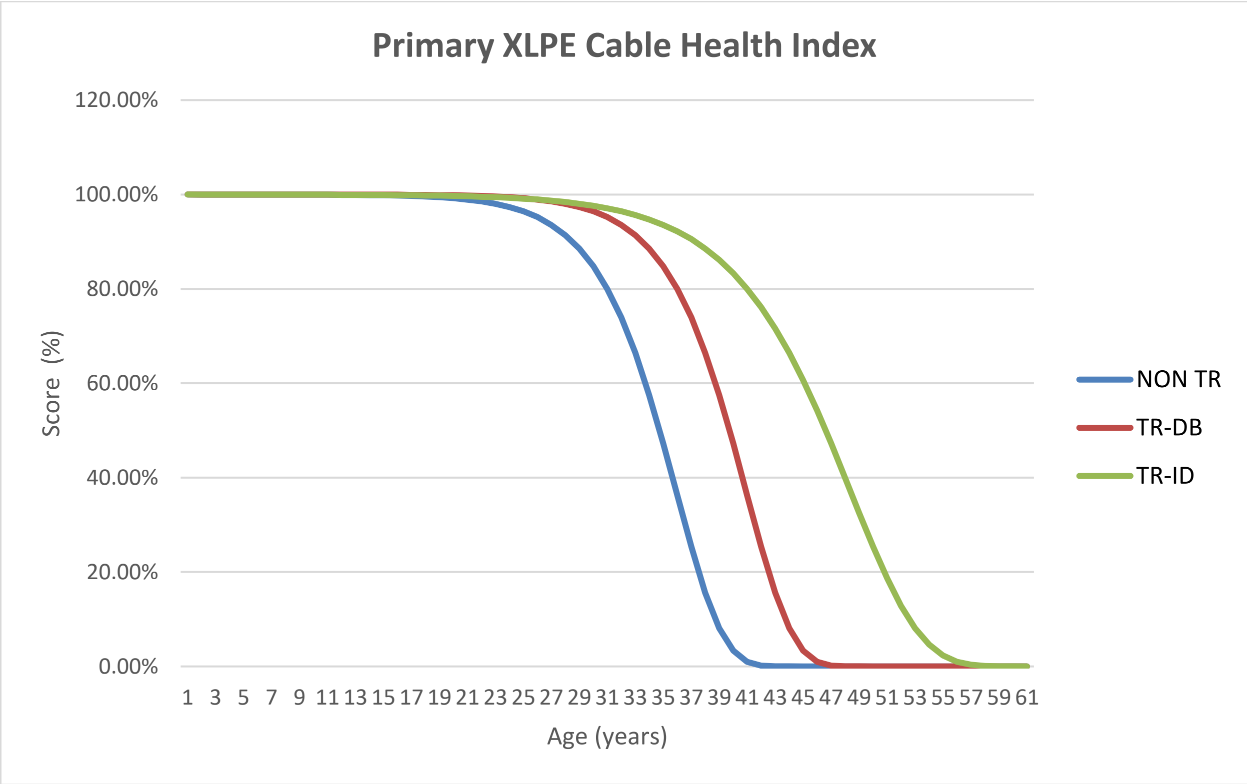


*Figure 25 Primary XLPE Cable Health Index as a function of age*

Health Index is computed as a function of age (i.e., percentage score), as shown in Table 18.

*Table 18 XLPE Cable Health Index Parameters and Weights*

| Input | Input Weight | Scoring Method |
|---|---|---|
| Age | 100% | Percentage Score |

Figure 26 shows the distribution of Health Index values of primary XLPE cables, classified from Very Poor to Very Good. The average DAI is 100%.

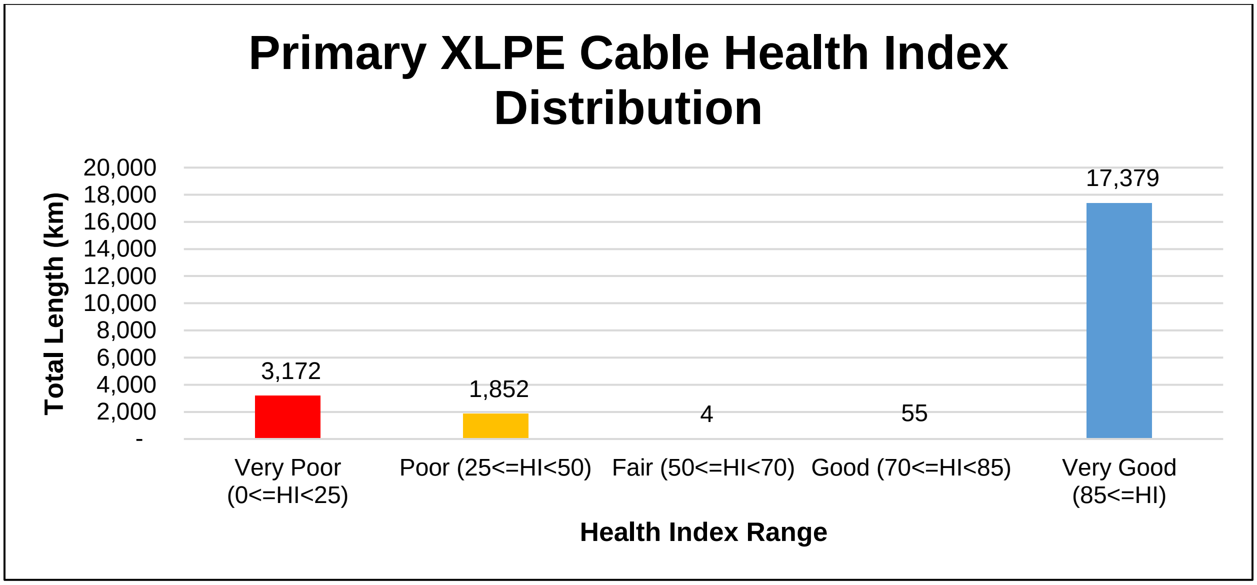


*Figure 26 Primary XLPE Cable Health Index Distribution for 2021*

### *5.7.3.3 Sustainment Pacing*

The total quantity in the Very Poor & Poor categories of XLPE cables is 5,024 km.

Table 19 shows the pacing scenarios, namely, Baseline, Moderate, or Slow, that correspond to sustainment quantities over 5, 7.5, and 10-year intervals, respectively.

*Table 19 XLPE Cable Pacing Scenarios*

| Pace | Description | Quantity per year |
|---|---|---|
| Baseline | Sustainment strategy targeting Very Poor & Poor assets over the **short-term** | $\frac{(Very\ Poor + Poor)}{5\ years} = 1005\ km$ |
| Moderate | Sustainment strategy targeting Very Poor & Poor assets over the **medium-term** | $\frac{(Very\ Poor + Poor)}{7.5\ years} = 670\ km$ |
| Slow | Sustainment strategy targeting Very Poor & Poor assets over the **long-term** | $\frac{(Very\ Poor + Poor)}{10\ years} = 502\ km$ |

### 5.7.4 Paper Insulated Lead Covered (PILC) Cables

#### *5.7.4.1 Asset Class Demographics*

Alectra's distribution system has 409 km of primary underground PILC cable. According to industry averages, primary PILC cables have a Typical Useful Life (TUL) of 60 years and are deemed to have reached End of Useful Life (EUL) at 70 years of age. Figure 27 shows the age demographics of PILC cables in Alectra's distribution system.

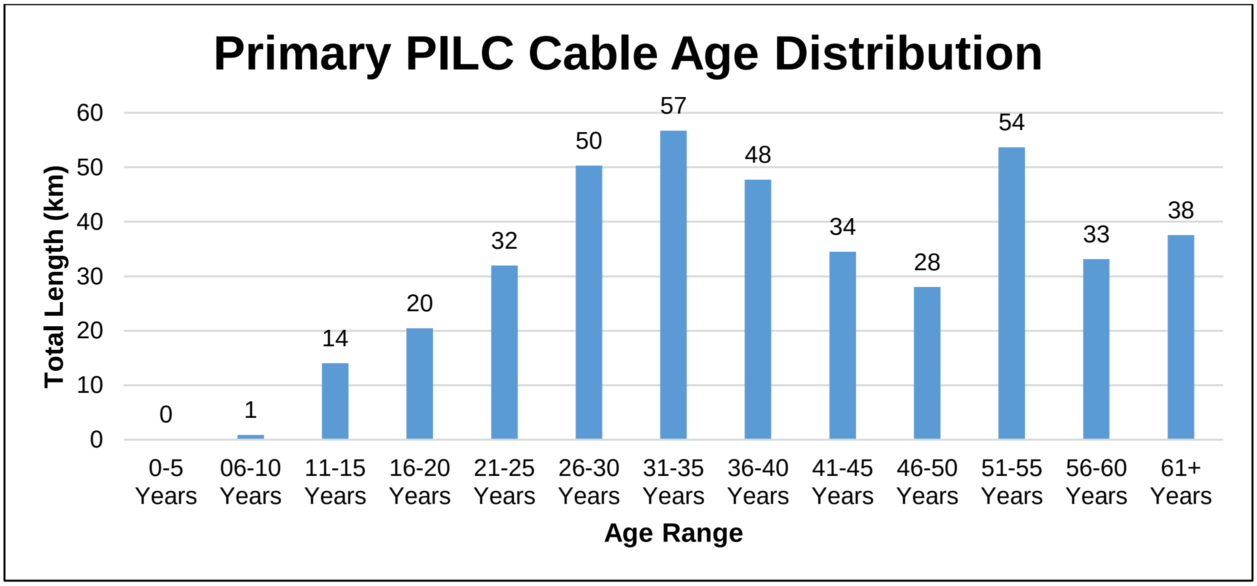


*Figure 27 Primary PILC Cable Age Distribution for 2021*

#### *5.7.4.2 Health Index Formula and Results*

Health index of Primary PILC cables is calculated using Age. The scoring method for age is described in *Section 2.1.2 Percentage Score.*

Health Index is computed as a function of age (i.e., percentage score), as shown in Table 20.

*Table 20 PILC Cable Health Index Parameters and Weights*

| Input | Input Weight | Scoring Method |
|---|---|---|
| Age | 100% | Percentage Score |

Figure 28 shows the distribution of Health Index values of primary PILC cables, classified from Very Poor to Very Good. The average DAI is 100%.

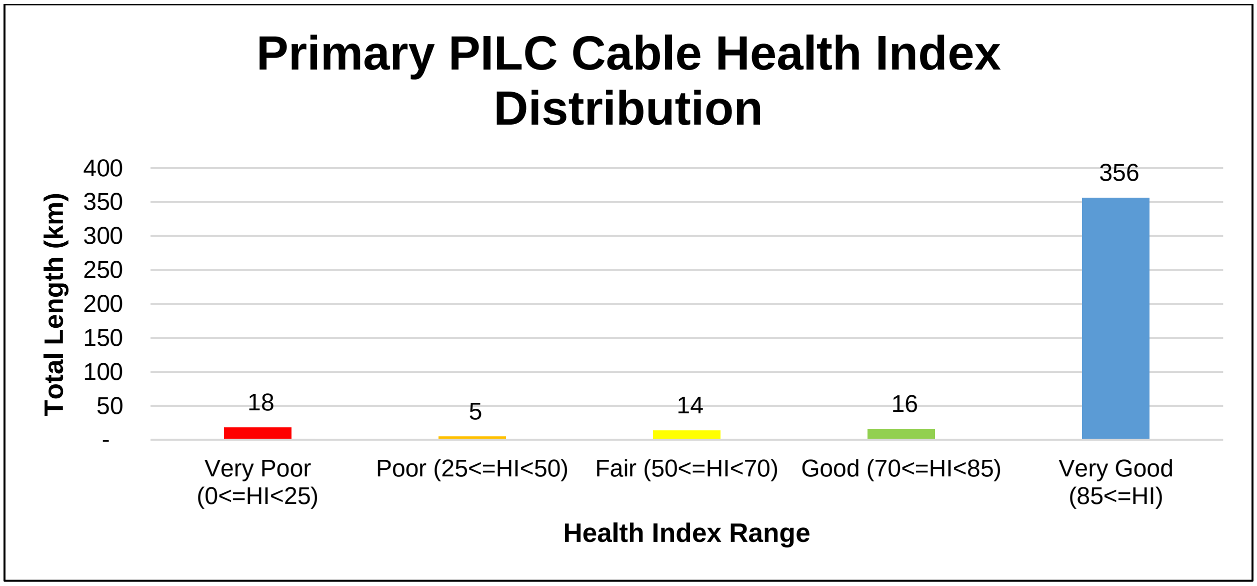


*Figure 28 Primary PILC Cable Health Index Distribution for 2021*

### *5.7.4.3 Sustainment Pacing*

The total quantity in the Very Poor & Poor categories of PILC is 23 km.

Table 21 shows the pacing scenarios, namely, Baseline, Moderate, or Slow, that correspond to sustainment quantities over 5, 7.5, and 10-year intervals, respectively.

*Table 21 PILC Cable Pacing Scenarios*

| Pace | Description | Quantity per year |
|---|---|---|
| Baseline | Sustainment strategy targeting Very Poor & Poor assets over the **short-term** | $\frac{(Very\ Poor + Poor)}{5\ years} = 5\ km$ |
| Moderate | Sustainment strategy targeting Very Poor & Poor assets over the **medium-term** | $\frac{(Very\ Poor + Poor)}{7.5\ years} = 3\ km$ |
| Slow | Sustainment strategy targeting Very Poor & Poor assets over the **long-term** | $\frac{(Very\ Poor + Poor)}{10\ years} = 2\ km$ |

### 5.7.5 Ethylene-Propylene Rubber (EPR) Cables

#### *5.7.5.1 Asset Class Demographics*

Alectra's distribution system has 90 km of primary underground EPR cable. EPR cables have a Typical Useful Life (TUL) of 25 years and are deemed to have reached End of Useful Life (EUL) at 45 years of age. Figure 29 shows the age demographics of EPR cables in Alectra's distribution system.

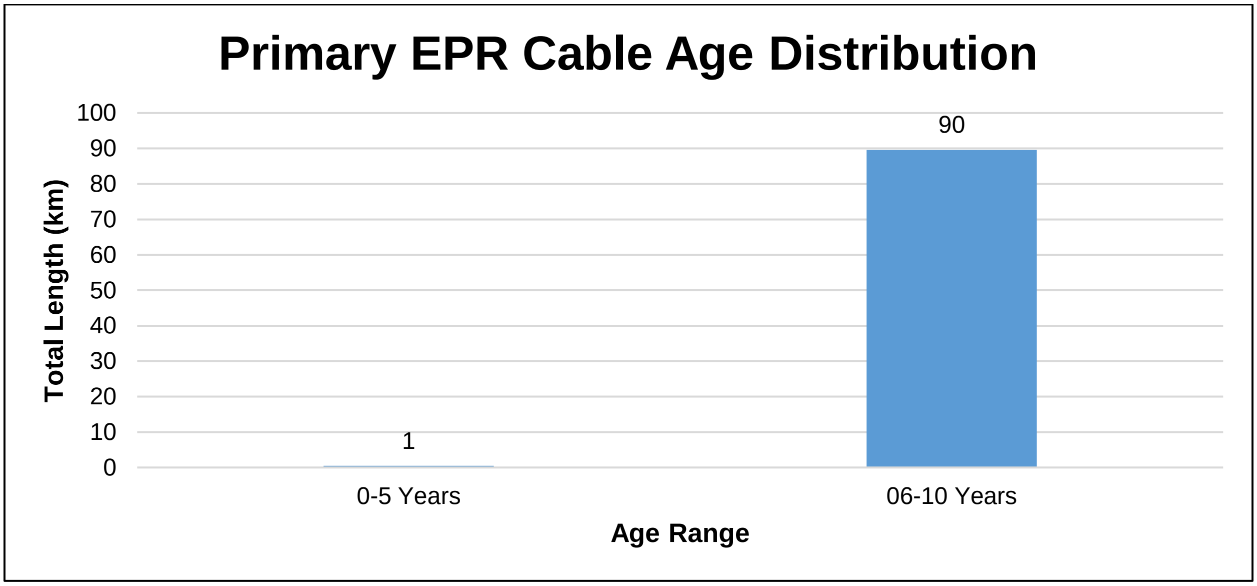


*Figure 29 Primary EPR Cable Age Distribution for 2021*

#### *5.7.5.2 Health Index Formula and Results*

Health index of Primary EPR cables is calculated using Age. According to industry averages, the TUL of EPR cable is 25 years and EUL is 45 years. The scoring method for age is described in *Section 2.1.2 Percentage Score.*

Health Index is computed as a function of age (i.e., percentage score), as shown in Table 22.

*Table 22 EPR Cable Health Index Parameters and Weights*

| Input | Input Weight | Scoring Method |
|---|---|---|
| Age | 100% | Percentage Score |

Figure 30 shows the distribution of Health Index values of EPR cables, classified from Very Poor to Very Good. The average DAI is 100%.

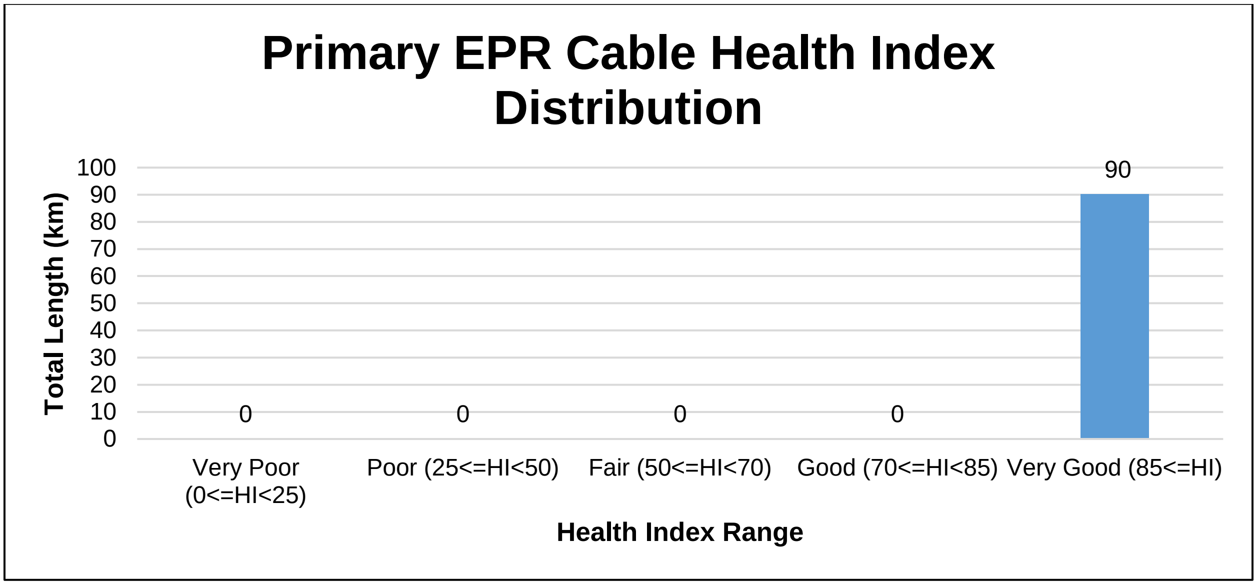


*Figure 30 Primary EPR Cable Health Index Distribution for 2021*

### *5.7.5.3 Sustainment Pacing*

There are no EPR cables in the Very Poor and Poor categories.

Table 23 shows the pacing scenarios, namely, Baseline, Moderate, or Slow, that correspond to sustainment quantities over 5, 7.5, and 10-year intervals, respectively.

*Table 23 EPR Cable Pacing Scenarios*

| Pace | Description | Quantity per year |
|---|---|---|
| Baseline | Sustainment strategy targeting Very Poor & Poor assets over the **short-term** | $\frac{(Very\ Poor + Poor)}{5\ years} = NONE$ |
| Moderate | Sustainment strategy targeting Very Poor & Poor assets over the **medium-term** | $\frac{(Very\ Poor + Poor)}{7.5\ years} = NONE$ |
| Slow | Sustainment strategy targeting Very Poor & Poor assets over the **long-term** | $\frac{(Very\ Poor + Poor)}{10\ years} = NONE$ |

# 6 Station Assets

The Alectra distribution system includes two classes of stations, transformer (TS) stations and municipal (MS) stations or substations. Alectra transformer stations are supplied from the high-voltage transmission grid at 115 kV or 230 kV. Alectra municipal stations are supplied from the medium-voltage distribution system at 44 kV or 27.6 kV from transformer stations owned by Hydro One. Alectra's system has 14 transformer stations and 150 municipal stations owned and operated by Alectra.

Stations may consist of many types of components and subcomponents. Station assets considered in this report include the following:

- Station power transformers
- Station circuit breakers
- Station class switchgear

## 6.1 Power Transformers

### 6.1.1 Summary of Asset Class

Station power transformers are used to step down transmission or sub-transmission voltage to distribution voltage. The two general classifications of station power transformers are transmission station (TS) transformers and station distribution transformers, also referred to as municipal station (MS) transformers. TS transformers are supplied from the high-voltage transmission grid at either 230 kV or 115 kV and step voltage down to 44 kV, 27.6 kV, or 13.8 kV. MS transformers are supplied from the medium-voltage distribution system at 44 kV, 27.6 kV, or 13.8 kV and step voltage down to 27.6 kV, 13.8 kV, 8.32 kV, or 4.16 kV. TS transformers owned and operated by Alectra have fully-cooled ratings of 50 MVA, 83.3 MVA, and 125 MVA, and MS transformer ratings typically have base Oil Natural Air Natural (ONAN) ratings ranging from 3 MVA to 22 MVA.

Power transformers employ many different design configurations, but they are typically made up of the following main components: Primary and secondary windings, Laminated iron core, Internal insulating mediums, Main tank, Bushings, Cooling system, including radiators, fans and pumps (Optional), Off-load tap changer (Optional), On-load tap changer (Optional), Instrument transformers, Control mechanism cabinets, Instruments and gauges.

Transformer primary and secondary windings are installed on a laminated iron core. In most power transformers, mineral oil serves as the insulating medium, providing insulation of energized coils, as well as the coolant. Some power transformers use a natural ester oil, such as FR3. The transformer coil insulation is reinforced with different forms of solid insulation that include wood-based paperboard (pressboard), wrapped paper, and insulating tapes. The transformer main tank holds the active components of the transformer in an oil volume and maintains a sealed environment through the normal variations of temperature and pressure. Typically, the main tank is designed to withstand a full vacuum for initial and subsequent oil fillings and can sustain a positive pressure. The main tank also supports the internal and external components of the transformers. Bushings are used to facilitate the egress of conductors to connect ends of the coils to a power supply system in an insulated, sealed (oil-tight and weather-tight) manner.

The purpose of a cooling system in a power transformer is to efficiently dissipate heat generated due to copper and iron losses and to help maintain the windings and insulation temperature within an acceptable range. Multiple cooling stages allow for increases in load carrying capability. Loss of any stage or cooling element may result in a forced de-rating of the transformer. Transformer cooling system ratings are typically expressed as one of the following:

- Self-cooled (radiators) with designation as ONAN (oil natural, air natural)
- Forced cooling first stage (fans) with designation as ONAF (oil natural, air forced)
- Forced cooling second stage (fans and pumps) with designation as OFAF (oil forced, air forced)

From the view of both financial and operational risk, power transformers are the most important asset installed on the distribution and transmission systems.

### 6.1.2 Asset Degradation

For a majority of transformers, end of life is typically established as the failure of the insulation system and, more specifically, the failure of pressboard and paper insulation. While the insulating oil can be treated or changed, it is not practical to change the paper and pressboard insulation. The condition and degradation of the insulating oil, however, plays a significant role in aging and deterioration of a transformer, as it directly influences the speed of degradation of the paper insulation. The degradation of oil and paper in transformers is essentially an oxidation process. The three important factors that impact the rate of oxidation of oil and paper insulation are presence of oxygen, high temperature, and moisture.

Transformer oil is made up of complex hydrocarbon compounds, containing anti-oxidation compounds. Despite the presence of oxidation inhibitors, oxidation occurs slowly under normal operating conditions. The rate of oxidation is a function of internal operating temperature and age. The oxidation rate increases as the oil ages, reflecting both the depletion of the oxidation inhibitors and the catalytic effect of the oxidation products on the oxidation reactions. The products of oxidation of hydrocarbons are moisture, which causes further deterioration of the insulation system, and organic acids, which result in formation of solids in the form of sludge. Increasing acidity and water levels result in the oil being more aggressive to the paper, hence accelerating the ageing of the paper insulation. Formation of sludge adversely impacts the cooling capability of the transformer and adversely impacts its dielectric strength. An indication of the condition of insulating oil can be obtained through measurements of its acidity, moisture content, and breakdown strength.

The paper insulation consists of long cellulose chains. As the paper ages through oxidization, these chains are broken. The tensile strength and ductility of insulting paper are determined by the average length of the cellulose chains; therefore, as the paper oxidizes the tensile strength and ductility are significantly reduced and insulating paper becomes brittle. In addition to the general oxidation of the paper, degradation and failure can also result from partial discharge (PD). PD can be initiated if the level of moisture is allowed to develop in the paper, or if there are other minor defects within active areas of the transformer.

The relative levels of carbon dioxide and carbon monoxide dissolved in oil can provide an indication of paper degradation. Detection and measurement of furans in the oil provides a more direct measure of the paper degradation. Furans are a group of chemicals that are created as a by-product of the oxidation process of the cellulose chains. The occurrence of partial discharge and other electrical and thermal faults in the transformer can be detected and monitored by measurement of hydrocarbon gases in the oil through Dissolved Gas Analysis (DGA).

### 6.1.3 Asset Class Demographics

Alectra's system has 292 power transformers, including 29 spare units. These are comprised of 31 TS transformers, three of which are spares, and 261 MS transformers which include 26 spares and units undergoing refurbishment. According to industry averages, power transformers have a Typical Useful Life (TUL) of 45 years and are deemed to have reached End of Useful Life (EUL) at 60 years of age. Figure 31 shows the age demographics of power transformers in Alectra's distribution system as of the summer of 2021.

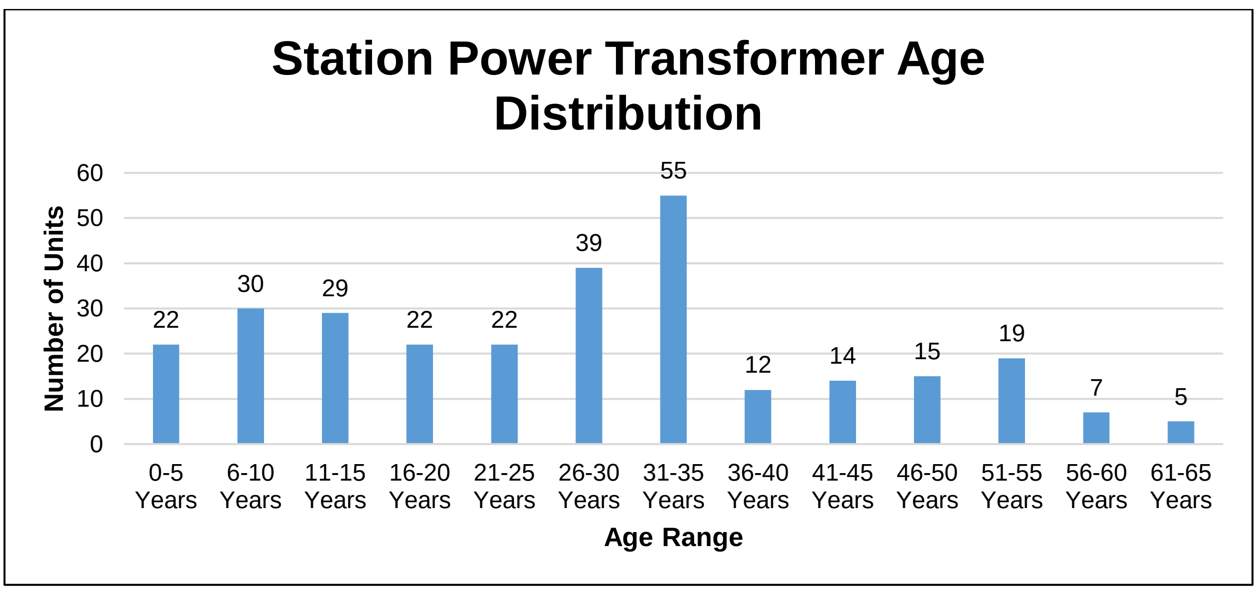


*Figure 31 Station Power Transformer Age Distribution for 2021*

### 6.1.4 Health Index Formula & Results

Health index of power transformers assesses the condition of the transformer according to four main components: Insulation, Cooling, Sealing and Connection, and Age. Insulation is considered to be the primary condition indicator and contributes to 70% of the Health Index. Included in insulation condition are oil quality analysis, oil dissolved gas analysis (DGA), and winding Doble and furan test results.

Age represents deterioration due to other factors not captured by the other components of the model. The scoring method for age is described in *Section 2.1.2 Percentage Score.* Age contributes to only 10% of the Health Index for power transformers.

The Health Index is computed by adding the weighted components of overall condition and age, as shown in Table 24.

*Table 24 Power Transformer Health Index Parameters and Weights*

| # | Input | Input Weight | Scoring Method |
|---|---|---|---|
| 1 | Insulation | 70% | Step Score |
| 2 | Cooling | 10% | Step Score |
| 3 | Sealing and Connection | 10% | Step Score |
| 4 | Age | 10% | Percentage Score |

**DGA Multiplier**

If a power transformer's oil sample results indicate a low overall oil DGA score, it will have a maximum Health Index of 50%.

$$DGA\ multiplier = 50\%$$

**Explosive Gas Multiplier**

A high concentration of acetylene in a power transformer's oil sample results indicates that there is a potential for an explosive failure and that the transformer should be removed from service for further diagnostics. A transformer with high concentration of acetylene will be considered as a candidate for replacement and will have a maximum Health Index of 10%.

$$Explosive\ Gas\ multiplier = 10\%$$

Where both multipliers (Explosive Gas and DGA) are triggered, the lower of the two applies (i.e., the Explosive Gas multiplier).

Figure 32 shows the distribution of Health Index values of power transformers, classified from Very Poor to Very Good. The average DAI is 96%.

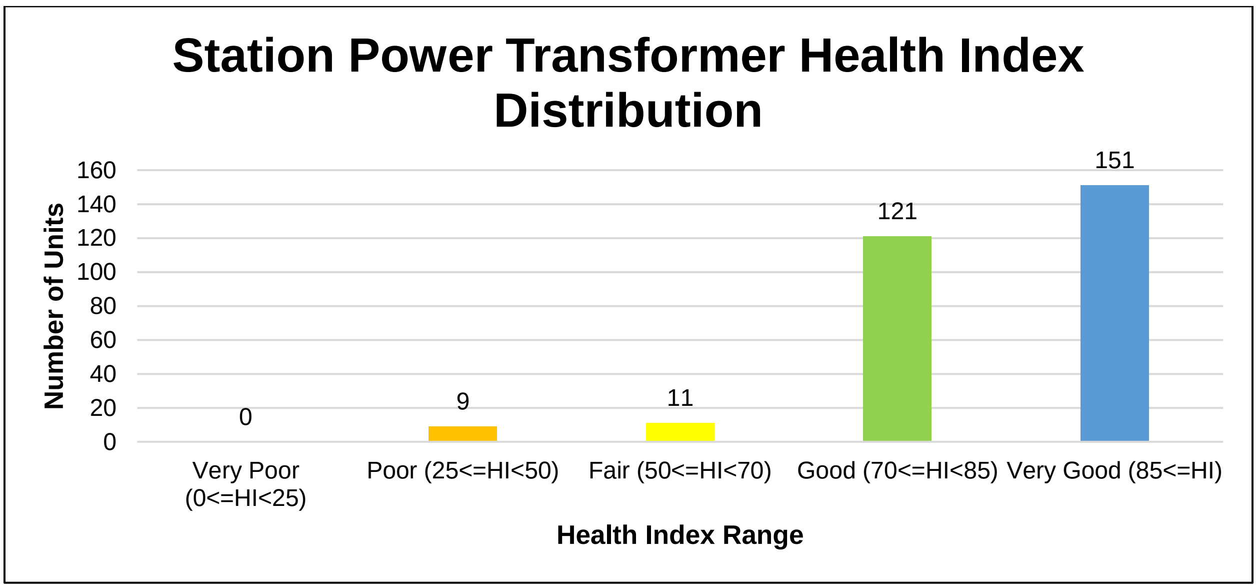


*Figure 32 Station Power Transformer Health Index Distribution for 2021*

## 6.2 Circuit Breakers

### 6.2.1 Summary of Asset Class

Circuit breakers are used to sectionalize and isolate circuits or other assets. They are often categorized by the insulation medium used in the circuit breaker and by the interruption process. The common types include oil circuit breakers, air circuit breakers, vacuum circuit breakers, and $SF_6$ circuit breakers.

Oil circuit breakers (OCB) interrupt current under oil and use the gas generated by the decomposition of the oil to assist in arc extinguishing.

Air insulated circuit breakers are generally found at distribution system voltages and below. Air-type circuit breakers fall into two classifications: air-blast, and air-magnetic.

Air-blast circuit breakers use compressed air as the quenching, insulating and actuating mechanism. In a typical device, a blast of air carries the arc into an arc chute to be extinguished. Air-blast circuit breakers at distribution voltages are often in metal-enclosed switchgear.

Air-magnetic circuit breakers use the magnetic effect of the current undergoing interruption to draw an arc into an arc chute for cooling, splitting and extinction. Sometimes, an auxiliary puffer or air-blast piston may help interrupt low-level currents. The air-magnetic circuit breakers have short duty cycles, require frequent maintenance, and approach their end-of-life at much faster rates than either $SF_6$ or vacuum circuit breakers. They also have limited transient recovery voltage capabilities and can experience re-strike when switching capacitive currents.

$SF_6$ circuit breakers interrupt currents by opening a blast valve and allowing high pressure $SF_6$ to flow through a nozzle along the arc drawn between fixed and moving contacts. This process rapidly deionizes, cools, and interrupts the arc. After interruption, low-pressure gas is compressed for re-use in the next operation. $SF_6$ is, however, a very potent greenhouse gas, having a global warming potential of about 23,500 times that of carbon dioxide. It is very important that any gas leaks are mitigated promptly.

In vacuum circuit breakers, the parting contacts are placed in an evacuated chamber (i.e., vacuum bottle). There is generally one fixed and one moving contact in a butting configuration. A bellows attached to the moving contact permits the required short stroke to occur while maintaining the vacuum. Arc interruption occurs at current zero after withdrawal of the moving contact. Vacuum circuit breakers are also safe and protective of the environment.

### 6.2.2 Asset Degradation

Circuit breakers “make” and “break” high currents and experience erosion caused by the arcing accompanying these operations. All circuit breakers undergo some contact degradation every time they open to interrupt an arc. Also, arcing produces heat and decomposition products that degrade surrounding insulation materials, nozzles, and interrupter chambers. The mechanical energy needed for the high contact velocities of these assets adds mechanical deterioration to their degradation processes.

Outdoor circuit breakers may experience adverse environmental conditions that influence their rate and severity of degradation. Additional degradation factors for outdoor-mounted circuit breakers include corrosion, effects of moisture, and bushing, insulator, and mechanical deterioration.

Corrosion and moisture commonly cause degradation of internal insulation, circuit breaker performance mechanisms and major components such as bushings, structural components, and oil seals. Another widespread problem involves corrosion of operating mechanism linkages that result in eventual link seizures. Corrosion also causes damage to metal flanges, bushing hardware, and support insulators.

Outdoor circuit breakers experience moisture ingress through defective seals, gaskets, and pressure relief and venting devices. Moisture in the interrupter tank can lead to general degradation of internal components.

Mechanical degradation presents greater end-of-life concerns than electrical degradation. Operating mechanisms, bearings, linkages, and drive rods represent components that experience most mechanical degradation problems. Other effects that arise with aging include loose primary and grounding connections, oil contamination and/or leakage (oil circuit breakers only), and deterioration of concrete foundation affecting circuit breaker stability.

For oil circuit (OCB) breakers, the interruption of load and fault currents involves the reaction of high pressure with large volumes of hydrogen gas and other arc decomposition products. Thus, both contacts and oil degrade more rapidly in OCBs than they do in vacuum designs, especially when the OCB undergoes frequent switching operations. Generally, four to eight fault interruptions with contact erosion and oil carbonization will lead to the need for maintenance, including oil filtration. OCBs can also experience restrike when switching low load or line charging currents with high recovery-voltage values. Sometimes this can lead to catastrophic circuit breaker failures.

### 6.2.3 Asset Class Demographics

Alectra's distribution system has 1,268 installed circuit breakers at its stations, 235 of which are associated with transformer stations. According to industry averages, circuit breakers have a Typical Useful Life (TUL) of 40 years and are deemed to have reached End of Useful Life (EUL) at 60 years of age. Figure 33 shows the age demographics of circuit breakers at stations in Alectra's distribution system as of the summer of 2021.

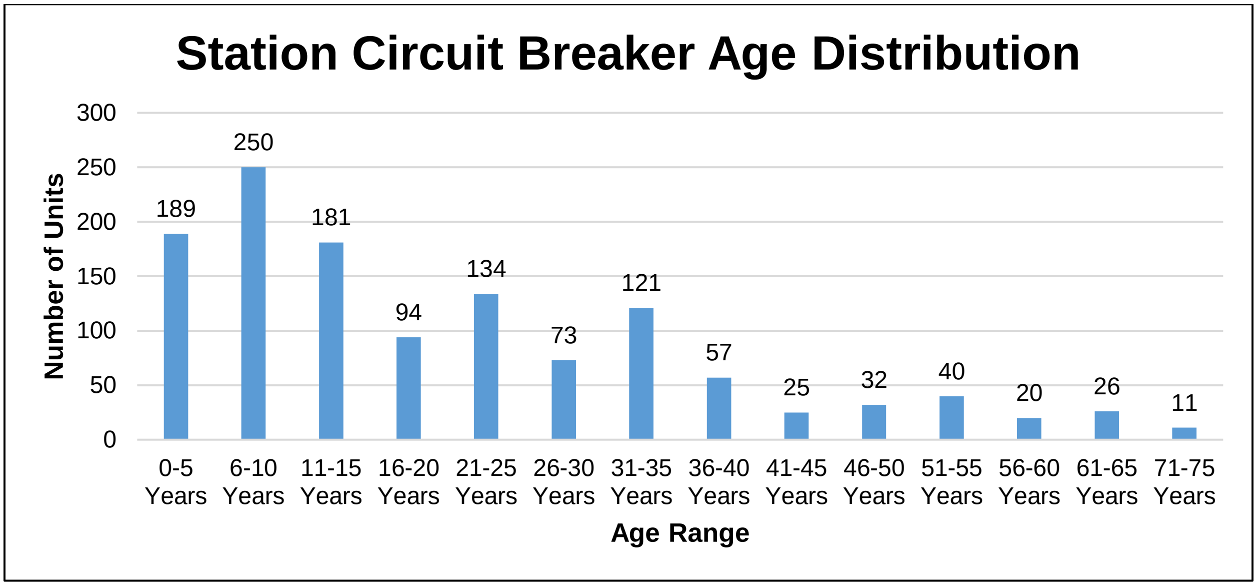


*Figure 33 Station Circuit Breaker Age Distribution for 2021*

### 6.2.4 Health Index Formula & Results

Health index of circuit breakers assesses the condition of the circuit breaker according to seven main components: Insulation, Operating mechanism, Contact performance, Arc extinction, Oil leaks (where applicable), Overall performance, and Age.

Age represents deterioration due to other factors not captured by the other components of the model. The scoring method for age is described in *Section 2.1.2 Percentage Score.*

The Health Index is computed by adding the weighted components of overall condition and age, as shown in Table 25.

*Table 25 Circuit Breaker Health Index Parameters and Weights*

| # | Input | Input Weight (OIL) | Input Weight (AIR) | Input Weight (Vacuum) | Input Weight ($SF_6$) | Scoring Method |
|---|---|---|---|---|---|---|
| 1 | Insulation | 4.8% | 5.6% | 7.4% | 6.1% | Step Score |
| 2 | Operating Mechanism | 33.3% | 38.9% | 25.9% | 33.3% | Step Score |
| 3 | Contact Performance | 16.7% | 19.4% | 26.0% | 21.2% | Step Score |
| 4 | Arc Extinction | 21.4% | 16.7% | 14.8% | 18.2% | Step Score |
| 5 | Oil Leaks | 7.1% | 0.0% | 0.0% | 0.0% | Step Score |
| 6 | Overall Performance | 12.5% | 14.6% | 19.4% | 15.9% | Step Score |
| 7 | Age | 4.2% | 4.8% | 6.5% | 5.3% | Percentage Score |

**Obsolescence Multiplier**

A circuit breaker may be deemed obsolete if it is no longer supported by the manufacturer, parts are no longer readily available, and/or no longer meet current safety or performance standards. If a circuit breaker is deemed to be obsolete, it will have a maximum Health Index of 50%.

$$Obsolescence\ multiplier = 50\%$$

Figure 34 shows the distribution of Health Index values of circuit breakers, classified from Very Poor to Very Good. The average DAI is 88.6%.

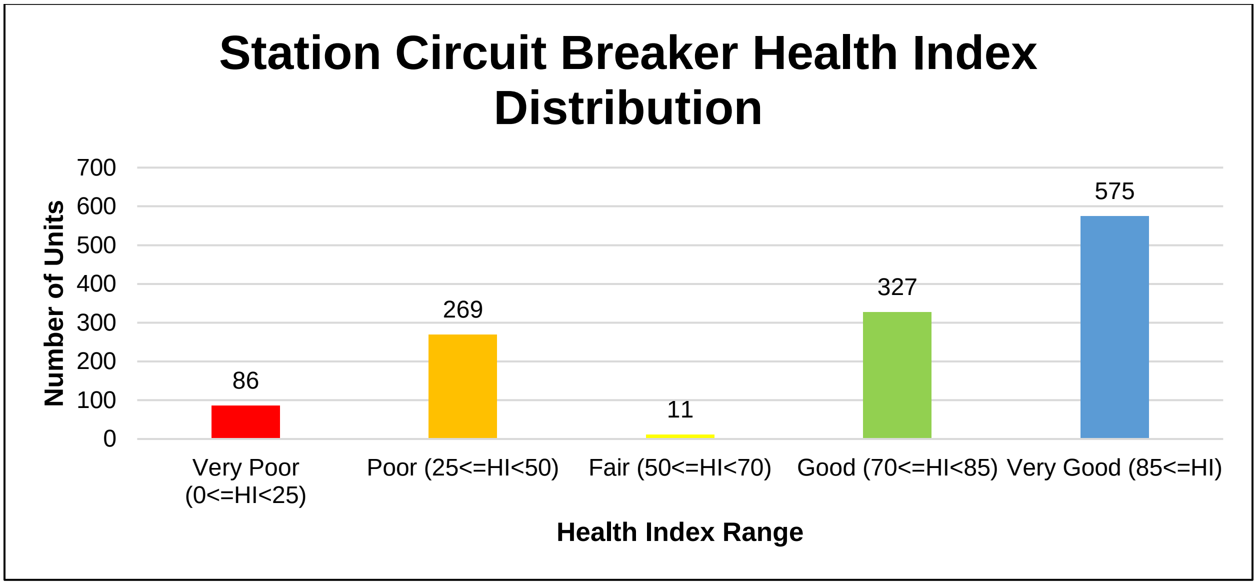


*Figure 34 Station Circuit Breaker Health Index Distribution for 2021*

## 6.3 Station Switchgear

### 6.3.1 Summary of Asset Class

Station switchgear, hereafter referred to simply as "switchgear", consists of an assembly of retractable/racked devices that are totally enclosed in a metal envelope (metal-enclosed). These devices operate in the medium-voltage range, from 4.16 kV to 34 kV. The switchgear includes circuit breakers, disconnect switches or fuse gear, current transformers (CTs), potential transformers (PTs), and occasionally some or all of the following: metering, protective relays, internal DC and AC power, battery charger(s), and AC station service transformation. The switchgear is modular in that each circuit breaker is enclosed in its own metal envelope (cell). The switchgear also is compartmentalized, having separate compartments for circuit breakers, control, incoming/outgoing cables or bus duct, and busbars associated with each cell.

### 6.3.2 Asset Degradation

Station switchgear degradation is a function of several factors: mechanism operation and performance, degradation of solid insulation, general degradation/corrosion, environmental factors, and post fault maintenance (condition of contacts and arc control devices). Degradation of the circuit breaker used is also a factor. However, the degradation mechanism differs slightly between air-insulated and gas-insulated switchgear types. Note that circuit breakers are evaluated separately from switchgear.

The greatest cause of maloperation of switchgear is related to mechanism malfunction. Deterioration due to corrosion or wear due to lubrication failure may compromise mechanical performance by either preventing or slowing down the operation of the circuit breaker. This is a serious issue for all types of switchgear.

In older air-filled equipment, degradation of active solid insulation, such as drive links, has been a significant problem for some types of switchgear. Some of the materials used in this equipment, particularly those manufactured using cellulose-based materials (pressboard, SRBP, laminated wood), are susceptible to moisture absorption. This results in a degradation of their dielectric properties, resulting in thermal runaway or dielectric breakdown. An increasingly significant area of solid insulation degradation relates to the use of more modern polymeric insulation. Polymeric materials, which are now widely used in switchgear, are very susceptible to discharge damage. These electrical stresses must be controlled to prevent any discharge activity in the vicinity of polymeric material. Failures of relatively new switchgear due to discharge damage and breakdown of polymeric insulation have been relatively common over the past couple of decades.

Temperature, humidity, and air pollution are also significant degradation factors. The safe and efficient operation of switchgear and its longevity may all be significantly compromised if the station environment is not adequately controlled.

### 6.3.3 Asset Class Demographics

Alectra's distribution system has 365 station switchgear. According to industry averages, station switchgear have a Typical Useful Life (TUL) of 40 years and are deemed to have reached End of Useful Life (EUL) at 60 years of age. Figure 35 shows the age demographics of station switchgear in Alectra's distribution system.

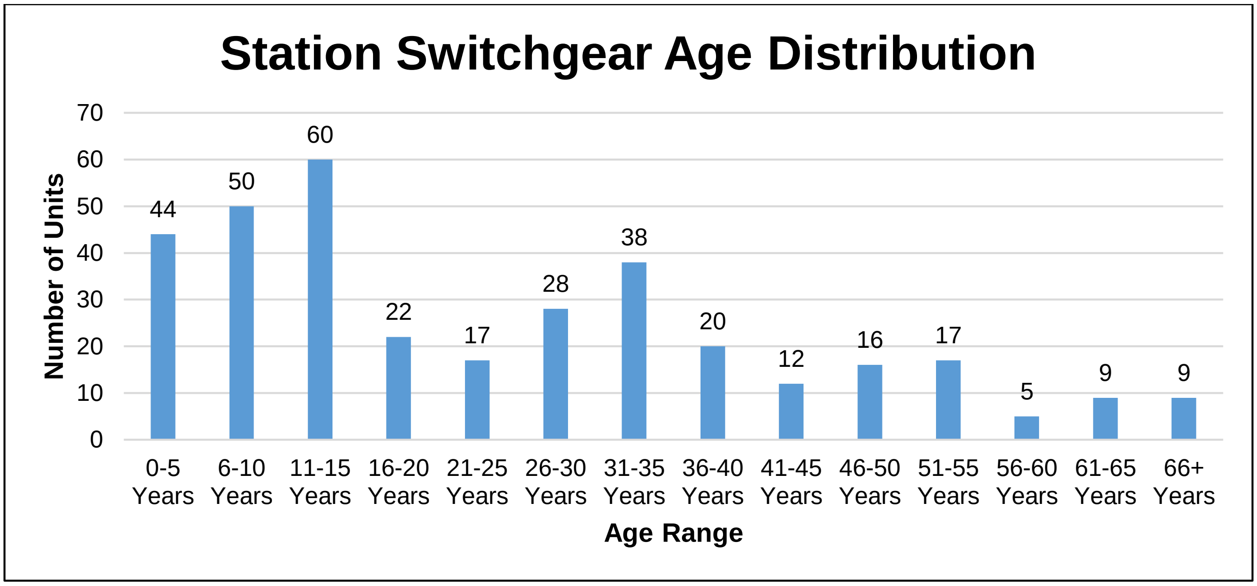


*Figure 35 Station Switchgear Age Distribution for 2021*

### 6.3.4 Health Index Formula & Results

Health index of station switchgear assesses the condition of the switchgear according to five main components: Enclosure condition, Bus and cable compartment, Low-voltage compartment, Overall Performance, and Age. Circuit breakers analyzed separately.

Age represents deterioration due to other factors not captured by the other components of the model. The scoring method for age is described in *Section 2.1.2 Percentage Score.*

The Health Index is computed by adding the weighted components of overall condition and age, as shown in Table 26.

*Table 26 Station Switchgear Health Index Parameters and Weights*

| # | Input | Input Weight | Scoring Method |
|---|---|---|---|
| 1 | Enclosure Condition | 25% | Step Score |
| 2 | Bus & Cable Compartment | 37.5% | Step Score |
| 3 | Low-Voltage Compartment | 12.5% | Step Score |
| 4 | Overall Performance | 18.75% | Step Score |
| 5 | Age | 6.25% | Percentage Score |

Figure 36 shows the distribution of Health Index values of station switchgear, classified from Very Poor to Very Good. The average DAI is 86.2%.

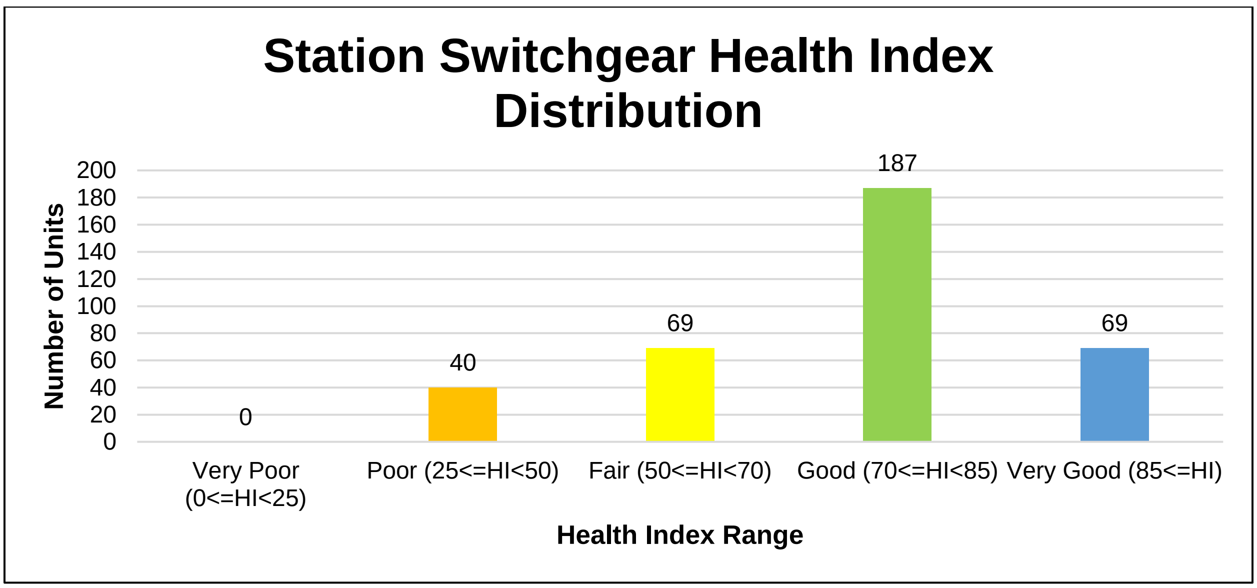


*Figure 36 Station Switchgear Health Index Distribution for 2021*

# AMPCO-10

# Attachment 2
# Alectra 2022 ACA Report

2022

Discover the possibilities

# Asset Condition Assessment - 2022

## ASSET MANAGEMENT

2022 ACA REPORT
MAY 2023

# Table of Contents

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# Executive Summary

In 2018, Alectra Utilities harmonized its Asset Condition Assessment (ACA) practices. Alectra Utilities compiles an annual report based on the latest inputs to the ACA. This report presents the 2022 ACA using input data as of December 2021.

Alectra's service territory extends from the city of St. Catharines, located on the shores of Lake Ontario, to the town of Penetanguishene, located along the southeastern shores of Georgian Bay. The service territory spans over 1,800 square kilometers, providing electricity to approximately one million customers. In this territory, Alectra owns, operates, and maintains an electrical distribution system consisting of distribution and station-class assets. Asset condition assessments are used to assist in developing asset sustainment strategies and guiding investments.

Asset condition assessment involves monitoring and inspecting assets and analyzing the collected data to determine their condition. Assessment is performed using Health Index (HI) models. The HI model is an analytical one that quantifies the condition of an asset in a consistent manner. Models reflect asset degradation, industry guidelines, and Alectra's experience. HI model formulas, parameters, inputs, and results are stored in a Relational Database, enabling a unified source for performing HI computations and providing the agility for future enhancements.

Health Index is calculated for the distribution asset classes listed below:

- Pad-mounted transformers
- Pole-mounted transformers
- Vault type transformers (including submersible)
- Pad-mounted switchgear
- Pole-mounted load interrupting switches
- Overhead primary conductors
- Wood poles
- Concrete poles
- Underground medium-voltage power cables

A summary of distribution asset HI results is presented in Figure 1.

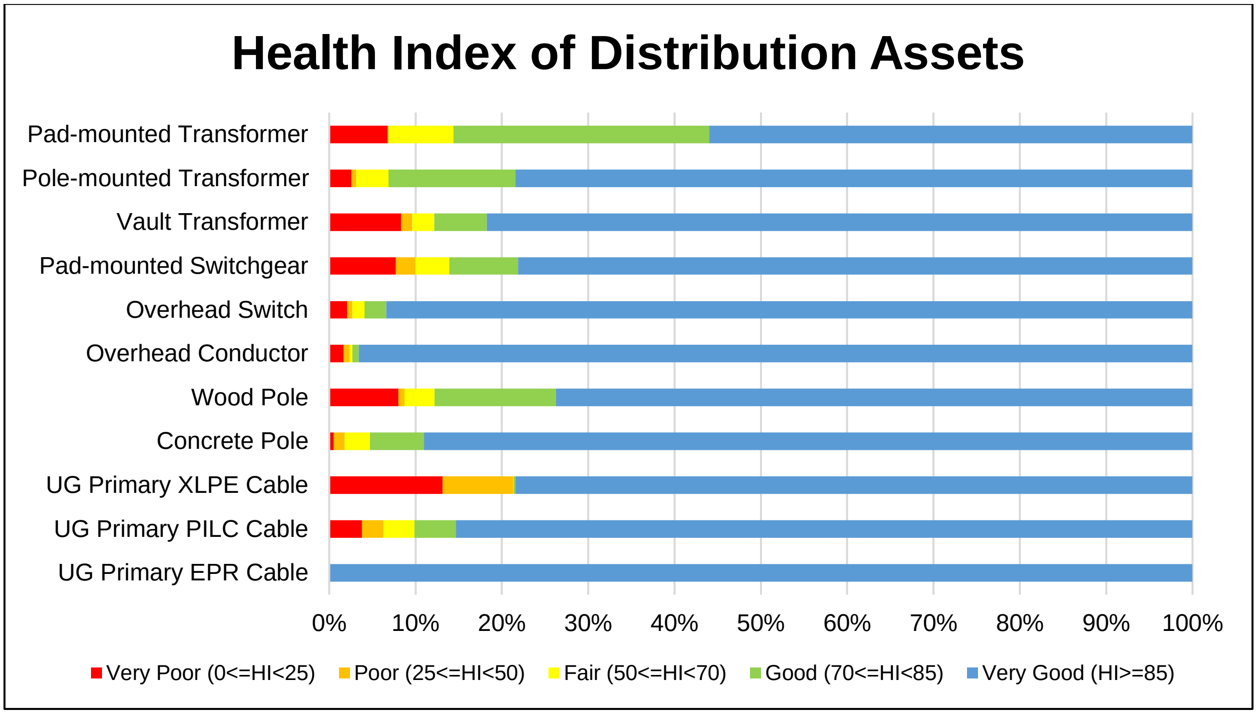


*Figure 1 Distribution Asset Health Index Results Summary for 2022*

Distribution asset HI results and sustainment pacing recommendations are provided to subject matter experts (SME) for each asset class. SMEs determine system sustainment needs and develop business cases based on a recommended number of assets that require attention. Business cases are submitted for optimization using Alectra's Capital Investment Portfolio application (Copperleaf Portfolio).

HI is calculated for the station asset classes listed below:

- Station power transformers
- Station class switchgear
- Station circuit breakers

A summary of station asset HI results is presented in Figure 2.

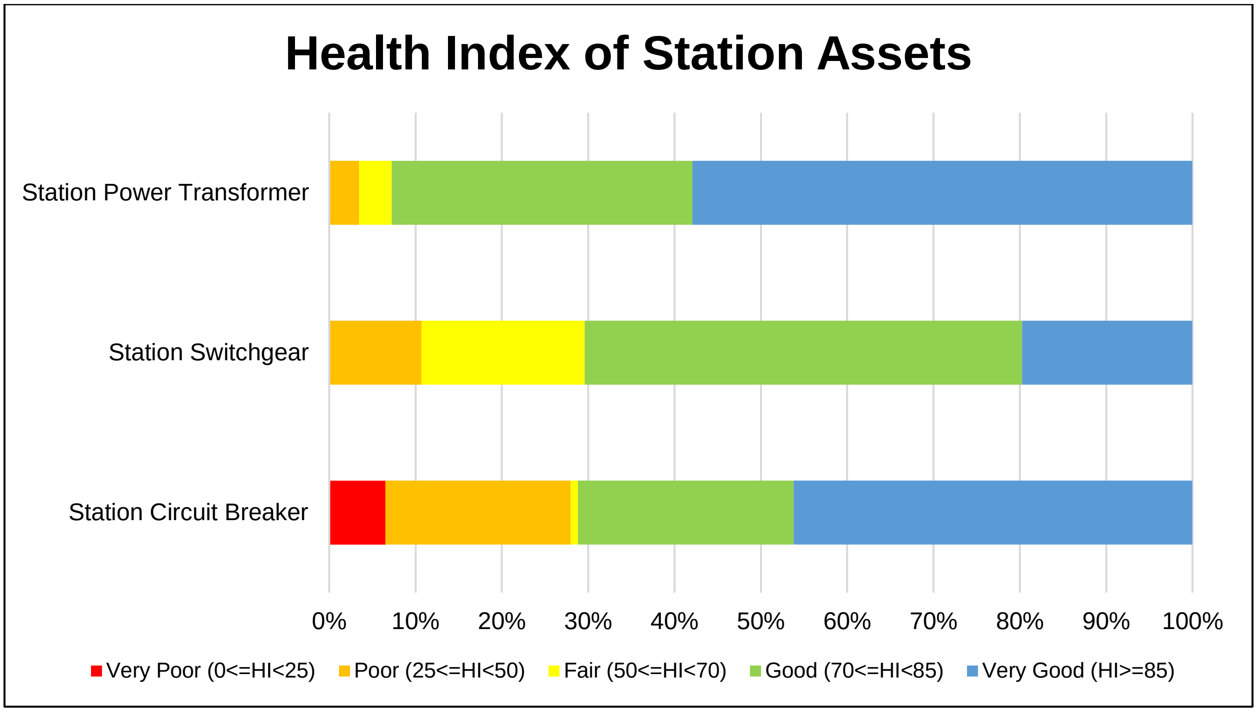


*Figure 2 Station Asset Health Index Results Summary for 2022*

Stations' asset HI results are compiled on a per-station basis and published to SMEs for evaluation. Grouping assets by station facilitates a station-centric approach, enabling a thorough review process involving SMEs in multiple departments. SMEs leverage the HI results, along with other considerations that include the following: station decommissioning schedules associated with voltage conversion projects, expansion requirements, magnitude and criticality of the load that is supplied, type of customers supplied, potential stranded load conditions, distribution system load transfer capabilities, obsolescence, availability of parts, maintainability, safety and environmental concerns, and available budget. SMEs prepare business cases for station needs and opportunities identified through this exercise and submit them into Copperleaf Portfolio for optimization.

# 1 Introduction

This Asset Condition Assessment (ACA) report is prepared to address system renewal and sustainment investment needs drivers as part of Alectra's Asset Management practices.

The 2022 ACA represents an update, incorporating condition and inventory information available as of December 2022 using the same practices that were harmonized in 2018 after Alectra's formation.

This report describes an analytical approach to asset condition assessment using Health Indices for Alectra's distribution and station assets. Health Index (HI) is an input for SMEs when they derive system sustainment and asset management strategies.

ACA is an internal process used by Alectra as part of the overall asset management process. Outputs from the ACA are evaluated for sustainment needs. Figure 3 shows the needs drivers in Alectra's asset management process and identifies the alignment of the ACA in the process.

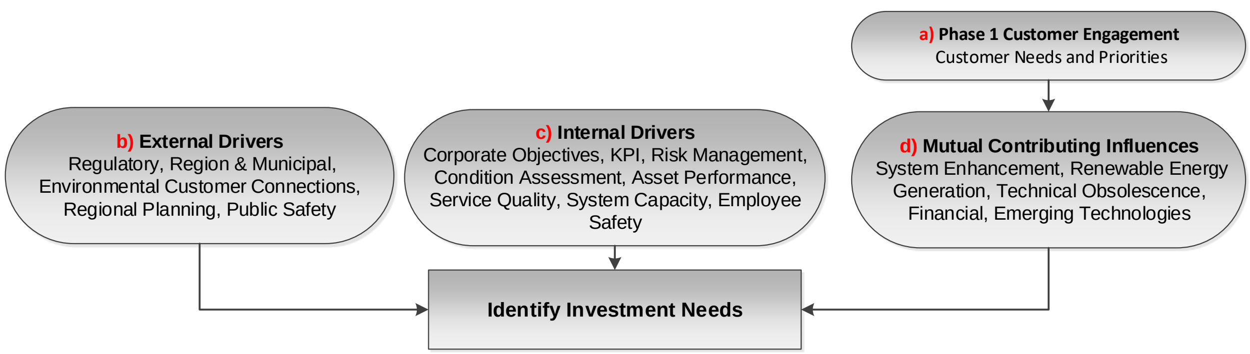


*Figure 3 Asset Management Process Investment Drivers and Considerations*

Distribution asset ACA results are provided to SMEs for evaluation to determine system sustainment needs and for business case development. SMEs incorporate the outcome of the ACA to build business cases for assets that warrant action. Distribution asset business cases are based on a recommended number of assets that require attention. Business cases are documented in Alectra's Capital Investment Portfolio system (Copperleaf Portfolio). Figure 4 illustrates the process of identifying investment needs for distribution assets.


Figure 4 Distribution Asset Condition Process

Stations’ asset HI results for multiple asset classes are grouped for each station and provided to SMEs for evaluation. Grouping multiple assets classes by the station facilitates a station-centric approach, enabling a thorough review process with SMEs in multiple departments. SMEs determine the system sustainment needs, where HI is one of several considerations considered in determining the needs.

In addition to the HI data, decisions on sustainment for station assets include considerations related to: station decommissioning schedules associated with voltage conversion projects, expansion requirements, magnitude and criticality of the load that is supplied, number of customers that are supplied, potential stranded load conditions, distribution system load transfer capabilities, obsolescence, availability of parts, maintainability, safety and environmental concerns, and available budget. Where station needs warrant sustainment activities, business cases are documented in Copperleaf Portfolio, integrating all applicable cross-functional drivers as part of Alectra’s integrated planning. Figure 5 shows the process identifying investment needs for station assets.

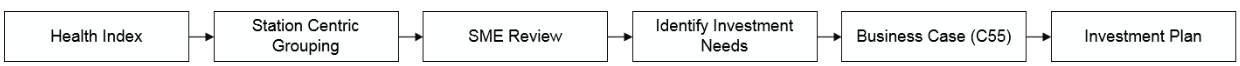


*Figure 5 Station Asset Condition Assessment Drivers*

Capital investment portfolio optimization is completed in Copperleaf Portfolio, where investments are optimized across all Alectra investment categories. The optimization provides the prioritized allocation and pacing of investments. The optimization considers the risk and benefit in conjunction with financial attributes, such as weighted average cost of capital, and inflation factors.

# 2 Health Index Methodology

The Health Index (HI) model quantifies the condition of an asset in a consistent manner. Each asset class has different inputs to inform the HI model. The input weights are based on the asset's characteristics, the extent to which the input reflects asset degradation, industry guidelines, and Alectra Utilities' experience. Health Index model formulas, parameters, inputs, and results are stored in a Relational Database, enabling a unified source for performing HI computations and providing the agility for future enhancements. Figure 6 shows a flowchart summarizing the HI methodology.

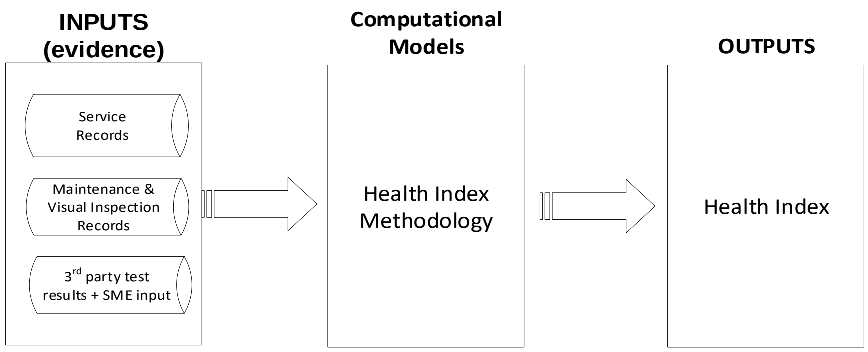


*Figure 6 Health Index Methodology: Inputs, Computation, and Outputs*

The advantage of using an evidence-based HI is having a practical and consistent method to gauge the condition of assets analytically in a quantified manner. Having a standardized model for assets across Alectra ensures that all assets are being measured in a consistent manner to guide asset management strategies and policies. The generic equation below shows the calculation of the Health Index:

$$\boldsymbol{Health\ Index} = \frac{\sum_{i=1}^{n}(Input\ Weight_{\,i} \times\ Input\ Score_{\,i}\,)}{\sum_{i=1}^{n}(Input\ Weight_{\,i}\,)} * Condition\ Multiplier \qquad (\mathbf{1})\,,\quad where$$

$$\boldsymbol{n}: number\ of\ available\ inputs\ for\ an\ asset\ class,$$

$$\boldsymbol{Input\ Score}: percentage\ (0 - 100\%)\ ,$$

$$\boldsymbol{Health\ Index}: percentage\ (0 - 100\%),$$

$$\boldsymbol{Input\ Weight}: percentage, where \sum_{i=1}^{n} Input\ Weight_{\,i} = 100\%$$

$$\boldsymbol{Condition\ Multiplier}: maximum\ allowable\ HI\ given\ asset\ specific\ metrics$$

$$described\ further\ in\ this\ report$$

## 2.1 Input Score

Inputs to the Health Index (HI) are scored in one of two ways: a step score, or a percentage score. Each input that makes up the HI is scored accordingly.

### 2.1.1 Step Score

Step score is a points-based scoring method used for inputs of the HI calculation that are non-continuous. Field inspections are an example. Step scoring is reserved for inputs with distinct levels measured against defined criteria.

Station assets and distribution assets are inspected and monitored through different processes and criteria. Field inspections and HI components that use step scoring for distribution assets have a six-point scoring system (0-5). Table 1 shows the distribution asset step scoring criteria and associated scores in percentage.

*Table 1 Distribution Asset Step Scoring*

| Inspection Score | Criteria | HI Input Score |
|---|---|---|
| 5 | Excellent condition | 100% |
| 4 | Relatively good condition | 80% |
| 3 | Fair condition | 60% |
| 2 | Moderate degradation | 40% |
| 1 | Major degradation/not fit for service | 20% |
| 0 | Imminent failure | 0% |

Field inspections and HI components that use step scoring for station assets have a five-point scoring system (0-4). Table 2 shows the station asset step scoring criteria and associated scores in percentage.

*Table 2 Station Asset step Scoring*

| Inspection Score | Criteria | HI Input Score |
|---|---|---|
| 4 | Excellent - Like new | 100% |
| 3 | Good - Within operating context | 75% |
| 2 | Fair - Not failed but monitoring | 50% |
| 1 | Poor - Not within operating context | 25% |
| 0 | Very Poor - Imminent failure | 0% |

### 2.1.2 Percentage Score

Percentage scoring is the continuous (i.e., graduated) scoring of an input. Percentage scoring is used when more granular data are available and where step scoring is not accurately representative of an input's impact. This representation is used for certain measurements, such as pole residual remaining strength, as well as for other data, such as age.

For example, age is represented as a percentage score based on a continuous function given by the Gompertz-Makeham Model described by the following set of equations:

$$Age\ score = e^{\frac{-(f(t)-e^{-\alpha\beta})}{\beta}} \qquad (\mathbf{2}) \quad ,where$$

$$f(t) = e^{\beta(t-\alpha)}, where$$

$$t: age\ (years)$$

$$\alpha, \beta: \text{constants}$$

The constants α, β are calculated to yield an age score of 80% at the Typical Useful Life (TUL), and 1% at the End of Useful Life (EUL) of an asset. Use of the Gompertz-Makeham Model is a widely accepted industry practice for assessing asset condition.

Asset TUL is based on the "Asset Depreciation Study for the Ontario Energy Board Kinectrics Inc. Report No: K-418033-RA-001-R000 July 8, 2010" report. Similarly, asset EUL is based on the Maximum Useful Life (Max UL) from the same report.

## 2.2 Condition Multiplier

To adequately represent the health of an asset using the Health Index (HI), conditions that determine major degradation or imminent failure of an asset are accounted for by limiting the HI to a maximum value by using the condition multiplier. Once certain conditions are triggered, the HI of an asset is limited to a maximum score, regardless of the status of other inputs.

Condition multipliers are based on dominant HI inputs that significantly impact the asset's health. For example, pole residual strength is a dominant input and indicator of a wood pole's health.

Examples of condition multipliers are as follows:

- **Field inspection multiplier** is applied to assets that exhibit major degradation or imminent failure as determined by field inspection.
- **Measurement multiplier** is applied to assets that exhibit major degradation or imminent failure as determined by a measurement.
- **Safety hazard multiplier** is applied to assets that pose a safety hazard or in a condition that is below the acceptable industry safety standards, guidelines, and practices.
- **Obsolescence multiplier** is applied to assets that are no longer supported by vendors, have limited or no parts availability, and/or no longer meet current safety or performance standards. Obsolescence is largely driven by specification changes, compatibility, and/or manufacturer/supplier.

Where two or more condition multipliers are applicable, the smallest multiplier (by value) is applied.

## 2.3 Health Index Categorization

The Health Index (HI) of assets is expressed as a percentage. Categorization based on percentage ranges enables the identification of groups within an asset class that exhibit similar characteristics from an overall condition perspective. The HI is classified into one of five categories, as shown in Table 3.

*Table 3 Health Index Categories*

| Category | Criteria | Range |
|---|---|---|
| **Very Good** | Asset is in excellent condition. | $HI \geq 85\%$ |
| **Good** | Asset is still relatively in excellent condition. | $70\% \leq HI < 85\%$ |
| **Fair** | Asset is functional but showing signs of deterioration. | $50\% \leq HI < 70\%$ |
| **Poor** | Asset is exhibiting degraded condition. | $25\% \leq HI < 50\%$ |
| **Very Poor** | Asset is showing major degradation / imminent failure. | $HI < 25\%$ |

A bar chart displaying the five asset Health Index categories as a function of HI score is presented in Figure 7.

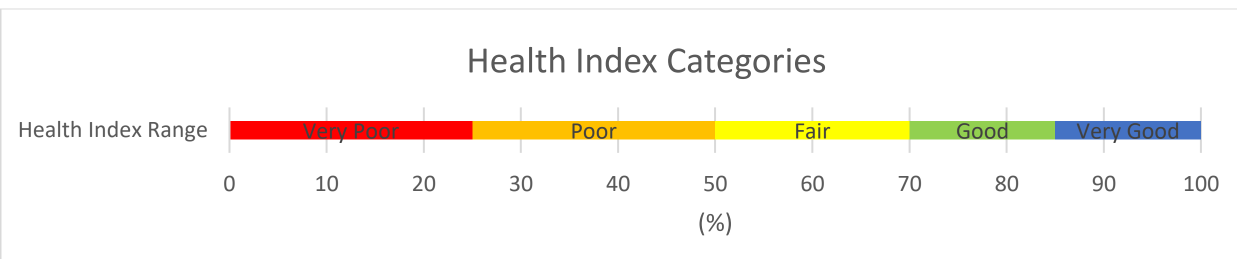


*Figure 7 Health Index Categories*

## 2.4 Data Availability

To assess the data completeness required by the computational model, a Data Availability Index (DAI) is calculated for each asset evaluated in this report.

The main function of DAI is to represent the amount of information, in percentage by input data weight, that went into calculating the HI of an asset. DAI only represents the completeness and not the quality of data.

$$DAI = \sum_{i=1}^{m} (Input\ Weight_i \times\ Input\ Data\ Available_i) \qquad (\mathbf{3})$$

$$, where$$

$$\boldsymbol{m}: number\ of\ inputs\ required\ in\ the\ Health\ Index\ model\ of\ an\ asset\ class$$

$$\boldsymbol{Input\ Weight}: percentage, where \sum_{i=1}^{n} Input\ Weight_i = 100\%$$

$$\boldsymbol{Input\ Data\ Available}:\ True = 1\ or\ False = 0$$

$$\boldsymbol{DAI}: percentage\ (0 - 100\%)$$

The average DAI is provided in the Health Index results section for each asset class. SMEs use the average DAI in decision-making for assessing overall data availability. However, it is sensitive to model improvements. For example, when the model is enhanced by adding a new input parameter, the average DAI may initially be reduced until new data has been collected.

As Alectra harmonizes its inspection, maintenance, testing and data collection practices over time, asset DAI is expected to increase.

# 3 System Sustainment Strategies

The Asset Condition Assessment (ACA) identifies assets within each asset class that require action. System sustainment strategies are dependent on the type of asset, consequences of failure, and asset management practices. These strategies are:

- **Further assessment** (detailed risk assessment, inspection, testing)
- **Planned replacements** (like-for-like or right sizing)
- **Maintenance or rehabilitation**
- **Continue to monitor**
- **Run to failure**

**Further assessment** is required to ensure the prudent selection of a strategy. This is applicable to assets that can be maintained to extend their service life. For example, poles can be rehabilitated in some cases to restore them to acceptable operational and safety parameters. Such further assessments determine the viability of maintenance (versus replacement) on a case-by-case basis.

**Planned replacement** approach applies to critical assets that carry significant risk to the safe and reliable operation of the distribution system and protection of the environment. This strategy is also applicable to assets that have undergone further investigation and were determined unmaintainable. Safety considerations include safety of both the public and distribution system workers (Alectra's staff and contractors). For example, failure of wood poles carries significant safety risk to the public; therefore, a planned replacement strategy is prudent. In the case of concrete poles, if maintenance is not an option, a planned replacement strategy is applicable.

**Maintenance or rehabilitation** strategy applies to assets where only certain components of the asset are exhibiting degradation that can be corrected by cleaning or washing, repairing, replacing, or re-tightening of components, or utilizing technologies such as cable rejuvenation or concrete bracing.  For example, dirty insulators in air-insulated switchgear may be remedied by dry-ice cleaning.

**Continue to monitor** applies to assets where condition is approaching what is typically considered to be its end of life. Monitoring strategies may involve increasing asset inspection cycles and/or installing on-line monitoring, such as on power transformers. Transformer on-line monitoring, in conjunction with analytical tools, can provide an indication of the condition of the transformer's insulation, which is a primary indication of the transformer's health. Adoption of on-line monitoring and associated analytical tools, in conjunction with the development of a modified condition-based maintenance protocol, is a strategy for prolonging the operational life of a transformer.

**Run to failure** applies to assets having minimal impact on reliability, on public or employee safety, and on the environment. Such assets are run to failure and are replaced reactively when they no longer perform their intended function. The decision to run to failure considers redundancy, contingencies, and availability of spare units or components.

From a system sustainment perspective, Alectra has aligned its sustainment outlook horizons to match the Ontario Energy Board's Distribution System Plan (DSP) cycles, where one cycle is five years, as shown below.

- **Short-term** outlook is based on one DSP cycle (**5 years**)
- **Medium-term** outlook is between short-term and long-term outlooks (**7.5 years**)
- **Long-term** outlook is based on two DSP cycles (**10 years**)

**Distribution asset** SMEs use quantities of Very Poor and Poor assets as the needs-driver for business cases. Work is strategically paced to assist SMEs and ensure smooth transitions between DSP cycles so that sudden increases in rates and resource requirements are avoided. A pacing guideline using three scenarios based on the three planning outlook scenarios is shown in Table 4.

*Table 4 Distribution Asset Sustainment Pacing Scenarios*

| Pace | Description | Quantity per year |
|---|---|---|
| Baseline pace | Sustainment strategy targeting Very Poor & Poor assets over the **short-term** | $\frac{(Very\ Poor + Poor)}{5\ years}$ |
| Moderate pace | Sustainment strategy targeting Very Poor & Poor assets over the **medium-term** | $\frac{(Very\ Poor + Poor)}{7.5\ years}$ |
| Slow pace | Sustainment strategy targeting Very Poor & Poor assets over the **long-term** | $\frac{(Very\ Poor + Poor)}{10\ years}$ |

**Stations' asset** investments follow a risk-based approach incorporating a station-centric approach to identify specific asset sustainment initiatives. SMEs consider multiple factors along with the HI results for individual components. The sustainment strategies for station assets are primarily guided by risk mitigation and not pacing/timing.

# 4 ACA Data and Implementation

The implementation of this Asset Condition Assessment (ACA) used a Microsoft Structured Query Language (SQL) database. This implementation enabled the following:

- **Integrating multiple data sources**, which enables the integration of multiple static data sources, while maintaining data integrity and consistency in the transfer process
- **Centralized storage**, which provides a common repository for the required ACA data and calculations
- **Multiple user access,** which allows for simultaneous access by multiple users, thus providing significant contribution to productivity
- **Version control**, which enables future assessments while maintaining a high level of productivity, data accuracy and benchmarking functionality
- **Development agility**, which enables fast and accurate future improvements/development to the ACA data, models, and computations

Using this new process methodology for data collection, storage, harmonization, and computation of HI through an SQL database has provided better data management, version control, development agility, and productivity improvements. In 2021, Alectra adopted Alteryx software to assist in data analytics and asset information.

# 5 Distribution Asset Class Details and Results

Alectra's distribution asset details are described in terms of asset degradation, demographics, Health Index (HI) results categorization, and sustainment pacing. The assets covered as part of distribution are:

- Distribution transformers
- Distribution switchgear
- Overhead switches
- Overhead conductors
- Wood poles
- Concrete poles
- Underground primary cables

## 5.1 Distribution Transformers

Distribution transformers are a vital component to servicing the end users from the distribution system at utilization voltages. Distribution transformers include three types: Overhead, Underground, and Vault. Distribution transformers are moderately complex assets with a varying price per unit.

### 5.1.1 Summary of Asset Class

Underground transformers, also referred to as pad-mounted transformers, connect customers to the distribution system where service laterals are underground. Pad-mounted transformers typically employ sealed tank construction and are liquid filled, with mineral oil being the predominant insulating medium.

Overhead transformers, also known as pole-mounted transformers, convert primary distribution voltages from overhead conductors to secondary voltages (utilization voltages) for use in residential and commercial applications. Typically, overhead transformers connect customers to the distribution system where service laterals are overhead. This type of transformer is mounted on wood or concrete poles. Overhead transformers include single-phase transformers, banked single-phase transformers, and three-phase (polyphase) transformers.

Vault transformers are similar to overhead transformers in construction, but are designed to be placed in chambers, ether below or above grade, or in rooms inside buildings. Vault transformers connect customers to the distribution system where service laterals are underground.

### 5.1.2 Asset Degradation

Distribution-class transformer life is affected by several factors including, but not limited to the following: voltage impulses from lightning and switching, current surges resulting from secondary cable faults, mechanical damage from vehicle contact and corrosive salts, loading, and ambient temperature. Therefore, a combination of field inspection attributes and age criteria are commonly used to determine the health of the asset.

Field inspections provide considerable information on transformer asset condition. Presence and magnitude of oil leaks and structural corrosion are quantified during field inspections.

The failure of a distribution transformer has a relatively minor impact on reliability. However, if a transformer is in a condition that poses risk to the safety of the public or to the environment, a proactive replacement strategy is executed.

### 5.1.3 Asset Class Demographics

Alectra's distribution system has 129,030 distribution transformers, comprising of 82,829 pad-mounted transformers, 33,544 pole-mounted transformers, and 12,657 vault transformers. Figure 8, Figure 9, and Figure 10 show the age demographics of distribution transformers, by type, in Alectra's distribution system.

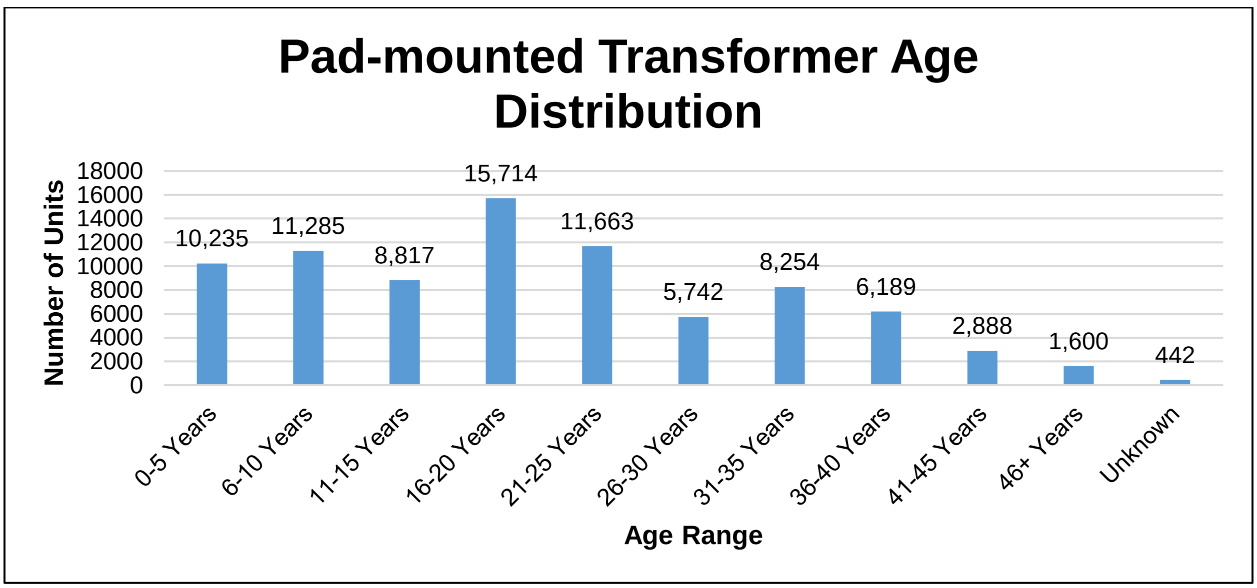


*Figure 8 Pad-mounted Transformer Age Distribution for 2022*

The pad-mounted transformers have a Typical Useful Life (TUL) of 40 years and are deemed to have reached End of Useful Life (EUL) at 45 years of age.

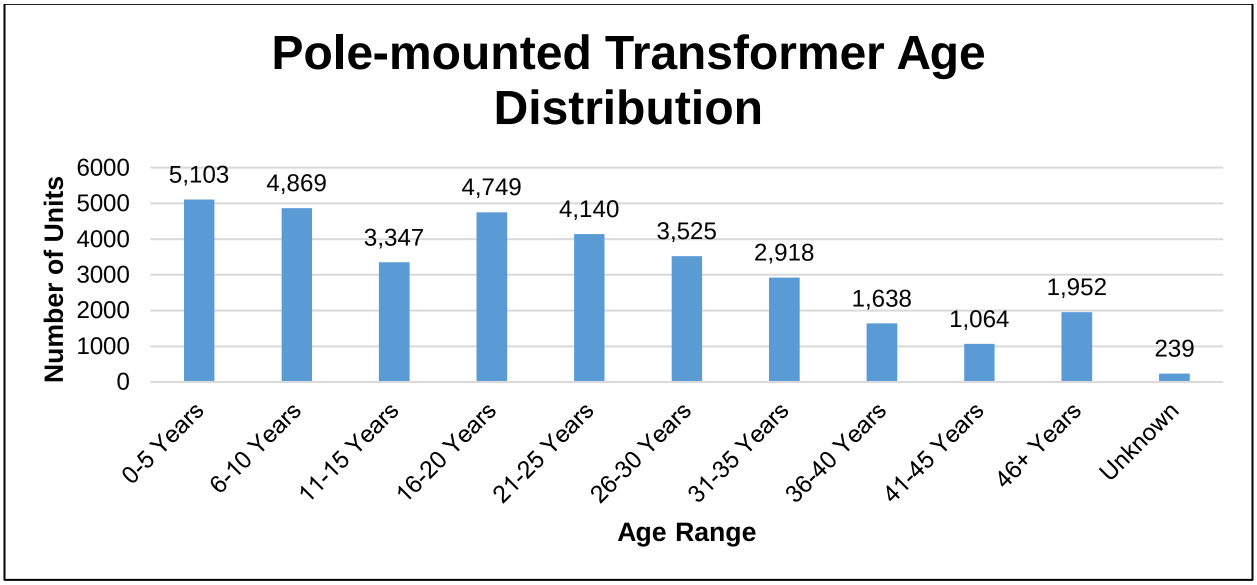


*Figure 9 Pole-mounted Transformer Age Distribution for 2022*

A pole-mounted transformer, also known as overhead transformer, has a TUL of 40 years and is deemed to have reached EUL at 60 years of age.

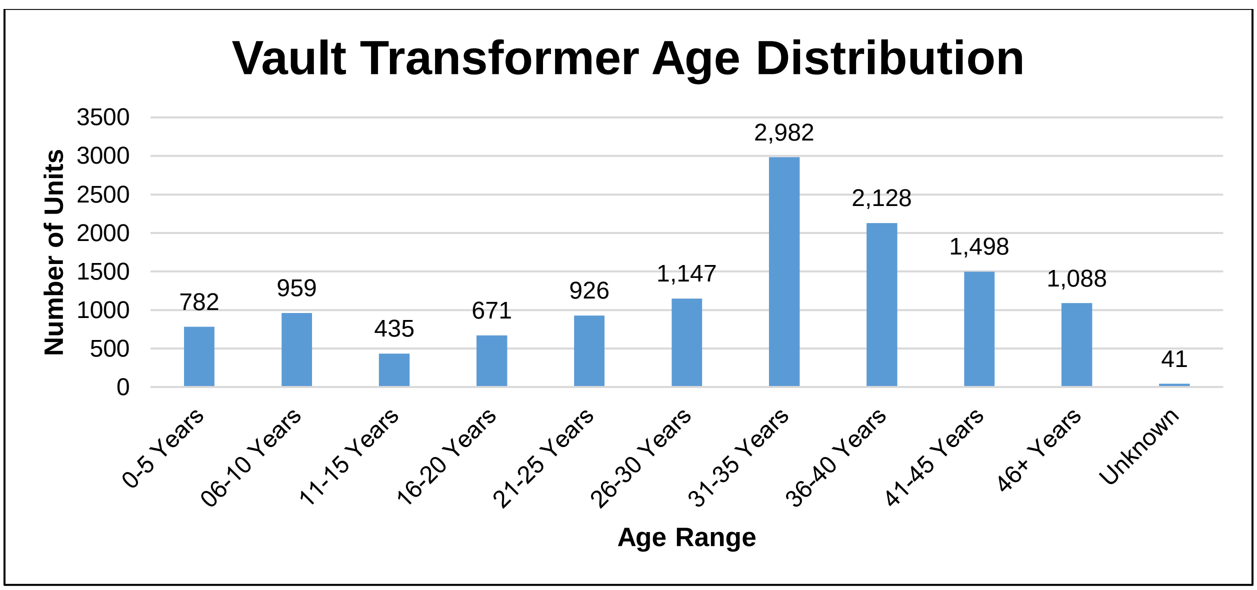


*Figure 10 Vault Transformer Age Distribution for 2022*

Vault transformers have a TUL of 35 years and are deemed to have reached EUL at 45 years of age.

### 5.1.4 Health Index Formula and Results

Health index of distribution transformers assesses the condition according to three components: Corrosion, Oil leak, and Age. Severity of corrosion and oil leak are determined through inspections and are scored as a step score.

Age represents deterioration due to factors not captured by the other components of the model. The scoring method for age is described in *Section 2.1.2 Percentage Score*.

The Health Index is computed by adding the weighted inputs of corrosion, oil leak and age, as shown in Table 5.

*Table 5 Distribution Transformer Health Index Parameters and Weights*

| # | Input | Input Weight for Pad-mounted Transformer | Input Weight for Pole-mounted Transformer | Input Weight for Vault Transformer | Scoring Method |
|---|---|---|---|---|---|
| 1 | Corrosion | 44% | 35% | 25% | Step Score |
| 2 | Oil Leak | 44% | 35% | 61% | Step Score |
| 3 | Age | 12% | 30% | 14% | Percentage Score |

**Field Inspection Multiplier**

If a distribution transformer exhibits major degradation or imminent failure, as determined by field inspection, it is considered to be of very poor health. The physical conditions considered in this criterion are major corrosion or major oil leak.

$$Field\ inspection\ multiplier = 25\%$$

Figure 11 shows the distribution of Health Index values of pad-mounted transformers, classified from Very Poor to Very Good. The average DAI is 87.6%.

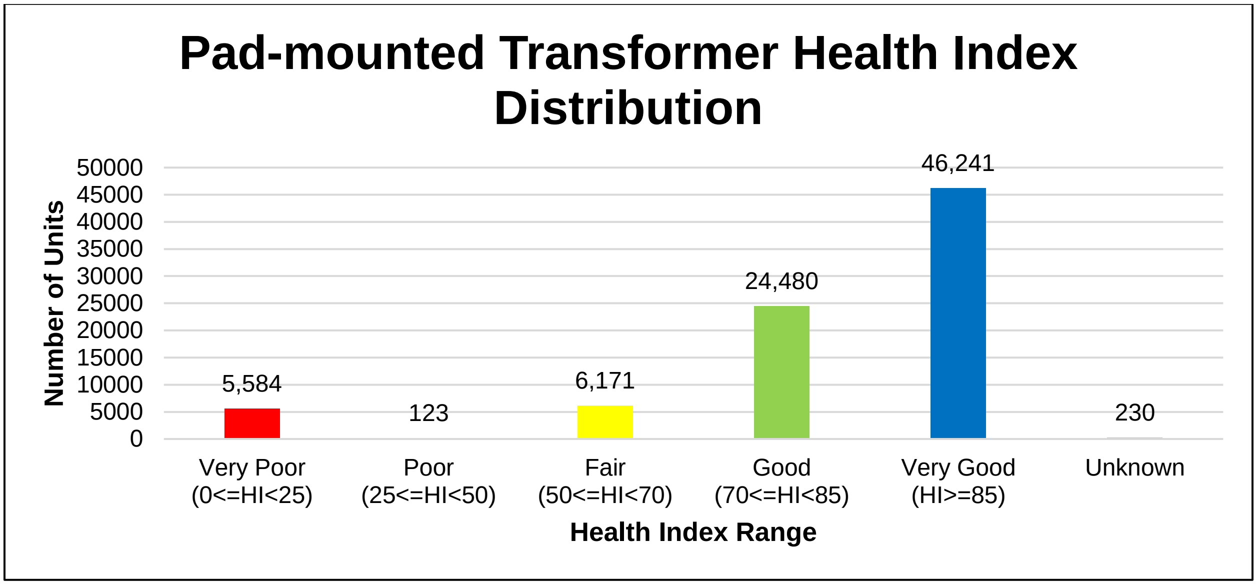


*Figure 11 Pad-mounted Transformer Health Index Distribution for 2022*

Figure 12 shows the distribution of Health Index values for pole-mounted transformers, classified from Very Poor to Very Good. The average DAI is 81.8%.

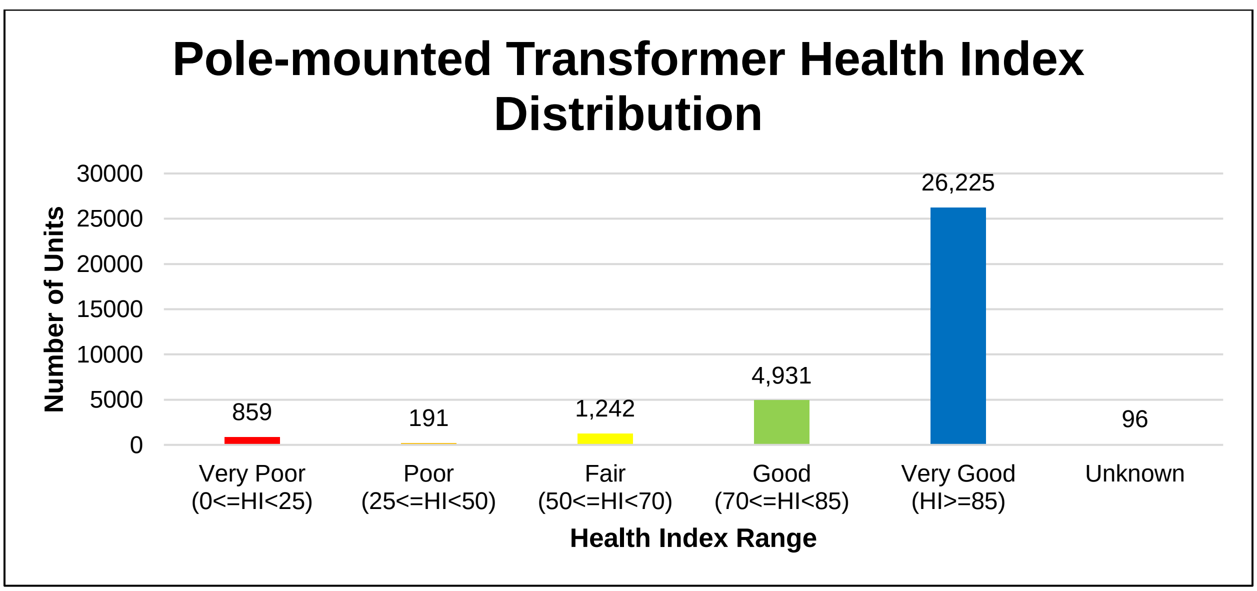


*Figure 12 Pole-mounted Transformer Health Index Distribution for 2022*

Figure 13 shows the distribution of Health Index values of vault transformers, classified from Very Poor to Very Good. The average DAI is 61.9%.

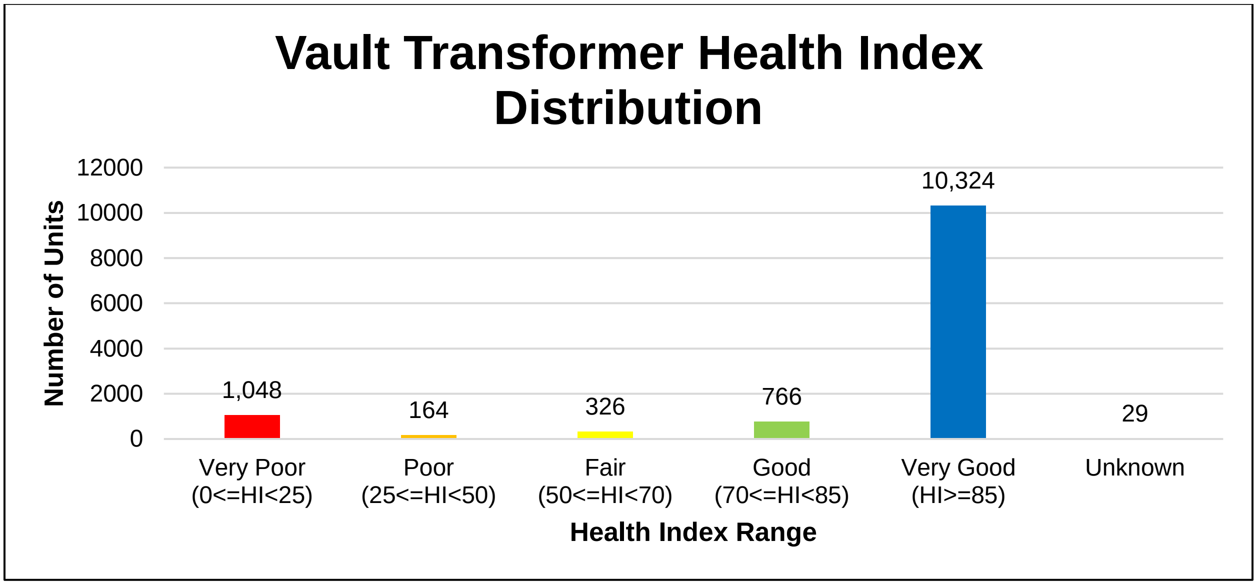


*Figure 13 Vault Transformer Health Index Distribution for 2022*

### 5.1.5 Sustainment Pacing

The total quantity of all distribution transformers in the Very Poor and Poor categories presented in Figure 11, Figure 12, and Figure 13 is 7,969 units.

Table 6 shows the pacing scenarios, namely, Baseline, Moderate, or Slow, that correspond to sustainment quantities over 5, 7.5, and 10-year intervals, respectively.

*Table 6 Distribution Transformer Pacing Scenarios*

| Pace | Description | Quantity per year |
|---|---|---|
| Baseline | Sustainment strategy targeting Very Poor & Poor assets over the **short-term** | $\frac{(Very\ Poor + Poor)}{5\ years} = 1594\ units$ |
| Moderate | Sustainment strategy targeting Very Poor & Poor assets over the **medium-term** | $\frac{(Very\ Poor + Poor)}{7.5\ years} = 1063\ units$ |
| Slow | Sustainment strategy targeting Very Poor & Poor assets over the **long-term** | $\frac{(Very\ Poor + Poor)}{10\ years} = 797\ units$ |

## 5.2 Distribution Switchgear

### 5.2.1 Summary of Asset Class

Pad-mounted switchgear units are used in the underground distribution system to facilitate the connection of local distribution circuits from main-line underground feeder cable systems, as well as to interconnect main-line feeder circuits. Switchgear provides fused connection points for residential subdivisions and commercial/industrial customers. Switchgear units are used for isolating, sectionalizing, fusing for laterals, and reconfiguring cable loops for maintenance, restoration, and other operating requirements. A single switchgear can impact as many as 5,000 customers.

### 5.2.2 Asset Degradation

Switchgear aging and eventual end of life are often established by mechanical failures, such as rusting of the enclosures or ingress of moisture and dirt into the switchgear, causing corrosion of operating mechanism and degradation of insulation.

To extend the life of these assets and to minimize in-service failures, a number of strategies are employed on a regular basis, including inspection with thermographic analysis and cleaning with $CO_2$ for air insulated pad-mounted switchgear.

Failures of switchgear are most often not directly related to the age of the equipment but are associated instead with outside influences. For example, pad-mounted switchgear is most likely to fail due to dirt/contamination, vehicle accidents, rusting of the enclosure, rodents, and broken insulators caused by misalignment during switching. Failures caused by fuse malfunctions can result in a catastrophic switchgear failure.

Automated switchgear has the same construction as pad-mounted switchgear, but with the addition of motorized remote switch controls. Automated switchgear has the same degradation mechanism as pad-mounted switchgear. In addition, failure of motor and/or its control may contribute to the end of life of the switchgear.

### 5.2.3 Asset Class Demographics

Alectra’s distribution system has 3,607 pad-mounted switchgear, with varying insulation types, namely, air, solid dielectric, $SF_6$, and oil. According to industry averages, pad-mounted switchgear has a Typical Useful Life (TUL) of 30 years and are deemed to have reached End of Useful Life (EUL) at 45 years of age.

Air-insulted switchgear operating on the 27.6 kV system have different life characteristics. Based on Alectra's and industry experience, the TUL for these units is 20 years and EUL is 35 years of age.

Figure 14 shows the age demographics of all pad-mounted switchgear in Alectra's distribution system.

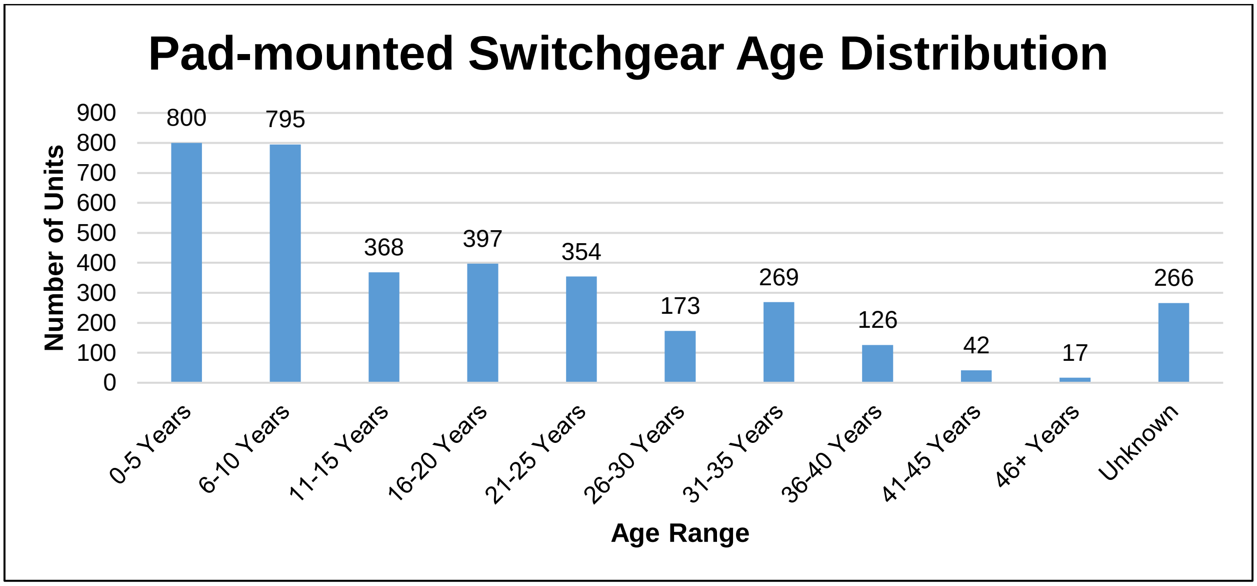


*Figure 14 Pad-mounted Switchgear Age Distribution for 2022*

### 5.2.4 Health Index Formula and Results

Health Index of pad-mounted switchgear assesses the condition according to five components: Corrosion, Component Failure, Insulation, Oil Leak (for oil types), and Age. Presence and magnitude of oil leaks (for oil insulated switchgear), and structural corrosion are quantified during field inspections and are scored as a step score.

Age represents deterioration due to factors not captured by the other components of the model. The scoring method for age is described in *Section 2.1.2 Percentage Score*.

The Health Index for Air, Solid Dielectric, and $SF_6$ type switchgear is computed by adding the weighted components of: Corrosion, Component Failure (such as signs of damage to mechanical springs, motors in motorized units, and fuse supports), Insulation, and Age, as shown in Table 7.

*Table 7 Pad-mounted Air, Solid Dielectric, and $SF_6$ Switchgear Health Index Parameters and Weights*

| # | Input | Input Weight (AIR, $SF_6$, SD) | Scoring Method |
|---|---|---|---|
| 1 | Corrosion | 21% | Step Score |
| 2 | Component Failure | 21% | Step Score |
| 3 | Insulation | 43% | Step Score |
| 4 | Age | 15% | Percentage Score |

The Health Index for Oil type switchgear is computed by adding the weighted components of: Corrosion, Component Failure (such as signs of damage to mechanical springs, motors in motorized units, and fuse supports), Insulation, Oil Leak, and Age, as shown in Table 8.

*Table 8 Pad-mounted Oil-type Switchgear Health Index Parameters and Weights*

| # | Input | Input Weight (OIL) | Scoring Method |
|---|---|---|---|
| 1 | Corrosion | 15% | Step Score |
| 2 | Component Failure | 15% | Step Score |
| 3 | Insulation | 40% | Step Score |
| 4 | Oil Leak | 15% | Step Score |
| 5 | Age | 15% | Percentage Score |

### Field Inspection Multiplier

If a pad-mounted switchgear exhibits major degradation or imminent failure, as determined by field inspection, it is considered to be of very poor health. The physical conditions considered in this criterion are major corrosion, major oil leak, major component failure, and major insulation failure.

$$Field\ inspection\ multiplier = 25\%$$

### Accelerated Degradation Multiplier

Air-insulated switchgear are highly susceptible to flashover due to contamination from dust particles that breach the enclosure. Their continuous nominal operating voltage rating is 25 kV with a maximum operating rating of 29.2 kV. These units function relatively well when new; however, during their normal duty, they are exposed to multiple voltage stresses that reduce their insulating performance, particularly when installed on the 27.6 kV distribution system. The 25 kV nominal voltage rating has been an inherent flaw in the equipment since it was first introduced to the Ontario market. This lower nominal voltage contributes to the reduced life of the switchgear and reduces the ability of the switchgear to perform under abnormal conditions, leading to premature failures.

$$Aceelerated\ degradation\ multiplier = 50\%$$

Figure 15 shows the distribution of Health Index values of pad-mounted switchgear, classified from Very Poor to Very Good. The average DAI is 64.5%.

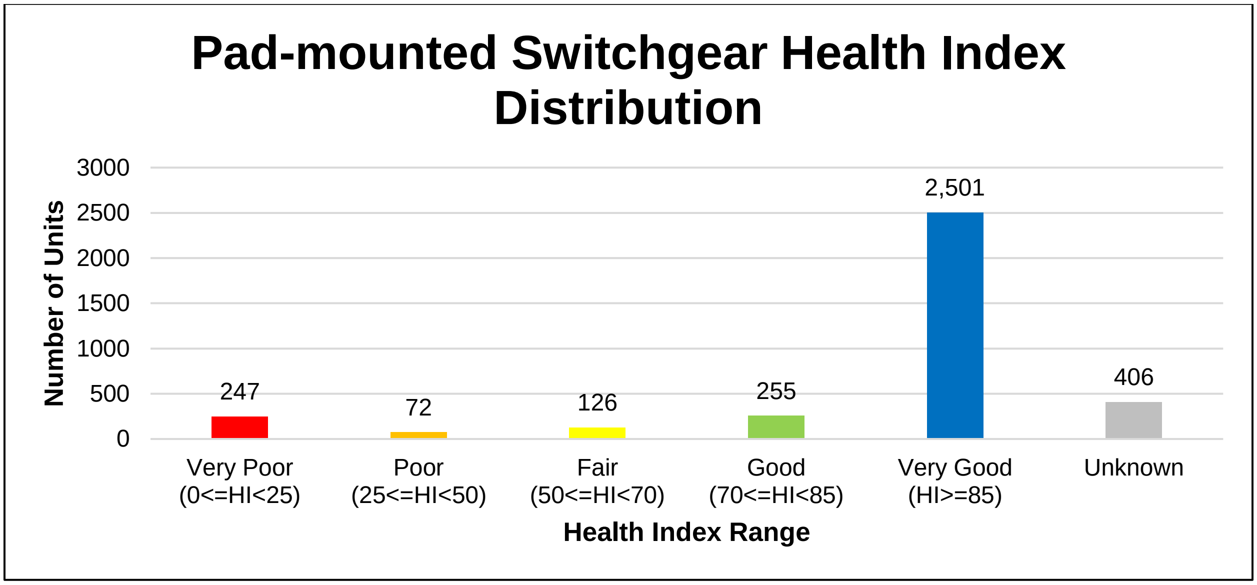


*Figure 15 Pad-mounted Switchgear Health Index Distribution for 2022*

### 5.2.5 Sustainment Pacing

The total quantity of all pad-mounted switchgear in the Very Poor and Poor categories is 319 units.

Table 9 shows the pacing scenarios, namely, Baseline, Moderate, or Slow, that correspond to sustainment quantities over 5, 7.5, and 10-year intervals, respectively.

*Table 9 Pad-mounted Switchgear Pacing Scenarios*

| Pace | Description | Quantity per year |
|---|---|---|
| Baseline | Sustainment strategy targeting Very Poor & Poor assets over the **short-term** | $\frac{(Very\ Poor + Poor)}{5\ years} = 64\ units$ |
| Moderate | Sustainment strategy targeting Very Poor & Poor assets over the **medium-term** | $\frac{(Very\ Poor + Poor)}{7.5\ years} = 43\ units$ |
| Slow | Sustainment strategy targeting Very Poor & Poor assets over the **long-term** | $\frac{(Very\ Poor + Poor)}{10\ years} = 32\ units$ |

## 5.3 Overhead Switches

### 5.3.1 Summary of Asset Class

The primary function of overhead switches is to facilitate transfer of loads between feeders and to allow isolation of line sections or equipment for maintenance, safety, or other operating requirements. This class of switch is also known as a Load-Break Disconnect Switch (LBDS), or a Load Interrupting Switch (LIS), and can break load current.

### 5.3.2 Asset Degradation

The main degradation processes associated with switches include:

- Corrosion of steel hardware or operating rod
- Mechanical deterioration of linkages
- Switch blades falling out of alignment, which may result in excessive arcing during operation
- Loose connections
- Damaged insulators

The rate and severity of these degradation processes depend on several inter-related factors, including the operating duties and the environment in which the equipment is installed. In most cases, corrosion or rust represents a critical degradation process.

Consequences of overhead line switch failure may include customer interruption and safety concerns for operators.

### 5.3.3 Asset Class Demographics

Alectra's distribution system has 3,444 overhead switches. According to industry averages, overhead switches have a Typical Useful Life (TUL) of 40 years and are deemed to have reached End of Useful Life (EUL) at 55 years of age.

Figure 16 shows the age demographics of overhead switches in Alectra's distribution system.

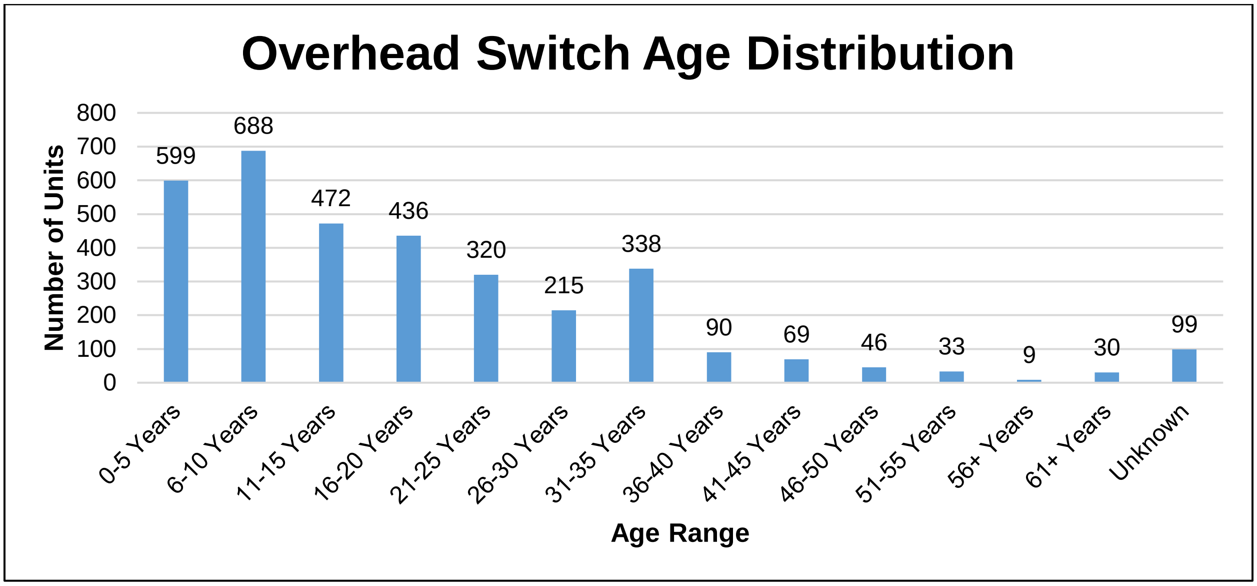


*Figure 16 Overhead Switch Age Distribution for 2022*

### 5.3.4 Health Index Formula and Results

Health index of overhead switches assesses the condition according to two components: Age and Field Inspection. Age represents a proxy measure for switch deterioration over time. Field Inspection is assessed to determine the degree of degradation due to environmental and operational factors. Health Index is computed as a function of Age (i.e., percentage score) and Field Inspection (i.e., step score), as shown in Table 10.

*Table 10 Overhead Switch Health Index Parameters and Weights*

| Input | Input Weight | Scoring Method |
|---|---|---|
| Age | 31% | Percentage Score |
| Field Inspection | 69% | Step Score |

Age represents deterioration due to factors not captured by the other components of the model. The scoring method for age is described in *Section 2.1.2 Percentage Score*.

Figure 17 shows the distribution of Health Index values of overhead switches, classified from Very Poor to Very Good. The average DAI is 59.6%.

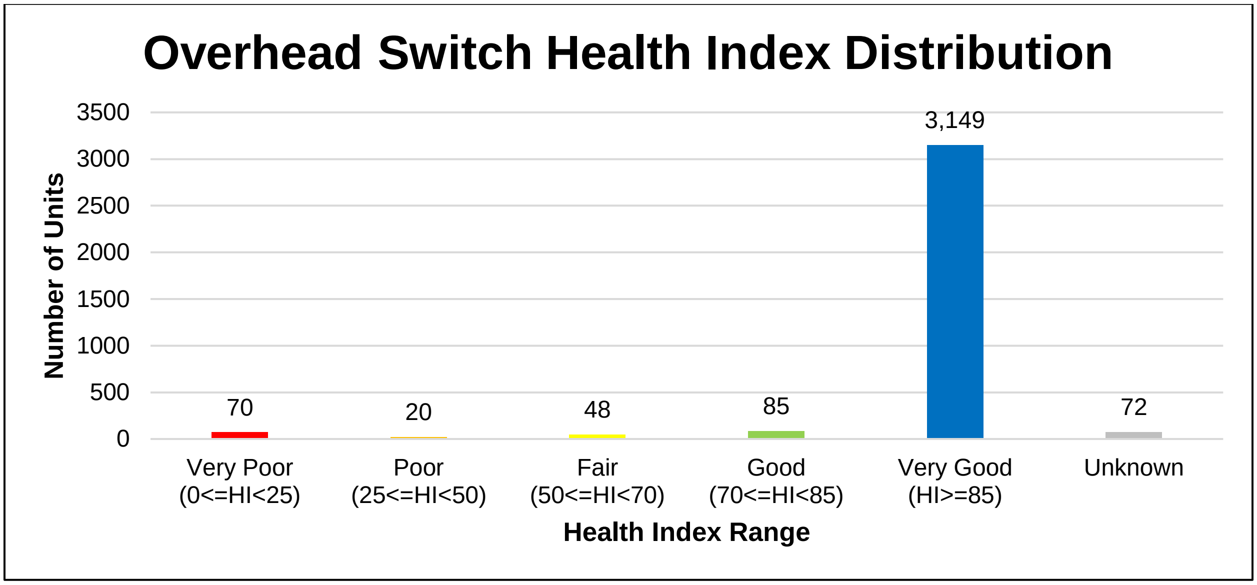


*Figure 17 Overhead Switch Health Index Distribution for 2022*

### 5.3.5 Sustainment Pacing

The total quantity of overhead switches in the Very Poor and Poor categories is 90 units.

Table 11 shows the pacing scenarios, namely, Baseline, Moderate, or Slow, that correspond to sustainment quantities over 5, 7.5, and 10-year intervals, respectively.

*Table 11 Overhead Switch Pacing Scenarios*

| Pace | Description | Quantity per year |
|---|---|---|
| Baseline | Sustainment strategy targeting Very Poor & Poor assets over the **short-term** | $\frac{(Very\ Poor + Poor)}{5\ years} = 18\ units$ |
| Moderate | Sustainment strategy targeting Very Poor & Poor assets over the **medium-term** | $\frac{(Very\ Poor + Poor)}{7.5\ years} = 12\ units$ |
| Slow | Sustainment strategy targeting Very Poor & Poor assets over the **long-term** | $\frac{(Very\ Poor + Poor)}{10\ years} = 9\ units$ |

## 5.4 Overhead Conductors

### 5.4.1 Summary of Asset Class

Electrical current flows through distribution line conductors, facilitating the movement of power throughout the distribution system. These conductors are supported by metal, wood, or concrete structures to which they are attached by insulator strings selected based on operating voltage. The conductors are sized for the maximum amount of current to be carried, as well as other design requirements. Conductors hold mechanical tension in conjunction with electrical properties that facilitate flow of electricity.

### 5.4.2 Asset Degradation

The flow of electrical current causes the conductors' temperature to increase. As a result, the conductors expand. Fluctuations of current flow cause the conductors to expand and contract in a cyclical manner, which contributes to conductor deterioration over time. Mechanical processes, such as fatigue, creep, and corrosion, are accelerated by the expansion and contraction. The rate of degradation depends on several factors, including the size of conductor, metal/alloy component(s) of the conductor, type of conductor (e.g., solid or stranded), ambient temperature, the flow of current, the variation in the flow of current, and ambient temperature.

Overloading conductors accelerates the deterioration process and can cause serious safety concerns, as well as excessive fault currents. Conductor failure is a safety hazard to the public and can cause significant power interruptions.

### 5.4.3 Asset Class Demographics

Alectra's distribution system has 18,467 km of overhead conductors with various sizes and ages. According to industry averages, an overhead conductor has a Typical Useful Life (TUL) of 60 years and is deemed to have reached End of Useful Life (EUL) at 75 years of age.

Figure 18 shows the age demographics of overhead conductors in Alectra's distribution system.

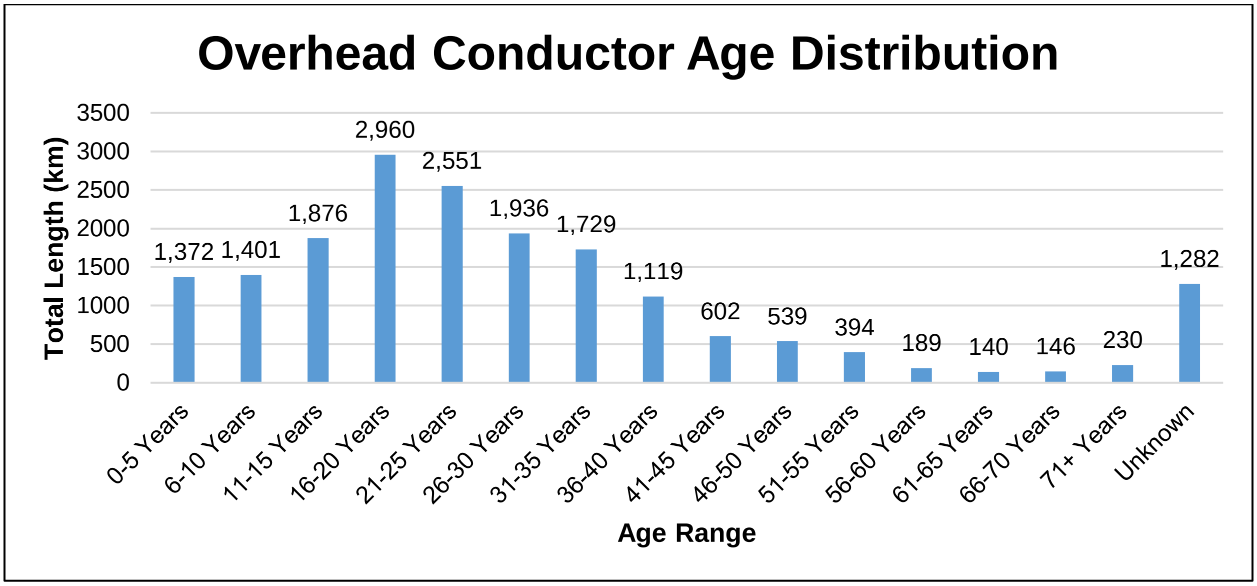


*Figure 18 Overhead Conductor Age Distribution for 2022*

### 5.4.4 Health Index Formula and Results

Health Index of overhead conductors assesses the condition based on Age (i.e., percentage score), as shown in Table 12.

*Table 12 Overhead Conductor Health Index Parameters and Weights*

| Input | Input Weight | Scoring Method |
|---|---|---|
| Age | 100% | Percentage Score |

Age represents a proxy measure for conductor deterioration over time due to environmental and operational factors. The scoring method for age is described in *Section 2.1.2 Percentage Score.*

**Restricted Conductors Multiplier**

Certain conductors fall below the acceptable size for the safe and reliable operation of the system. Any conductor below wire AWG (American Wire Gauge) size #6 is considered restricted and undersized according to current utility practices. Such conductors represent a major safety risk.

$$Restricted\ conductor\ multiplier = 25\%$$

Figure 19 shows the distribution of Health Index values of overhead conductors, classified from Very Poor to Very Good. The average DAI is 93%.

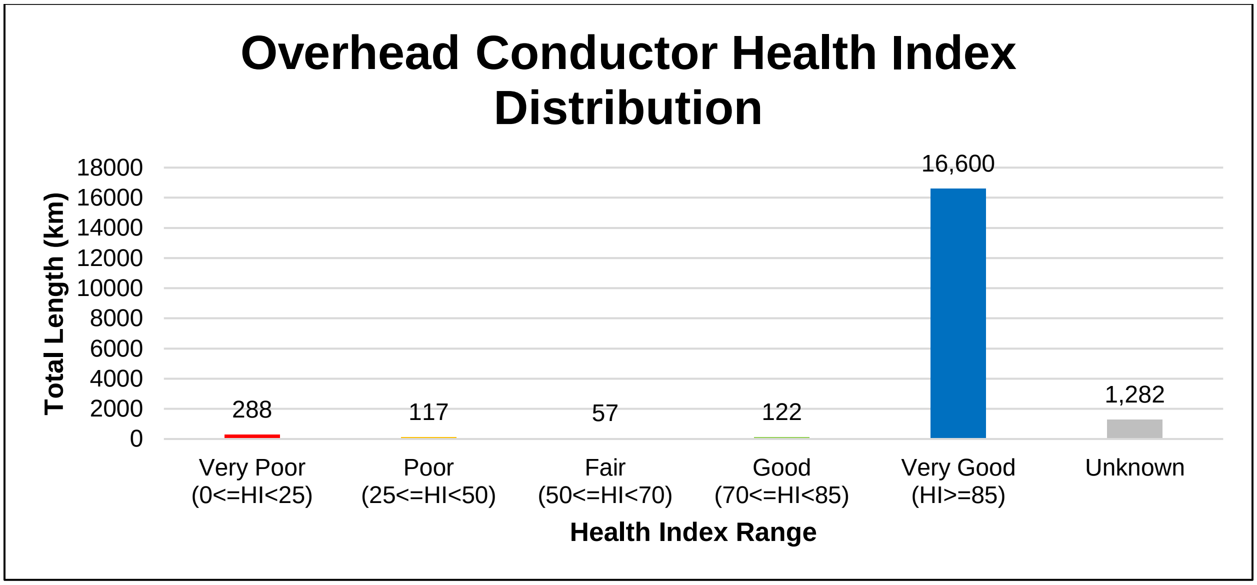


*Figure 19 Overhead Conductor Health Index Distribution for 2022*

### 5.4.5 Sustainment Pacing

The total quantity of overhead conductors in the Very Poor and Poor categories is 405 kilometers.

Table 13 shows the pacing scenarios, namely, Baseline, Moderate, or Slow, that correspond to sustainment quantities over 5, 7.5, and 10-year intervals, respectively.

*Table 13 Overhead Conductor Pacing Scenarios*

| Pace | Description | Quantity per year |
|---|---|---|
| Baseline | Sustainment strategy targeting Very Poor & Poor assets over the **short-term** | $\frac{(Very\ Poor + Poor)}{5\ years} = 81\ km$ |
| Moderate | Sustainment strategy targeting Very Poor & Poor assets over the **medium-term** | $\frac{(Very\ Poor + Poor)}{7.5\ years} = 54\ km$ |
| Slow | Sustainment strategy targeting Very Poor & Poor assets over the **long-term** | $\frac{(Very\ Poor + Poor)}{10\ years} = 41\ km$ |

## 5.5 Wood Poles

### 5.5.1 Summary of Asset Class

Wood poles support overhead primary and secondary distribution lines. Any deterioration in structural strength of poles impacts the safe and reliable operation of the distribution system. Poles are a critical component of the distribution system and support many assets including conductors, transformers, switches, streetlights, telecommunication attachments, and other items, as well as providing physical separation between ground level and energized conductors. As a pole's physical condition and structural strength deteriorate, the pole may become inadequate for its intended function, and should be replaced to maintain the integrity of the distribution system and to protect public safety. A regular field inspection is conducted on wood poles to assess their condition. In addition to the field inspection, a remaining strength measurement is conducted using third party testing to provide evidence-based measurement that reflects the integrity of the pole. The wood species commonly used for distribution wood poles include Red Pine, Jack Pine, and Western Red Cedar (WRC).

### 5.5.2 Asset Degradation

Since wood is a natural material, the degradation processes are different from those which affect other physical assets on electricity distribution systems. The degradation processes result in decay of the wood fibers, thus reducing the structural strength of the pole. The nature and severity of the degradation depends both on the type of wood, treatment preservatives, and the environment.

As a structural asset, assessing the condition of a wood pole is based on measuring the remaining structural strength and inspecting for signs of deterioration, such as cracks. Field inspection checks for indicators of decay, such as hollowing, pole top feathering, structural cracks, and other field indications of degradation. Pole residual strength testing is a test performed by drilling a small probe through the pole to measure quantitatively the remaining structural strength of the wood fibers.

Consequences of a pole failure are quite serious. Poles with reduced strength present a significant risk to the public, Alectra staff, and contractors, and also have reliability impacts to the distribution system. The combination of severe weather, along with reduced strength, can lead to end-of-life failure scenarios where multiple poles lose their structural integrity and fail, possibly falling to the ground. The risk is mitigated through the regular inspection and field-testing to identify candidates for replacement prior to their failure.

### 5.5.3 Asset Class Demographics

Alectra's distribution system has 104,771 wood poles. According to industry averages, a wood pole has a Typical Useful Life (TUL) of 45 years and is deemed to have reached End of Useful Life (EUL) at 75 years of age. Figure 20 shows the age demographics of wood poles in Alectra's distribution system.

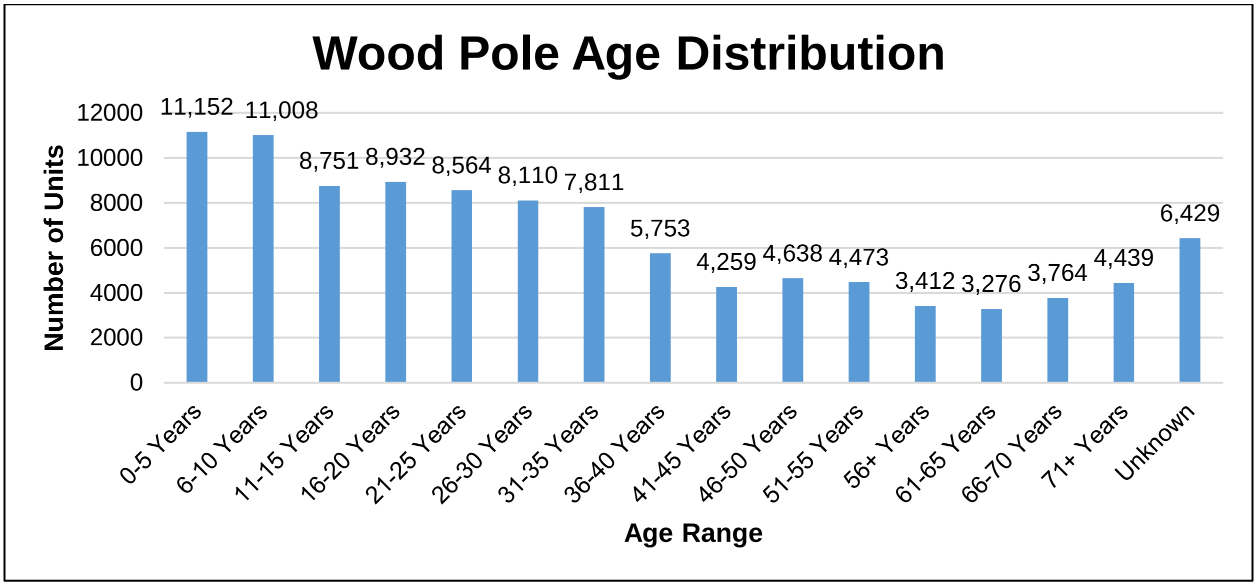


*Figure 20 Wood Pole Age Distribution for 2022*

### 5.5.4 Health Index Formula and Results

Health Index of poles assesses the condition of the pole according to three components: Pole Remaining Strength, Overall Condition, and Age. Pole Remaining Strength is a vital component to the Health Index of wood poles and is a specialized test that is performed by a third party. Remaining strength measurement is an evidence-based measurement of physical condition and it is scored using percentage scoring.

Overall Condition is captured during the field inspection cycle of the wood poles and includes, but is not limited to, signs of mechanical damage, cracks, and feathering. Overall Condition of a wood pole is scored using step scoring.

Age represents deterioration due to other factors not captured by the other components of the model. The scoring method for age is described in *Section 2.1.2 Percentage Score*.

The Health Index is computed by adding the weighted inputs of Pole Remaining Strength, Overall Condition, and Age, as shown in Table 14.

*Table 14 Wood Pole Health Index Parameters and Weights*

| # | Input | Input Weight | Scoring Method |
|---|---|---|---|
| 1 | Pole Strength | 49% | Percentage Score |
| 2 | Overall Condition (Field Inspection) | 36% | Step Score |
| 3 | Age | 15% | Percentage Score |

**Pole Residual Strength Multiplier**

If a wood pole is measured to have 60% or less in remaining strength, it is considered to be of very poor health.

The Canadian Safety Association (CSA) defines the standards for overhead distribution system construction and the use of wood poles. Among other factors, Alectra is guided in its pole assessment process by Clause 8.3.1.3 of CSA Standard C22.3 No. 1-10, which states that:

> *"when the strength of a structure has deteriorated to 60% of the required capacity, the structure shall be reinforced or replaced".*

$$Pole\ residual\ multiplier = 25\%$$

**Field Inspection Multiplier**

A score of 20% or less on Overall Condition based on field inspection is an indication that a wood pole is exhibiting major degradation or failure is imminent and is of very poor health. The physical conditions considered in this criterion are major rotting, decay, splitting, insect infestation, bending and leaning.

$$Field\ inspection\ multiplier = 25\%$$

Figure 21 shows the distribution of Health Index values of wood poles, classified from Very Poor to Very Good. The average DAI is 59.3%.

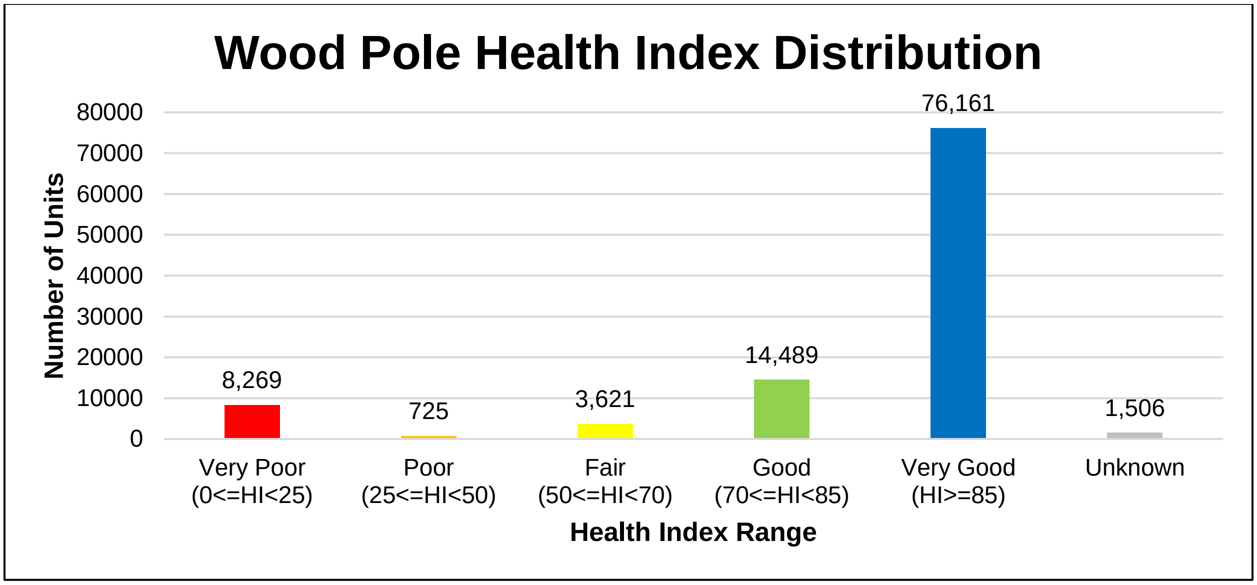


*Figure 21 Wood Pole Health Index Distribution for 2022*

### 5.5.5 Sustainment Pacing

The total quantity of wood poles in the Very Poor and Poor categories is 8,994.

Table 15 shows the pacing scenarios, namely, Baseline, Moderate, or Slow, that correspond to sustainment quantities over 5, 7.5, and 10-year intervals, respectively.

*Table 15 Wood Pole Pacing Scenarios*

| Pace | Description | Quantity per year |
|---|---|---|
| Baseline | Sustainment strategy targeting Very Poor & Poor assets over the **short-term** | $\frac{(Very\ Poor + Poor)}{5\ years} = 1{,}799\ poles$ |
| Moderate | Sustainment strategy targeting Very Poor & Poor assets over the **medium-term** | $\frac{(Very\ Poor + Poor)}{7.5\ years} = 1{,}199\ poles$ |
| Slow | Sustainment strategy targeting Very Poor & Poor assets over the **long-term** | $\frac{(Very\ Poor + Poor)}{10\ years} = 899\ poles$ |

## 5.6 Concrete Poles

### 5.6.1 Summary of Asset Class

Concrete poles support primary and secondary distribution lines. Any deterioration in structural strength of poles impacts the safe and reliable operation of the distribution system. Poles are a critical component of the distribution system and support many appurtenances, including conductors, transformers, switches, streetlights, telecommunication attachments and other items. Poles also provide physical separation between ground level and energized conductors. As a pole's physical condition and structural strength deteriorate, the pole may become inadequate for its intended function, and should be replaced to maintain the integrity of the distribution system and to protect public safety. A regular field inspection is conducted on concrete poles to assess their condition.

In some cases, concrete poles can be rehabilitated from mechanical damage, such as that caused by snowplows or other vehicular accidents, or by deterioration over time. Each case requires a specialized assessment by a subject matter expert to recommend the appropriate intervention.

### 5.6.2 Asset Degradation

Concrete poles age in the same manner as any other concrete structure. Any moisture ingress inside the concrete pores results in freezing during the winter and damage to the concrete surface. Road salt spray can further accelerate the degradation process and lead to concrete spalling (piece of concrete flaking off the pole). Cracks develop over time from stretching or bending forces. These cracks propagate over time, resulting in structural cracks and spalling of the concrete.

Concrete poles contain metal rebar for reinforcement, water ingress and contaminants lead to corrosion of the rebar, thus reducing the structural integrity of the concrete pole. Rebar corrosion can lead to the accelerated deterioration, resulting in a reduced lifespan of a concrete pole.

Consequences of a pole failure are quite serious. Poles with reduced strength present a significant risk to the public, Alectra staff, and contractors, and also have reliability impacts to the distribution system. The combination of severe weather, along with reduced strength, can lead to end-of-life failure scenarios where multiple poles lose their structural integrity and fail, possibly falling to the ground. The risk is mitigated through the regular inspection and field-testing to identify candidates for replacement prior to their failure.

### 5.6.3 Asset Class Demographics

Alectra's distribution system has 28,479 concrete poles. According to industry averages, concrete pole has a Typical Useful Life (TUL) of 60 years and is deemed to have reached End of Useful Life (EUL) at 80 years of age. Figure 22 shows the age demographics of concrete poles in Alectra's distribution system.

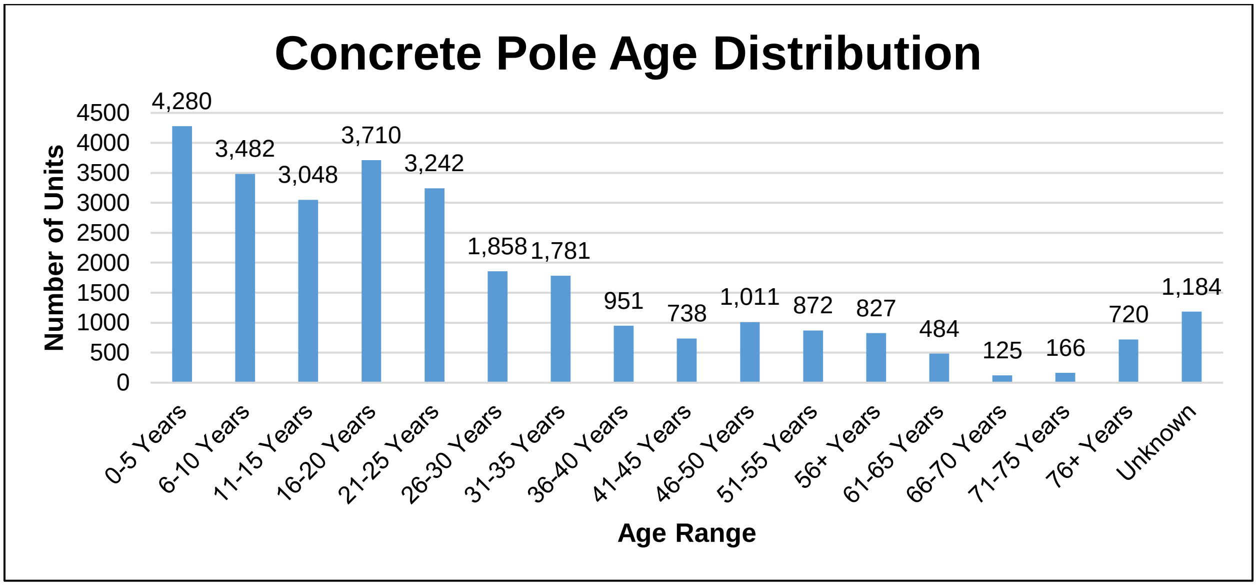


*Figure 22 Concrete Pole Age Distribution for 2022*

### 5.6.4 Health Index Formula and Results

Health Index of poles assesses the condition of the pole according to two inputs: Overall Condition and Age.

Overall Condition is captured during the field inspection cycle of the concrete poles and includes, but is not limited to, signs of mechanical damage and cracks. Age represents deterioration due to factors not captured by the other inputs of the model. The scoring method for age is described in *Section 2.1.2 Percentage Score.*

The Health Index is computed by adding the weighted inputs of Overall Condition from field inspection and Age, as shown in Table 16.

*Table 16 Concrete Pole Health Index Parameters and Weights*

| # | Input | Input Weight | Scoring Method |
|---|---|---|---|
| 1 | Overall Condition (Field Inspection) | 69% | Step Score |
| 2 | Age | 31% | Percentage Score |

### Field Inspection Multiplier

If a concrete pole exhibits major degradation or imminent failure as determined by field inspection, it is considered to be of very poor health. The physical conditions considered in this criterion are major cracking, exposed rebar, or rusted rebar.

$$Field\ inspection\ multiplier = 25\%$$

Figure 23 shows the distribution of Health Index values of concrete poles, classified from Very Poor to Very Good. The average DAI is 81.3%.

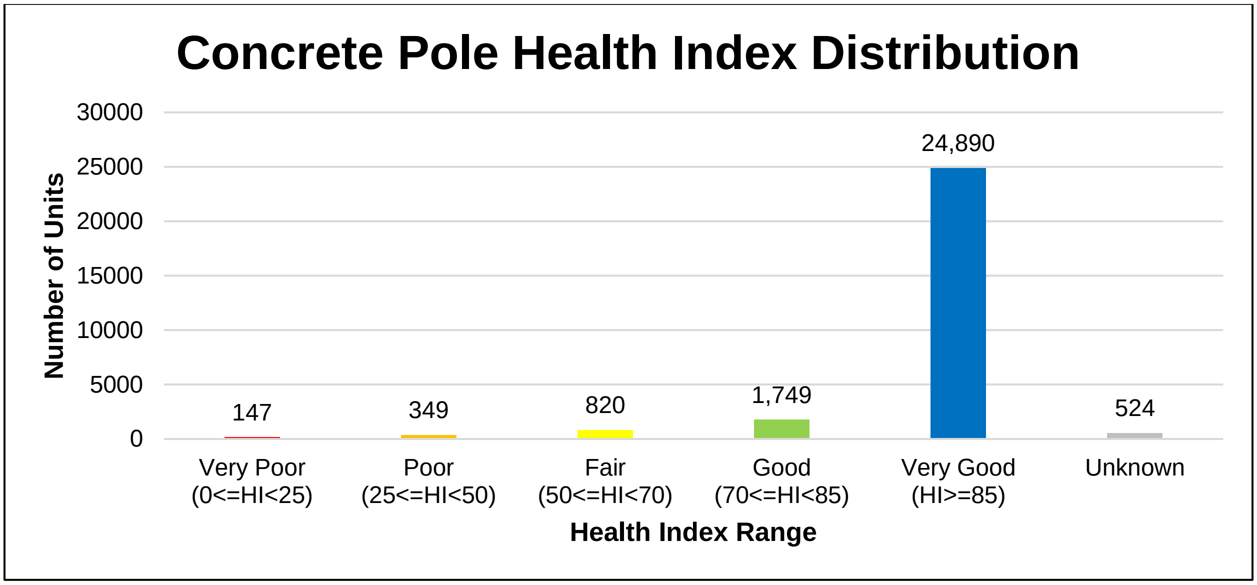


*Figure 23 Concrete Pole Health Index Distribution for 2022*

### 5.6.5 Sustainment Pacing

The total quantity of concrete poles in the Very Poor and Poor categories is 496.

Table 17 shows the pacing scenarios, namely, Baseline, Moderate, or Slow, that correspond to sustainment quantities over 5, 7.5, and 10-year intervals, respectively.

*Table 17 Concrete Pole Pacing Scenarios*

| Pace | Description | Quantity per year |
|---|---|---|
| Baseline | Sustainment strategy targeting Very Poor & Poor assets over the **short-term** | $\frac{(Very\ Poor + Poor)}{5\ years} = 99\ poles$ |
| Moderate | Sustainment strategy targeting Very Poor & Poor assets over the **medium-term** | $\frac{(Very\ Poor + Poor)}{7.5\ years} = 66\ poles$ |
| Slow | Sustainment strategy targeting Very Poor & Poor assets over the **long-term** | $\frac{(Very\ Poor + Poor)}{10\ years} = 50\ poles$ |

## 5.7 Underground Primary Cables

Underground distribution cables are mainly used in urban areas where obstacles to pole line construction are encountered. These can include aesthetic, legal, political, and physical constraints.

### 5.7.1 Summary of Asset Class

The asset categories of distribution system underground cables include underground cross-link-polyethylene (XLPE) cables, paper insulated lead covered (PILC) cables, and ethylene-propylene rubber (EPR) cables, all at voltage levels of 44 kV or below. Included are direct-buried and installed-in-duct feeder cables, underground cable sections running from stations to overhead lines, and from overhead lines to customer stations and switches.

### 5.7.2 Asset Degradation

Faults on primary underground cables are usually caused by insulation failure within a localized area.

Polymeric insulation is very sensitive to discharge activity. It is therefore very important that the cable, joints, and accessories are discharge-free when installed. Older-vintage cables are susceptible to moisture ingress (i.e., water treeing), especially if installed direct buried, or with terminations and splices susceptible to insulation breakdown that can result in localized failures.

Manufacturing improvements and development of tree-retardant XLPE cables have reduced the rate of deterioration and insulation breakdown from water treeing.

For PILC cables, the two significant long-term degradation processes are corrosion of the lead sheath, and dielectric degradation of the oil-impregnated paper insulation. Isolated sites of corrosion resulting in moisture penetration or isolated sites of dielectric deterioration resulting in insulation breakdown can result in localized failures. However, if either of these conditions becomes widespread, there will be frequent cable failures, and the cable can be deemed to be at end-of-life.

For EPR cables, long term degradation can occur due to mechanical damage, overheating, or the impact of moisture ingress and chemical deterioration.

### 5.7.3 Cross-Linked Polyethylene (XLPE) Cables

#### *5.7.3.1 Asset Class Demographics*

Alectra's distribution system has 22,867 km of primary underground XLPE cable. XLPE cables are categorized by type, as described below. Each type has a different expected useful life, based on industry averages and Alectra's experience.

- **Non-Tree-Retardant cables (NON-TR)**:
  Vintage 1988 or older; TUL 30 years; EUL 40 years
- **Tree-Retardant Direct-Buried cables (TR-DB)**:
  Vintage 1989-1993; TUL 35 years; EUL 45 years
- **Tree-Retardant or Strand-Blocked In-Duct cables (TR-ID):**
  Vintage 1994 or newer; TUL 40 years; EUL 55 years

Figure 24 shows the age demographics of XLPE cables in Alectra's distribution system.

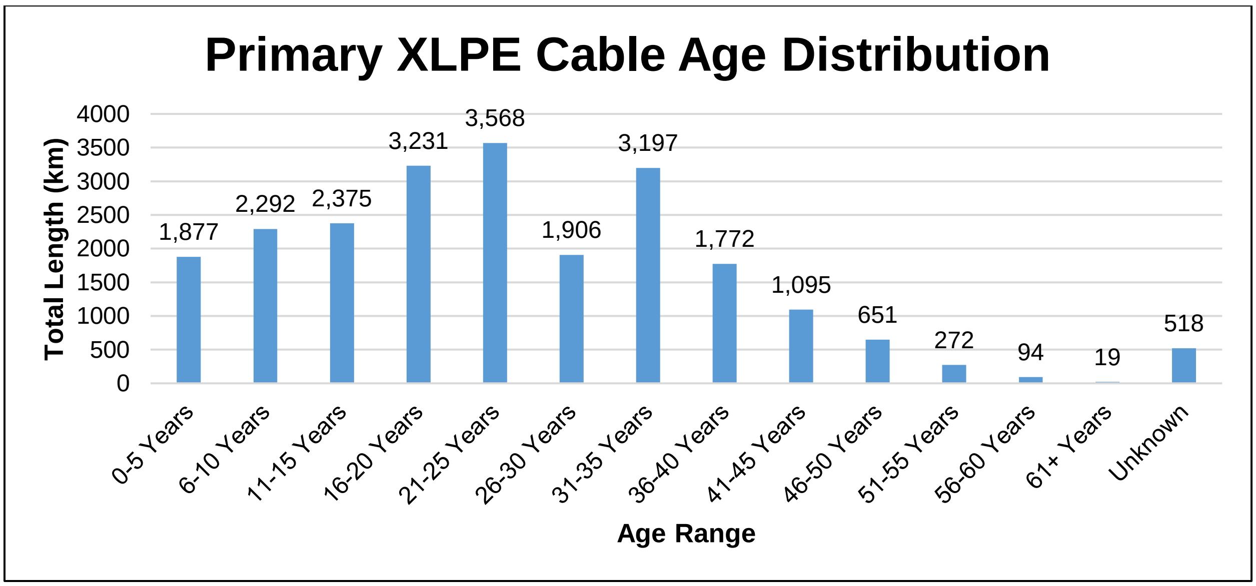


*Figure 24 Primary XLPE Cable Age Distribution for 2022*

#### *5.7.3.2 Health Index Formula and Results*

Health index of primary XLPE cables is calculated using Age. The scoring method for age is described in *Section 2.1.2 Percentage Score.*

Health index is scored according to the curves shown in Figure 25.

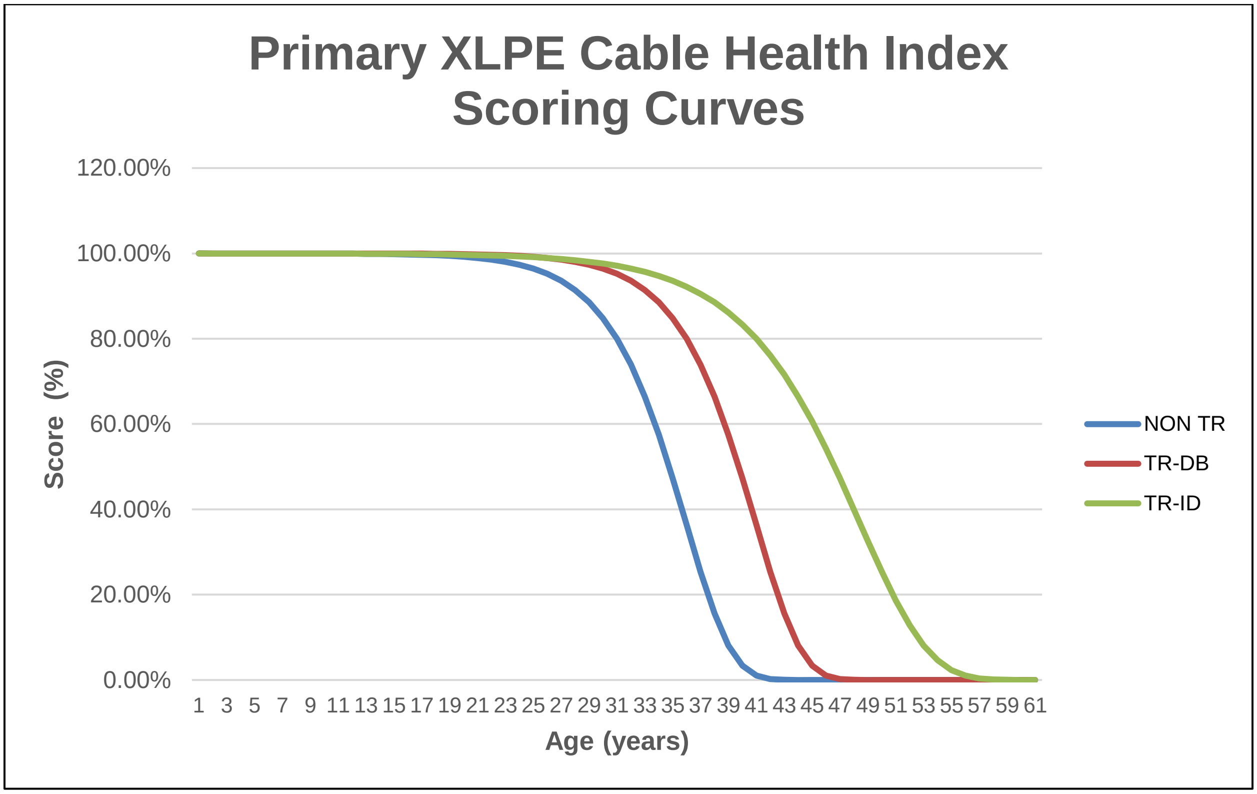


*Figure 25 Primary XLPE Cable Health Index as a function of age*

Health Index is computed as a function of age (i.e., percentage score), as shown in Table 18.

*Table 18 XLPE Cable Health Index Parameters and Weights*

| Input | Input Weight | Scoring Method |
|---|---|---|
| Age | 100% | Percentage Score |

Figure 26 shows the distribution of Health Index values of primary XLPE cables, classified from Very Poor to Very Good. The average DAI is 97%.

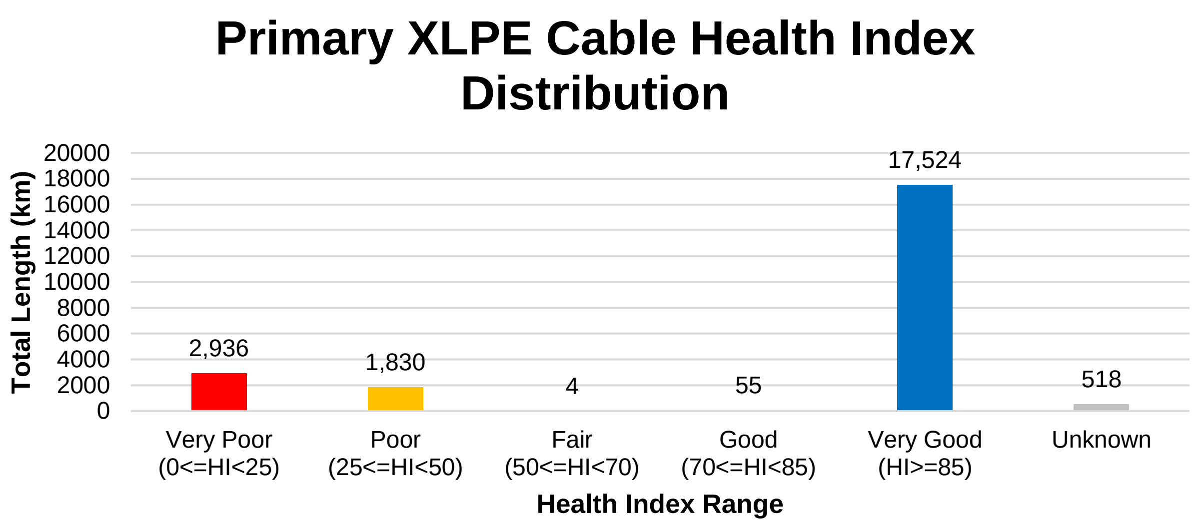


*Figure 26 Primary XLPE Cable Health Index Distribution for 2022*

### *5.7.3.3 Sustainment Pacing*

The total quantity of XLPE cables in the Very Poor and Poor categories is 4,766 km.

Table 19 shows the pacing scenarios, namely, Baseline, Moderate, or Slow, that correspond to sustainment quantities over 5, 7.5, and 10-year intervals, respectively.

*Table 19 XLPE Cable Pacing Scenarios*

| Pace | Description | Quantity per year |
|---|---|---|
| Baseline | Sustainment strategy targeting Very Poor & Poor assets over the **short-term** | $\frac{(Very\ Poor + Poor)}{5\ years} = 953\ km$ |
| Moderate | Sustainment strategy targeting Very Poor & Poor assets over the **medium-term** | $\frac{(Very\ Poor + Poor)}{7.5\ years} = 635\ km$ |
| Slow | Sustainment strategy targeting Very Poor & Poor assets over the **long-term** | $\frac{(Very\ Poor + Poor)}{10\ years} = 477\ km$ |

### 5.7.4 Paper Insulated Lead Covered (PILC) Cables

#### *5.7.4.1 Asset Class Demographics*

Alectra's distribution system has 478 km of primary underground PILC cable. According to industry averages, primary PILC cables have a Typical Useful Life (TUL) of 60 years and are deemed to have reached End of Useful Life (EUL) at 70 years of age. Figure 27 shows the age demographics of PILC cables in Alectra's distribution system.

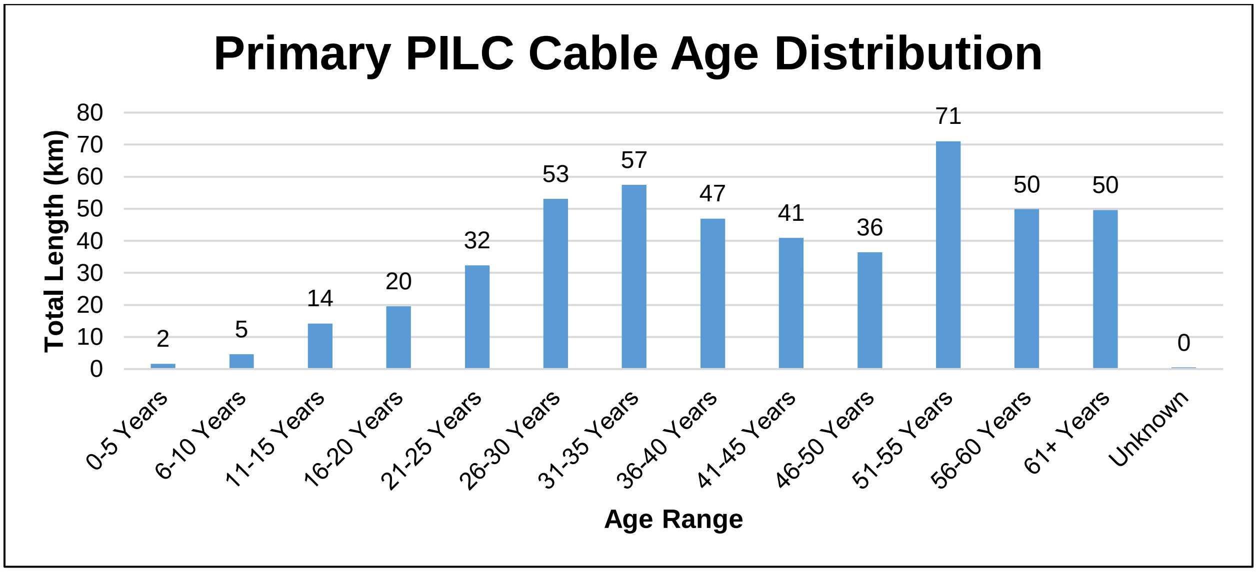


*Figure 27 Primary PILC Cable Age Distribution for 2022*

#### *5.7.4.2 Health Index Formula and Results*

Health index of Primary PILC cables is calculated using Age. The scoring method for age is described in *Section 2.1.2 Percentage Score.*

Health Index is computed as a function of age (i.e., percentage score), as shown in Table 20.

*Table 20 PILC Cable Health Index Parameters and Weights*

| Input | Input Weight | Scoring Method |
|---|---|---|
| Age | 100% | Percentage Score |

Figure 28 shows the distribution of Health Index values of primary PILC cables, classified from Very Poor to Very Good. The average DAI is 99%.

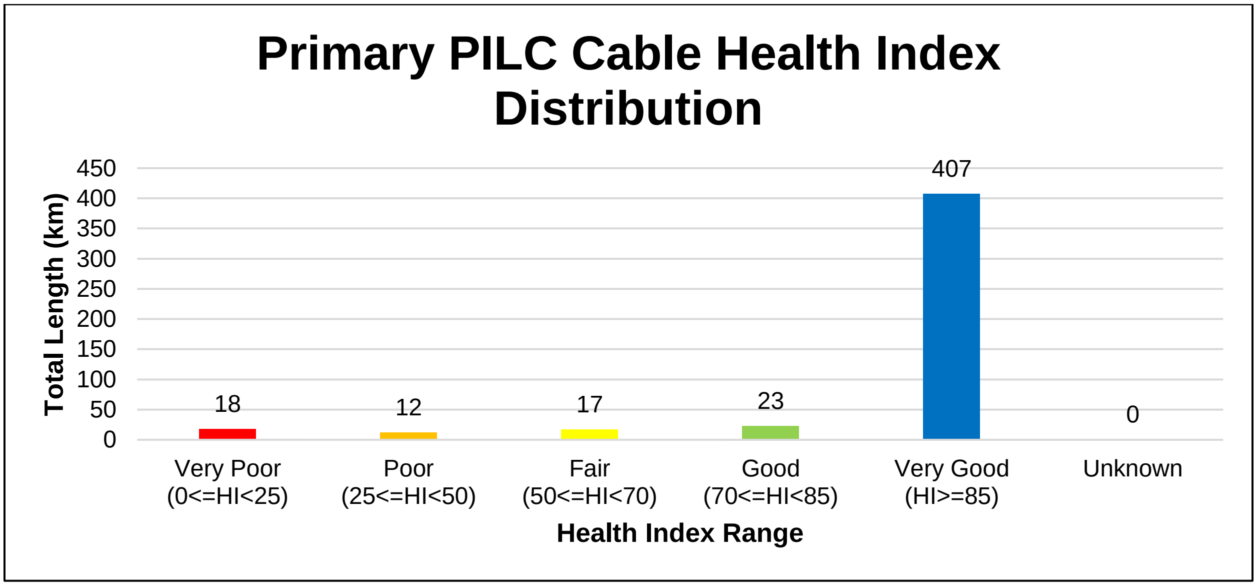


*Figure 28 Primary PILC Cable Health Index Distribution for 2022*

### *5.7.4.3 Sustainment Pacing*

The total quantity of PILC in the Very Poor and Poor categories is 30 km.

Table 21 shows the pacing scenarios, namely, Baseline, Moderate, or Slow, that correspond to sustainment quantities over 5, 7.5, and 10-year intervals, respectively.

*Table 21 PILC Cable Pacing Scenarios*

| Pace | Description | Quantity per year |
|---|---|---|
| Baseline | Sustainment strategy targeting Very Poor & Poor assets over the **short-term** | $\frac{(Very\ Poor + Poor)}{5\ years} = 6\ km$ |
| Moderate | Sustainment strategy targeting Very Poor & Poor assets over the **medium-term** | $\frac{(Very\ Poor + Poor)}{7.5\ years} = 4\ km$ |
| Slow | Sustainment strategy targeting Very Poor & Poor assets over the **long-term** | $\frac{(Very\ Poor + Poor)}{10\ years} = 3\ km$ |

### 5.7.5 Ethylene-Propylene Rubber (EPR) Cables

#### *5.7.5.1 Asset Class Demographics*

Alectra's distribution system has 115 km of primary underground EPR cable. EPR cables have a Typical Useful Life (TUL) of 25 years and are deemed to have reached End of Useful Life (EUL) at 45 years of age. Figure 29 shows the age demographics of EPR cables in Alectra's distribution system.

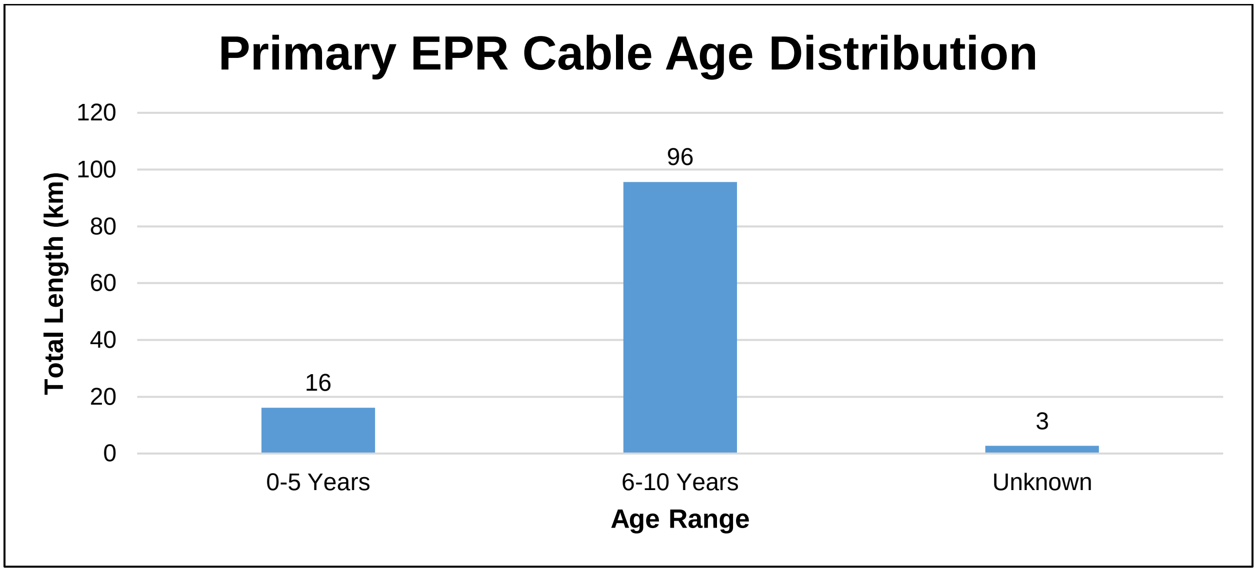


*Figure 29 Primary EPR Cable Age Distribution for 2022*

#### *5.7.5.2 Health Index Formula and Results*

Health index of Primary EPR cables is calculated using Age. According to industry averages, the TUL of EPR cable is 25 years and EUL is 45 years of age. The scoring method for age is described in *Section 2.1.2 Percentage Score.*

Health Index is computed as a function of age (i.e., percentage score), as shown in Table 22.

*Table 22 EPR Cable Health Index Parameters and Weights*

| Input | Input Weight | Scoring Method |
|---|---|---|
| Age | 100% | Percentage Score |

Figure 30 shows the distribution of Health Index values of EPR cables, classified from Very Poor to Very Good. The average DAI is 92%.

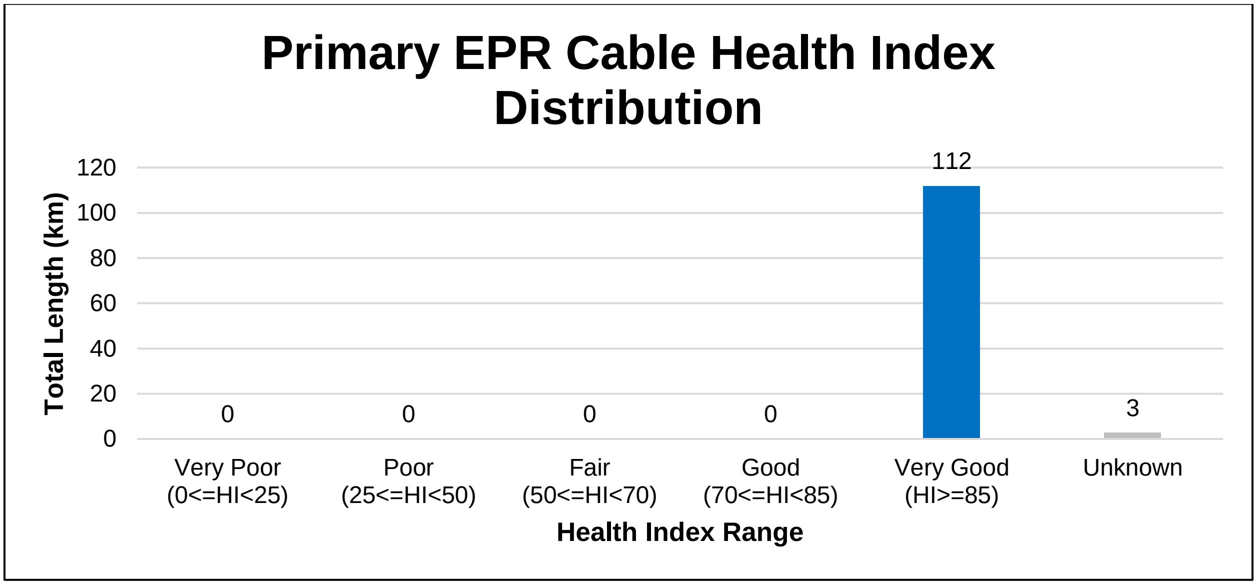


*Figure 30 Primary EPR Cable Health Index Distribution for 2022*

### *5.7.5.3 Sustainment Pacing*

There are no EPR cables in the Very Poor and Poor categories.

Table 23 shows the pacing scenarios, namely, Baseline, Moderate, or Slow, that correspond to sustainment quantities over 5, 7.5, and 10-year intervals, respectively.

*Table 23 EPR Cable Pacing Scenarios*

| Pace | Description | Quantity per year |
|---|---|---|
| Baseline | Sustainment strategy targeting Very Poor & Poor assets over the **short-term** | $\frac{(Very\ Poor + Poor)}{5\ years} = NONE$ |
| Moderate | Sustainment strategy targeting Very Poor & Poor assets over the **medium-term** | $\frac{(Very\ Poor + Poor)}{7.5\ years} = NONE$ |
| Slow | Sustainment strategy targeting Very Poor & Poor assets over the **long-term** | $\frac{(Very\ Poor + Poor)}{10\ years} = NONE$ |

# 6 Station Assets

The Alectra distribution system includes two classes of stations, transformer (TS) stations and municipal (MS) stations or substations. Alectra transformer stations are supplied from Hydro One's high-voltage transmission grid at 115 kV or 230 kV. Alectra municipal stations are supplied from the medium-voltage distribution system at 44 kV, 27.6 kV, or 13.8 kV from transformer stations. Alectra's system has 14 transformer stations and 149 municipal stations owned and operated by Alectra.

Stations may consist of many types of components and subcomponents. Station assets considered in this report include the following:

- Station power transformers
- Station circuit breakers
- Station class switchgear

## 6.1 Power Transformers

### 6.1.1 Summary of Asset Class

Station power transformers are used to step down transmission or sub-transmission voltage to distribution voltage. The two general classifications of station power transformers are transmission station (TS) transformers and station distribution transformers, also referred to as municipal station (MS) transformers. TS transformers are supplied from the high-voltage transmission grid at either 230 kV or 115 kV and step voltage down to 44 kV, 27.6 kV, or 13.8 kV. MS transformers are supplied from the medium-voltage distribution system at 44 kV, 27.6 kV, or 13.8 kV, and step voltage down to 27.6 kV, 13.8 kV, 8.32 kV, or 4.16 kV. TS transformers owned and operated by Alectra have fully-cooled ratings of 50 MVA, 83.3 MVA, and 125 MVA, and MS transformer ratings typically have base Oil Natural Air Natural (ONAN) ratings ranging from 3 MVA to 22 MVA.

Power transformers employ many different design configurations, but they are typically made up of the following main components: Primary and secondary windings, Laminated iron core, Internal insulating mediums, Main tank, Bushings, Cooling system, including radiators, fans and pumps (Optional), Off-load tap changer (Optional), On-load tap changer (Optional), Instrument transformers, Control mechanism cabinets, and Instruments and gauges.

Transformer primary and secondary windings are installed on a laminated iron core. In most power transformers, mineral oil serves as the insulating medium, providing insulation of the energized coils, as well as the coolant. Some power transformers use a natural ester oil, such as FR3. The transformer coil insulation is reinforced with different forms of solid insulation that include wood-based paperboard (pressboard), wrapped paper, and insulating tapes. The transformer main tank holds the active components of the transformer submersed in oil and maintains a sealed environment through the normal variations of temperature and pressure. Typically, the main tank is designed to withstand a full vacuum for initial and subsequent oil fillings and can sustain a positive pressure. The main tank also supports the internal and external components of the transformers. Bushings are used to facilitate the egress of conductors to connect ends of the coils to a power supply system in an insulated, sealed (oil-tight and weather-tight) manner.

The purpose of a cooling system in a power transformer is to efficiently dissipate heat generated due to copper and iron losses and to help maintain the windings and insulation temperature within an acceptable range. Multiple cooling stages allow for increases in load carrying capability. Loss of any stage or cooling element may result in a forced de-rating of the transformer. Transformer cooling system ratings are typically expressed as one of the following:

- Self-cooled (radiators) with designation as ONAN (oil natural, air natural)
- Forced cooling first stage (fans) with designation as ONAF (oil natural, air forced)
- Forced cooling second stage (fans and pumps) with designation as OFAF (oil forced, air forced)

From the view of both financial and operational risk, power transformers are the most important asset installed on the distribution and transmission systems.

### 6.1.2 Asset Degradation

For a majority of transformers, end of life is typically established as the failure of the insulation system and, more specifically, the failure of pressboard and paper insulation. While the insulating oil can be treated or changed, it is not practical to change the paper and pressboard insulation. The condition and degradation of the insulating oil, however, plays a significant role in aging and deterioration of a transformer, as it directly influences the speed of degradation of the paper insulation. The degradation of oil and paper in transformers is essentially an oxidation process. The three important factors that impact the rate of oxidation of oil and paper insulation are presence of oxygen, high temperature, and moisture.

Transformer oil is made up of complex hydrocarbon compounds, containing anti-oxidation compounds. Despite the presence of oxidation inhibitors, oxidation occurs slowly under normal operating conditions. The rate of oxidation is a function of internal operating temperature and age. The oxidation rate increases as the oil ages, reflecting both the depletion of the oxidation inhibitors and the catalytic effect of the oxidation products on the oxidation reactions. The products of oxidation of hydrocarbons are moisture, which causes further deterioration of the insulation system, and organic acids, which result in formation of solids in the form of sludge. Increasing acidity and water levels result in the oil being more aggressive to the paper, hence accelerating the ageing of the paper insulation. Formation of sludge adversely impacts the cooling capability of the transformer and adversely impacts its dielectric strength. An indication of the condition of insulating oil can be obtained through measurements of its acidity, moisture content, and breakdown strength.

The paper insulation consists of long cellulose chains. As the paper ages through oxidization, these chains are broken. The tensile strength and ductility of insulting paper are determined by the average length of the cellulose chains; therefore, as the paper oxidizes, the tensile strength and ductility are significantly reduced, and insulating paper becomes brittle. In addition to the general oxidation of the paper, degradation and failure can also result from partial discharge (PD). PD can be initiated if the level of moisture is allowed to develop in the paper, or if there are other minor defects, within active areas of the transformer.

The relative levels of carbon dioxide and carbon monoxide dissolved in oil can provide an indication of paper degradation. Detection and measurement of furans in the oil provides a more direct measure of the paper degradation. Furans are a group of chemicals that are created as a by-product of the oxidation process of the cellulose chains. The occurrence of partial discharge and other electrical and thermal faults in the transformer can be detected and monitored by measurement of hydrocarbon gases in the oil through Dissolved Gas Analysis (DGA).

### 6.1.3 Asset Class Demographics

Alectra's system has 290 power transformers, including 28 spare units. These are comprised of 31 TS transformers, three of which are spares, and 259 MS transformers, which include 25 spares and units undergoing refurbishment. According to industry averages, power transformers have a Typical Useful Life (TUL) of 45 years and are deemed to have reached End of Useful Life (EUL) at 60 years of age. Figure 31 shows the age demographics of power transformers in Alectra's distribution system as of the summer of 2022.

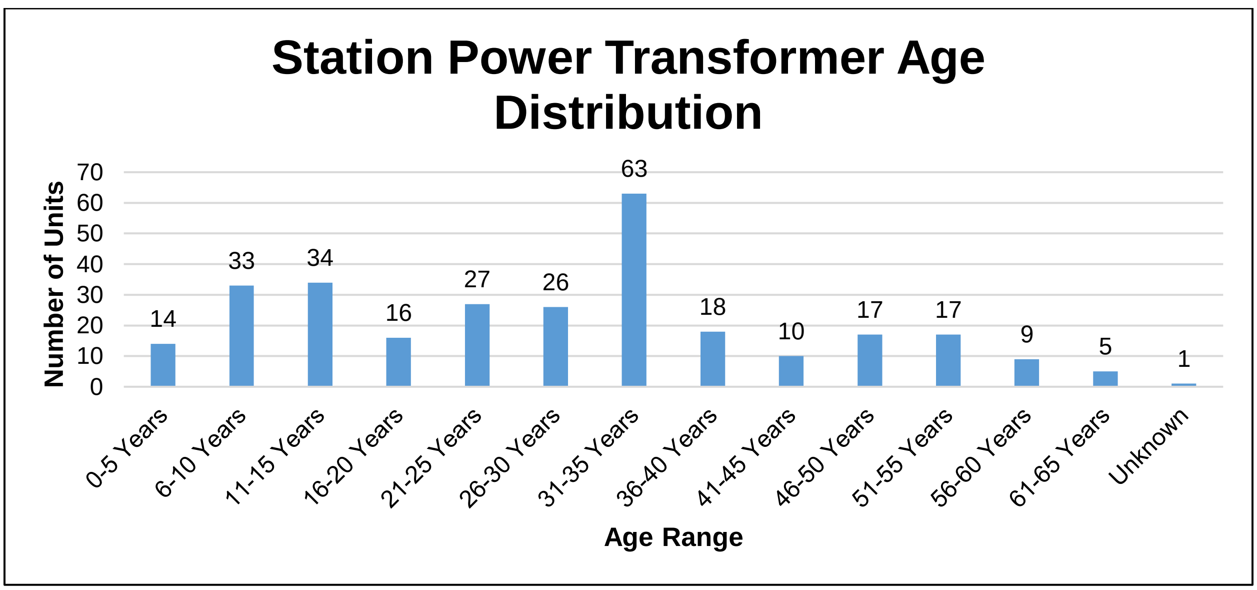


*Figure 31 Station Power Transformer Age Distribution for 2022*

### 6.1.4 Health Index Formula and Results

Health index of power transformers assesses the condition of the transformer according to four main components: Insulation, Cooling, Sealing and Connection, and Age. Insulation is considered to be the primary condition indicator and contributes to 70% of the Health Index. Included in insulation condition are oil quality analysis, oil dissolved gas analysis (DGA), and winding Doble and furan test results.

Age represents deterioration due to other factors not captured by the other components of the model. The scoring method for age is described in *Section 2.1.2 Percentage Score.* Age contributes to only 10% of the Health Index for power transformers.

The Health Index is computed by adding the weighted components of overall condition and age, as shown in Table 24.

*Table 24 Power Transformer Health Index Parameters and Weights*

| # | Input | Input Weight | Scoring Method |
|---|---|---|---|
| 1 | Insulation | 70% | Step Score |
| 2 | Cooling | 10% | Step Score |
| 3 | Sealing and Connection | 10% | Step Score |
| 4 | Age | 10% | Percentage Score |

**DGA Multiplier**

If a power transformer's oil sample results indicate a low overall oil DGA score, it will have a maximum Health Index of 50%.

$$DGA\ multiplier = 50\%$$

### Explosive Gas Multiplier

A high concentration of acetylene in a power transformer's oil sample results indicates that there is a potential for an explosive failure and that the transformer should be removed from service for further diagnostics. A transformer with high concentration of acetylene will be considered as a candidate for replacement and will have a maximum Health Index of 10%.

$$Explosive\ Gas\ multiplier = 10\%$$

Where both multipliers (Explosive Gas and DGA) are triggered, the lower of the two applies (i.e., the Explosive Gas multiplier).

Figure 32 shows the distribution of Health Index values of power transformers, classified from Very Poor to Very Good. The average DAI is 97.2%.

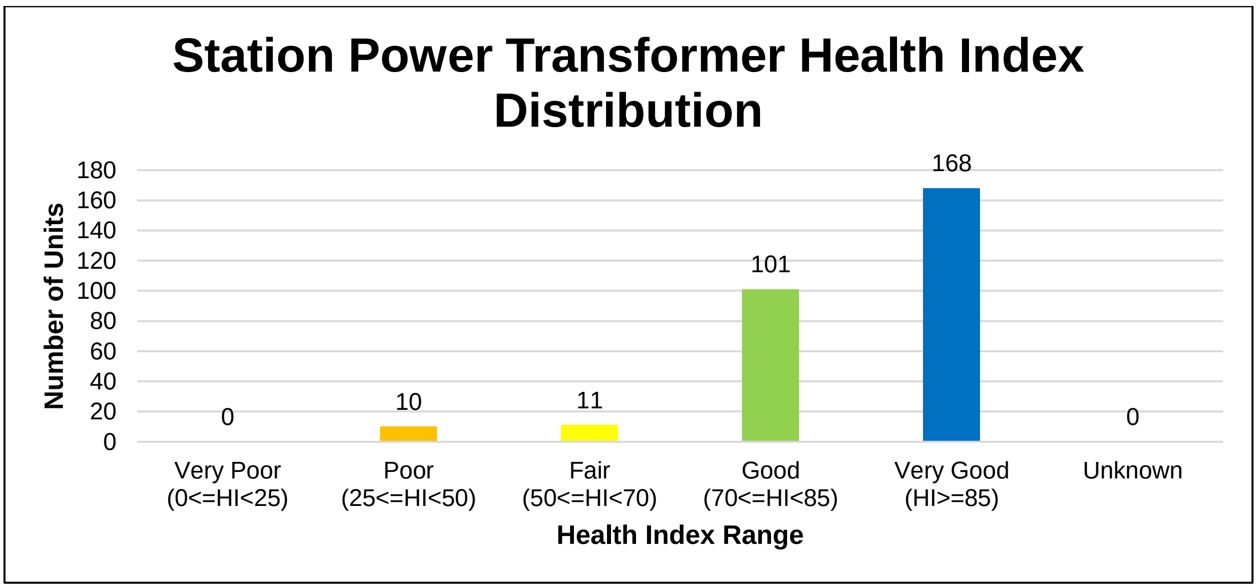


*Figure 32 Station Power Transformer Health Index Distribution for 2022*

## 6.2 Circuit Breakers

### 6.2.1 Summary of Asset Class

Circuit breakers are used to sectionalize and isolate circuits or other assets. They are often categorized by the insulation medium used in the circuit breaker and by the interruption process. The common types include oil circuit breakers, air circuit breakers, vacuum circuit breakers, and $SF_6$ circuit breakers.

Oil circuit breakers (OCB) interrupt current under oil and use the gas generated by the decomposition of the oil to assist in arc extinguishing.

Air insulated circuit breakers are generally found at distribution system voltages and below. Air-type circuit breakers fall into two classifications: Air-blast and Air-magnetic.

Air-blast circuit breakers use compressed air as the quenching, insulating and actuating mechanism. In a typical device, a blast of air carries the arc into an arc chute to be extinguished. Air-blast circuit breakers at distribution voltages are often in metal-enclosed switchgear.

Air-magnetic circuit breakers use the magnetic effect of the current undergoing interruption to draw an arc into an arc chute for cooling, splitting and extinction. Sometimes, an auxiliary puffer or air-blast piston may help interrupt low-level currents. The air-magnetic circuit breakers have short duty cycles, require frequent maintenance, and approach their end-of-life at much faster rates than either $SF_6$ or vacuum circuit breakers. They also have limited transient recovery voltage capabilities and can experience re-strike when switching capacitive currents.

$SF_6$ circuit breakers interrupt currents by opening a blast valve and allowing high pressure $SF_6$ to flow through a nozzle along the arc drawn between fixed and moving contacts. This process rapidly deionizes, cools, and interrupts the arc. After interruption, low-pressure gas is compressed for re-use in the next operation. $SF_6$ is, however, a very potent greenhouse gas, having a global warming potential of about 23,500 times that of carbon dioxide. It is very important that any gas leaks are mitigated promptly.

In vacuum circuit breakers, the parting contacts are placed in an evacuated chamber (i.e., vacuum bottle). There is generally one fixed and one moving contact in a butting configuration. A bellows attached to the moving contact permits the required short stroke to occur while maintaining the vacuum. Arc interruption occurs at current zero after withdrawal of the moving contact. Vacuum circuit breakers are also safe and protective of the environment.

### 6.2.2 Asset Degradation

Circuit breakers “make” and “break” high currents and experience erosion caused by the arcing accompanying these operations. All circuit breakers undergo some contact degradation every time they open to interrupt an arc. Also, arcing produces heat and decomposition products that degrade surrounding insulation materials, nozzles, and interrupter chambers. The mechanical energy needed for the high contact velocities of these assets adds mechanical deterioration to their degradation processes.

Outdoor circuit breakers may experience adverse environmental conditions that influence their rate and severity of degradation. Additional degradation factors for outdoor-mounted circuit breakers include corrosion, effects of moisture, and bushing, insulator, and mechanical deterioration.

Corrosion and moisture commonly cause degradation of internal insulation, circuit breaker performance mechanisms, and major components such as bushings, structural components, and oil seals. Another widespread problem involves corrosion of operating mechanism linkages that result in eventual link seizures. Corrosion also causes damage to metal flanges, bushing hardware, and support insulators.

Outdoor circuit breakers experience moisture ingress through defective seals, gaskets, and pressure relief and venting devices. Moisture in the interrupter tank can lead to general degradation of internal components.

Mechanical degradation presents greater end-of-life concerns than electrical degradation. Operating mechanisms, bearings, linkages, and drive rods represent components that experience most mechanical degradation problems. Other effects that arise with aging include loose primary and grounding connections, oil contamination and/or leakage (oil circuit breakers only), and deterioration of concrete foundation affecting circuit breaker stability.

For oil circuit (OCB) breakers, the interruption of load and fault currents involves the reaction of high pressure with large volumes of hydrogen gas and other arc decomposition products. Thus, both contacts and the insulation medium degrade more rapidly in OCBs than they do in vacuum designs, especially when the OCB undergoes frequent switching operations. Generally, four to eight fault interruptions with contact erosion and oil carbonization will lead to the need for maintenance, including oil filtration. OCBs can also experience restrike when switching low load or line charging currents with high recovery-voltage values. Sometimes this can lead to catastrophic circuit breaker failures.

### 6.2.3 Asset Class Demographics

Alectra's distribution system has 1,277 installed circuit breakers at its stations, 236 of which are associated with transformer stations. According to industry averages, circuit breakers have a Typical Useful Life (TUL) of 40 years and are deemed to have reached End of Useful Life (EUL) at 60 years of age. Figure 33 shows the age demographics of circuit breakers at stations in Alectra's distribution system as of the summer of 2022.

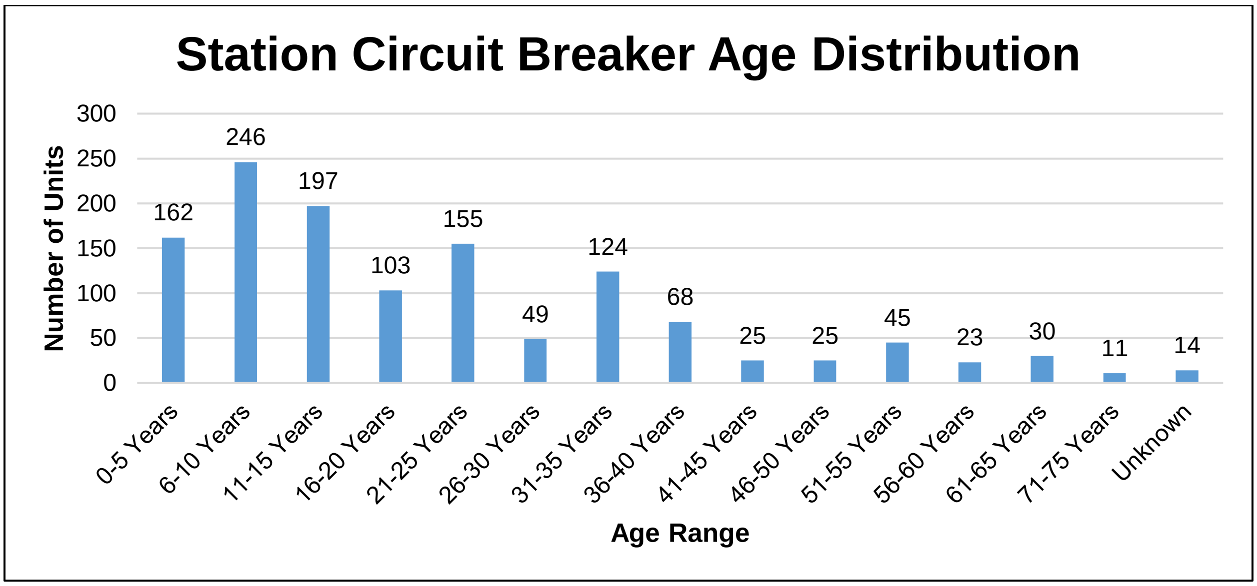


*Figure 33 Station Circuit Breaker Age Distribution for 2022*

### 6.2.4 Health Index Formula and Results

Health index of circuit breakers assesses the condition of the circuit breaker according to seven main components: Insulation, Operating mechanism, Contact performance, Arc extinction, Oil leaks (where applicable), Overall performance, and Age.

Age represents deterioration due to other factors not captured by the other components of the model. The scoring method for age is described in *Section 2.1.2 Percentage Score.*

The Health Index is computed by adding the weighted components of overall condition and age, as shown in Table 25.

*Table 25 Circuit Breaker Health Index Parameters and Weights*

| # | Input | Input Weight (OIL) | Input Weight (AIR) | Input Weight (Vacuum) | Input Weight ($SF_6$) | Scoring Method |
|---|---|---|---|---|---|---|
| 1 | Insulation | 4.8% | 5.6% | 7.4% | 6.1% | Step Score |
| 2 | Operating Mechanism | 33.3% | 38.9% | 25.9% | 33.3% | Step Score |
| 3 | Contact Performance | 16.7% | 19.4% | 26.0% | 21.2% | Step Score |
| 4 | Arc Extinction | 21.4% | 16.7% | 14.8% | 18.2% | Step Score |
| 5 | Oil Leaks | 7.1% | 0.0% | 0.0% | 0.0% | Step Score |
| 6 | Overall Performance | 12.5% | 14.6% | 19.4% | 15.9% | Step Score |
| 7 | Age | 4.2% | 4.8% | 6.5% | 5.3% | Percentage Score |

**Obsolescence Multiplier**

A circuit breaker may be deemed obsolete if it is no longer supported by the manufacturer, parts are no longer readily available, and/or no longer meet current safety or performance standards. If a circuit breaker is deemed to be obsolete, it will have a maximum Health Index of 50%.

$$Obsolescence\ multiplier = 50\%$$

Figure 34 shows the distribution of Health Index values of circuit breakers, classified from Very Poor to Very Good. The average DAI is 88.6%.

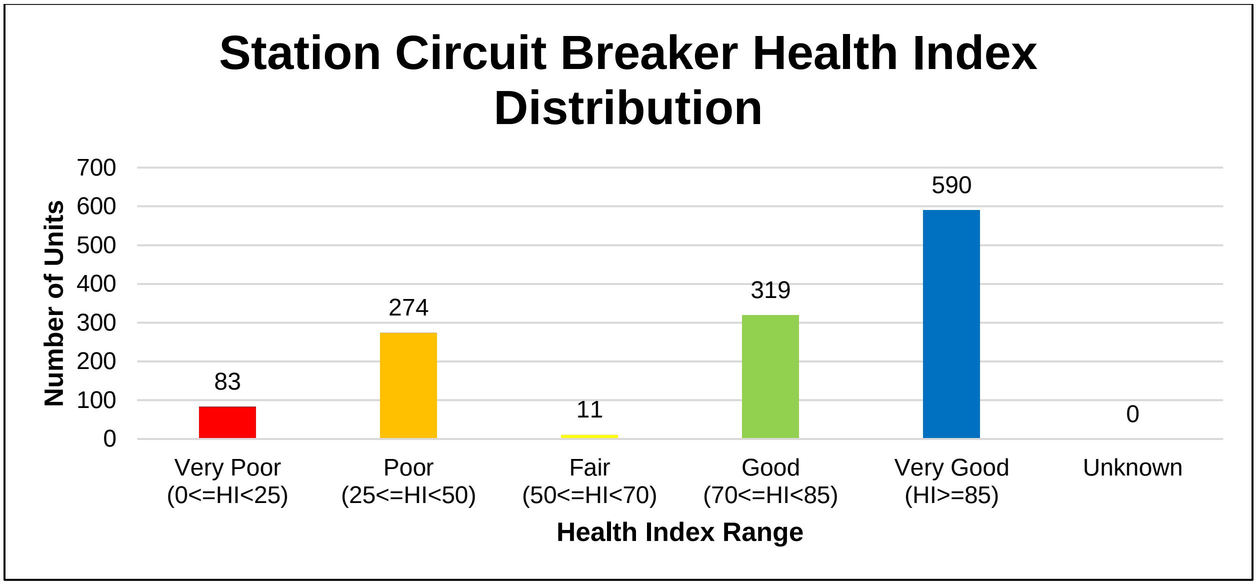


*Figure 34 Station Circuit Breaker Health Index Distribution for 2022*

## 6.3 Station Switchgear

### 6.3.1 Summary of Asset Class

Station switchgear consists of an assembly of retractable/racked devices that are totally enclosed in a metal envelope (metal-enclosed). These devices operate in the medium-voltage range, from 4.16 kV to 34 kV. Station switchgear includes circuit breakers, disconnect switches or fuse gear, current transformers (CTs), potential transformers (PTs), and occasionally some or all of the following: Metering, Protective relays, Internal DC and AC power, Battery charger(s), and AC station service transformation. Station switchgear is modular in that each circuit breaker is enclosed in its own metal envelope (cell). Station switchgear is also compartmentalized, having separate compartments for circuit breakers, control, incoming/outgoing cables or bus duct, and busbars associated with each cell.

### 6.3.2 Asset Degradation

Station switchgear degradation is a function of several factors: Mechanism operation and performance, Degradation of solid insulation, General degradation/corrosion, Environmental factors, and Post fault maintenance (condition of contacts and arc control devices). Degradation of the circuit breaker used is also a factor. However, the degradation mechanism differs slightly between air-insulated and gas-insulated switchgear types. Note that circuit breakers are evaluated separately from station switchgear.

The greatest cause of maloperation of station switchgear is related to mechanism malfunction. Deterioration due to corrosion or wear due to lubrication failure may compromise mechanical performance by either preventing or slowing down the operation of the circuit breaker. This is a serious issue for all types of station switchgear.

In older air-filled equipment, degradation of active solid insulation, such as drive links, has been a significant problem for some types of station switchgear. Some of the materials used in this equipment, particularly those manufactured using cellulose-based materials (pressboard, SRBP, laminated wood), are susceptible to moisture absorption. This results in a degradation of their dielectric properties, resulting in thermal runaway or dielectric breakdown. An increasingly significant area of solid insulation degradation relates to the use of more modern polymeric insulation. Polymeric materials, which are now widely used in station switchgear, are very susceptible to discharge damage. These electrical stresses must be controlled to prevent any discharge activity in the vicinity of polymeric material. Failures of relatively new station switchgear due to discharge damage and breakdown of polymeric insulation have been relatively common over the past couple of decades.

Temperature, humidity, and air pollution are also significant degradation factors. The safe and efficient operation of station switchgear and its longevity may all be significantly compromised if the station environment is not adequately controlled.

### 6.3.3 Asset Class Demographics

Alectra's distribution system has 365 station switchgear. According to industry averages, station switchgears have a Typical Useful Life (TUL) of 40 years and are deemed to have reached End of Useful Life (EUL) at 60 years of age. Figure 35 shows the age demographics of station switchgear in Alectra's distribution system.

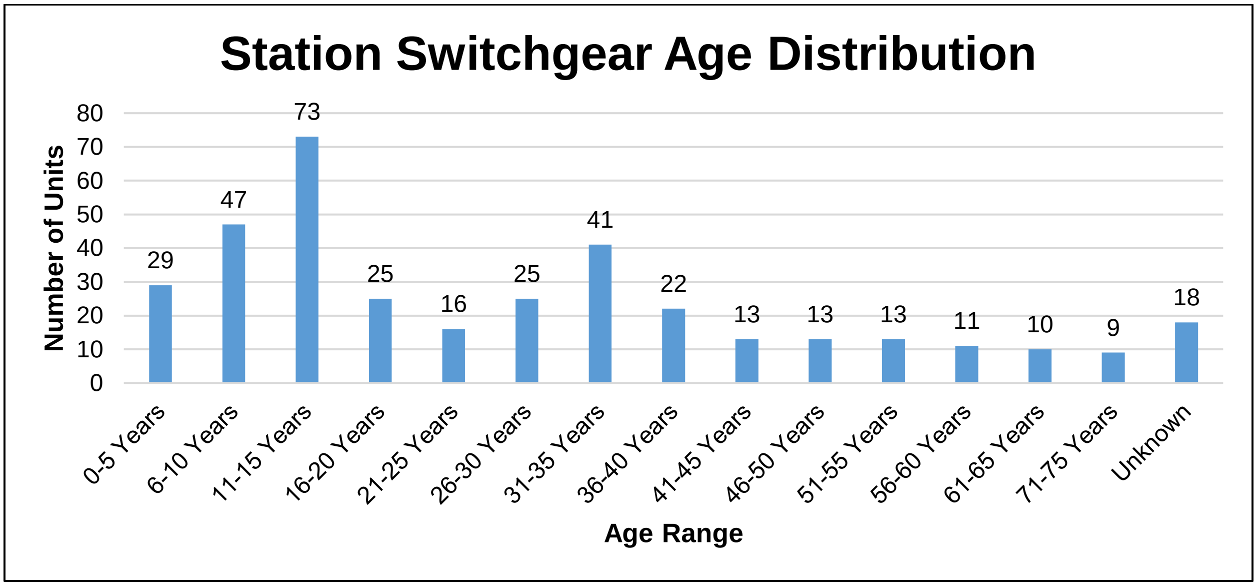


*Figure 35 Station Switchgear Age Distribution for 2022*

### 6.3.4 Health Index Formula and Results

Health index of station switchgear assesses the condition of the switchgear according to five main components: Enclosure condition, Bus and cable compartment, Low-voltage compartment, Overall Performance, and Age. Circuit breakers are analyzed separately.

Age represents deterioration due to other factors not captured by the other components of the model. The scoring method for age is described in *Section 2.1.2 Percentage Score.*

The Health Index is computed by adding the weighted components of overall condition and age, as shown in Table 26.

*Table 26 Station Switchgear Health Index Parameters and Weights*

| # | Input | Input Weight | Scoring Method |
|---|---|---|---|
| 1 | Enclosure Condition | 25% | Step Score |
| 2 | Bus & Cable Compartment | 37.5% | Step Score |
| 3 | Low-Voltage Compartment | 12.5% | Step Score |
| 4 | Overall Performance | 18.75% | Step Score |
| 5 | Age | 6.25% | Percentage Score |

Figure 36 shows the distribution of Health Index values of station switchgear, classified from Very Poor to Very Good. The average DAI is 86.3%.

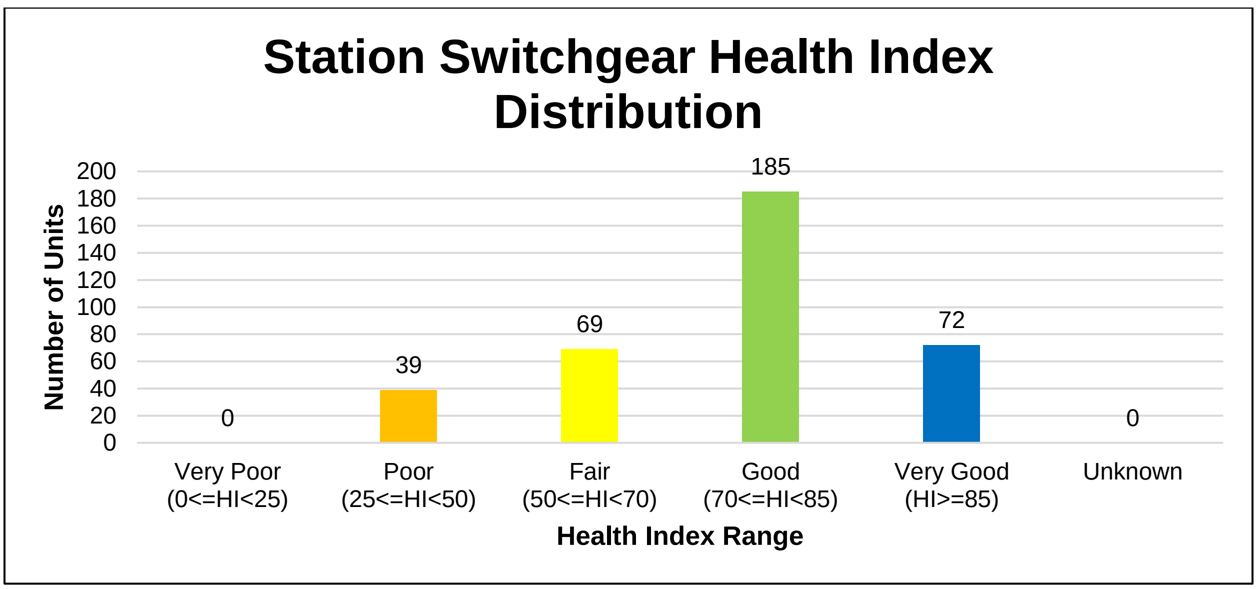


*Figure 36 Station Switchgear Health Index Distribution for 2022*

**AMPCO-11**

**Reference: Exhibit 3, Tab 1, Schedule 4, p. 2**

**Alectra indicates it responds to and remediates an average of 449 cable failures events each year.**

**a) Please provide the calculation.**

**b) Please provide the Cable & Accessories XLPE Outages in 2021 and 2022.**

**Response:**

a) and b)

Alectra Utilities has provided Table 1 below which includes the number of XLPE and Accessories outages (failures) between 2018 and 2022 inclusive of Major Event Days (‘MEDS”). The average number of cable failures over the 2018-2022 period is 449. The average number of cable failures without MEDs is 458.

**Table 1 – Number of XLPE and Accessories Outages per year (2018-2022) for Alectra Utilities**

| Number of XLPE and Accessories outages per year | |
|---|---|
| 2022 | 375 |
| 2021 | 452 |
| 2020 | 475 |
| 2019 | 411 |
| 2018 | 534 |
| **Average** | **449** |

**AMPCO-12**

**Reference: EB-2022-0013, AMPCO-1 (a)**

**Alectra indicates the Health Index formula of XLPE cable segments has three inputs:**
**a. XLPE type (tree retardant versus non-tree retardant)**
**b. Construction type (direct buried versus in-duct)**
**c. Age**

**a) Please confirm it is primarily age, not asset condition or cable failure rates, is determining the km of XLPE cable that is in poor and very poor condition.**

**b) Please provide the weighing in the Health Index formula for age.**

**c) Please discuss Alectra's ability to include more data in the Health Index formula for XLPE cable.**

**Response:**

a) As provided in response to 3.0-VECC-7, age is not the only input in determining the cable condition using the Health Index. Alectra Utilities tracks cable failures as part of its reliability statistics and investigates cable failure events to understand causes. The Health Index includes cable type (XLPE, Tree Retardant ("TR") XLPE, PILC, EPR), construction type (in-duct, direct buried), injection date (if applicable) and age for each cable segment. Also, Alectra Utilities performs cable testing on selected segments.

The proposed 16 ICM projects were selected due to the specific reliability concerns identified in the respective neighborhoods. These projects have been identified for ICM funding as the asset condition, reliability and quality of service in these areas create an urgent need for remediation. Further, as provided in Exhibit 3, Tab 1, Schedule 2, page 16, Lines 5-14, once Alectra Utilities' engineers identify emerging areas and hotspots for cable failures, a full engineering assessment of the site is completed, which includes:

- A complete reliability evaluation of all the outages the customers in the area have experienced over the last several years;
- Evaluation of all the assets in the area, including transformers and switchgear;
- Location of the cable, including available space considering other utilities in the corridor;

- Assessment of the phasing, fusing, plans and feeder configuration;
- Feasibility of applying cable injection to extend the life of the existing cable; and
- Other site-specific requirements (e.g., rear lot placement of cables and assets, environmental considerations such as conservation lands, driveways, roads, etc.).

b) The Health Index formula is not just a calculation through a pure mathematical formula; it contains logical decisions. For example, if a cable segment is injected, its age is adjusted to reflect the injection as discussed in Staff-14 (c). The presence of logical decisions makes it difficult to attribute a weight to a single input of the Health Index. In other words, the weights of cable type, construction, injection and injection date need to be determined first since they are inputs as well to Health Index calculation.

This is not to be confused with the ACA report's statement "Health Index is computed as a function of age (i.e., percentage score)" (ACA 2022 report, page 48) and the indicated weight of 100% (ACA report 2022, Table 18). The intention of that statement and the referenced table in the ACA report is to show that the age is weighted as 100% (i.e., multiplied by 1) as an input and not multiplied by any other factor. In other words, Alectra Utilities does not multiple or discount the age by a factor before using it in the computation of Health Index.

c) In terms of technical and analytical capabilities, Alectra is able to include more data inputs in the Health Index Formula for cable. However, including more input parameters to be represented by a single number (i.e. Health Index) compresses the information in a single metric. This compression removes the information granularity and would not support a targeted approach of renewal. Alectra Utilities considers multiple inputs and their correlations in geographical representation in the Asset Analytics Platform to allow for a targeted approach of renewal, where the Health Index is considered among other inputs (e.g., historical cable failures on the cable segments).

Investment in cable renewal necessitates consideration of multiple inputs and criteria warranting a detailed analysis, which Alectra Utilities performs. Engineering assessments and renewal decisions are better facilitated by considering the Health Index metric with other consideration (e.g., geographically represented failures, segments length) as opposed to blending the inputs into the Health Index.

**AMPCO-13**

**Reference: EB-2022-0013, Decision and Order, November 17, 2022, p. 19, Table 6**

**Table 6: Material Changes from DSP 2020 to 2024**

| **Summary of Material Changes $ millions** | **2020 Actual** | **2021 Actual** | **2022 Budget** | **2023 Forecast** | **2024 Forecast** | **Total** |
|---|---|---|---|---|---|---|
| Underground Asset Renewal | $0.4 | ($18.9) | ($26.9) | ($38.0) | ($41.8) | ($125.2) |
| Lines Capacity | ($9.9) | ($17.0) | ($12.7) | ($14.2) | ($3.2) | ($56.9) |
| Information Technology Systems | ($1.3) | ($4.4) | $9.5 | $17.1 | $13.4 | $34.3 |
| Other | ($16.1) | $22.1 | $1.1 | $1.6 | ($11.1) | ($2.4) |
| Total Reduction before Proposed ICM | ($26.9) | ($18.2) | ($29.0) | ($33.5) | ($42.7) | ($150.2) |
| Proposed ICM Investments | $0 | $0 | $0 | $25.4 | $26.9 | $52.3 |
| **Total Net Reduction** | **($26.9)** | **($18.2)** | **($29.0)** | **($8.1)** | **($15.8)** | **($97.9)** |

**Please update Table 6 to include: 2022 actuals, 2023 and 2024 forecast.**

**Response:**

Alectra Utilities has included Table 1 below which is updated to include 2022 actuals, 2023 and 2024 forecast.

**Table 1 – Material Changed from DSP 2020 to 2024 ($MM)**

| **Summary of Material Changes** | 2020 Actual | 2021 Actual | 2022 Actual | 2023 Forecast | 2024 Forecast | Total |
|---|---|---|---|---|---|---|
| **Underground Asset Renewal** | 0.4 | (18.9) | (35.3) | (33.9) | (44.5) | (132.2) |
| **Lines Capacity** | (9.9) | (17.0) | (15.0) | (19.1) | (9.9) | (70.9) |
| **Information Technology** | (1.3) | (4.4) | 6.0 | 10.5 | 11.0 | 21.8 |
| **Other** | (16.1) | 22.1 | (2.4) | 12.2 | (5.7) | 10.1 |
| **Total Reduction before Proposed ICM** | (26.9) | (18.2) | (46.7) | (30.3) | (49.1) | (171.2) |
| **Proposed ICM Investments** | 0.0 | 0.0 | 0.0 | 16.0 | 25.1 | 41.1 |
| **Total Net Reduction** | **(26.9)** | **(18.2)** | **(46.7)** | **(14.3)** | **(24.0)** | **(130.1)** |

**AMPCO-14**

**Reference: Exhibit 3, Tab 1, Schedule 4, p. 8, Table 22**

**Please provide the ICM Project List separately for the PowerStream and Enersource Rate Zones.**

**Response:**

The ICM Project Lists by rate zones are provided in Tables 1 and 2 below.

**Table 1 – ICM Projects PRZ ($MM)**

| Project # | Project Name | 2024 |
|---|---|---|
| 151329 | Cable Replacement – Raymerville Drive Area in Markham (M21) | $1.6 |
| 151361 | Cable Injection – Cairns Drive of Markham (M21) | $1.7 |
| 151367 | Cable Injection – McNaughton Road Area of Vaughan (V26) | $1.7 |
| 151456 | Cable Injection – Sovereign Court Area in Vaughan (V50) | $1.3 |
| 151459 | Cable Injection – Creditstone Road Area in Vaughan (V24) | $2.2 |
| 151517 | Cable Injection - 8th Line & Highway 11 Area in Bradford (BR5) | $1.0 |
| 151913 | Cable Replacement – Cochrane Drive & Scolberg in Markham (M44) | $2.1 |
| 151935 | Cable Replacement - Larkin Ave Area of Markham (M15) | $1.9 |
| 152373 | Cable Replacement - St. Joan of Arc Area of Vaughan (V26) | $1.9 |
| 152375 | Cable Replacement – Hammond Drive Area in Aurora (A09) | $1.4 |
| 152387 | Cable Injection – Bainbridge Ave (V51) | $0.6 |
| | **Total Proposed ICM Investment PRZ** | **$17.3** |

**Table 2 – ICM Projects ERZ ($MM)**

| Project # | Project Name | 2024 |
|---|---|---|
| 151403 | Cable Replacement - Montevideo & Battleford Area in Mississauga (Area 46) | $1.6 |
| 151407 | Cable Replacement – Glen Erin & Burnhamthorpe of Mississauga (Area 25) | $2.4 |
| 151431 | Cable Injection – Glen Erin Dr & Bell Harbour Dr in Mississauga (Area 39) | $1.3 |
| 151435 | Cable Injection – Derry Road & Ninth Line (Area 56) | $1.5 |
| 151903 | Cable Replacement – South Millway Area in Mississauga (Area 25) | $1.1 |
| | **Total Proposed ICM Investment ERZ** | **$7.9** |