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KINECTRICS

Asset Depreciation Study for the Ontario Energy Board

Kinectrics Inc. Report No: K-418033-RA-001-R000

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DISCLAIMER

The views expressed in this report are those of Kinectrics Inc. and do not necessarily represent the views of, and should not be attributed to the Ontario Energy Board, any individual Board member, or Board staff.

EXECUTIVE SUMMARY

Generally accepted accounting principles (GAAP) requires entities with property, plant and equipment (PP&E) to amortize the cost of assets over the period of time that they provide useful service. Prior to adoption of International Financial Reporting Standards (IFRS), GAAP in Canada permitted the use of asset service lives specified by the regulator. IFRS (without approval of a standard for Rate-regulated Activities) does not allow for the use of externally mandated depreciation rates. The Ontario Energy Board (OEB) stipulated that all Ontario's utilities are expected to adopt IFRS effective January 1, 2011[1]. At the same time, OEB is requiring all distributors to adopt useful life estimates that do not depend on the regulator and are determined by independent asset service life studies. In addition, IFRS is requiring componentization of assets placed in service by distributors at a sufficient level of detail to recognize that portions of an overall asset may be replaced or refurbished during the life of the asset of which they are a component, while the overall life of the asset may be somewhat longer.

The purpose of this Report is to assist utilities in making the transition from GAAP to IFRS and to assist them with determining appropriate initial service lives for assets most commonly used in the distribution of electricity in Ontario. This approach is considered an effective way to minimize the need and cost to Ontario consumers of a myriad of like studies by individual distributors. This report may also serve as a reference guide for the OEB in reviewing rate applications while keeping the responsibility for selecting and substantiating asset service lives with the utilities.

This Report identifies and describes common groups of assets and their most common "components". Total service lives are ascribed to each component, and assets are assigned to one of the following "parent" systems:

- Overhead Lines (OH)
- Transformer and Municipal Stations (TS&MS)
- Underground Systems (UG)
- Monitoring and Control Systems (S)

For each of the assets and their respective components, a useful life range and a typical useful life value within the range are given. This information is a composite of industry values known to Kinectrics Inc. (see Section E - 6) and information from six Ontario Local Distribution Companies (LDCs) of varying sizes and geographical locations selected as a sample, and with whom Kinectrics Inc. met on an individual basis.

It is also recognized that the useful lives of assets are dependent on a number of Utilization Factors (UFs) that are present within each jurisdiction. The degrees of impact of these influencing factors were qualitatively determined using information gathered from the LDCs. The UFs are identified as:

- Mechanical Stress
- Electrical Loading
- Operating Practices
- Environmental Conditions
- Maintenance Practices
- Non-Physical Factors

By considering the useful life ranges and the extent to which the utilization factors impact their assets, utilities will be able to select appropriate depreciation periods for their asset groups as

[1] *Report of the Board – Transition to International Financial Reporting Standards*, July 28, 2009

shown in the example for Power Transformers in Section E - 5 of this Report. The example demonstrates how UFs can be used in conjunction with local circumstances to estimate an appropriate depreciation period within the prescribed useful life range.

Table F-1 summarizes useful lives and the factors impacting those lives as developed by this report.

For completeness, Kinectrics has included a table that summarizes typical useful lives for Ontario's Local Distribution Companies' non-distribution assets, sometimes referred to as Minor Assets (Table F-2). The useful life values for Minor Assets were based on utility practices without further analysis.

In addition to the useful life information presented in this Report, Kinectrics has identified several areas for improvement that, once addressed, can enhance the Local Distributors' ability to improve the accuracy of their determination of asset service lives.

CREDENTIALS OF THE CONSULTANT

Kinectrics Inc is a recognized expert in determining useful lives of asset as a leader in developing "state of the art" Asset Condition Assessment methodology that estimates condition of assets based on their End-of-Life criteria and successfully completed a number of large scale Asset Management projects. These projects involved condition assessments of both station and lines distribution assets and included performing risk assessments based on the findings and recommending future life cycle sustaining investments, both capital and maintenance in nature.

Over the last year Kinectrics Inc completed a number of projects aimed at assisting Ontario's LDCs with the IFRS conversion. The projects involved developing LDC-specific assets groupings and componentization and for each asset grouping/component providing industry based useful life ranges. Kinectrics Inc has also provided information on typical industry time-based maintenance intervals and qualitative assessment of factors that may influence typical life within the range, such as operational practices, utilization, functional requirements, environmental impact etc. In addition, Kinectrics has acted as the Technical Due Diligence Consultant in many of the Ontario LDC mergers, in which depreciation assessments and valuation of assets were major tasks.

Kinectrics Inc observations on the useful life of assets as they relate to IFRS have recently been published in the November 2009 Special Edition of "The Distributor", an Electricity Distributors Association (EDA) publication.

Kinectrics staff understands power systems, having conducted comprehensive work on line design, standards, protection, losses and virtually every other aspect of planning and design for the last 30 years. Kinectrics has high voltage and high current lab testing expertise and has conducted many distribution asset failure investigations. Our theoretical knowledge is backed up by practical experience with power system components. This equipment expertise is of great practical value in working with utility staff whose mandate is to achieve the optimal physical and economic life cycle for these assets. Kinectrics asset management experience goes far deeper than logging equipment populations and demographics in computer databases.

Kinectrics has a unique and cost-effective capability covering a wide spectrum of areas including:

- Intimate knowledge of transmission and distribution systems equipment and their needs, and additional lifecycle-management or test result analysis services that we offer beyond testing and that are based on this extensive experience and understanding
- Kinectrics' testing facility that is world industry leader in capability and expertise in this domain and includes access to over 25 world-class Ontario-based laboratory and testing facilities, and to a range of proprietary technologies and processes
- In-depth experience in the management and execution of utility projects for numerous clients in Ontario and Canada, as well as North America and the rest of the world
- Access to staff from Kinectrics and other utility experts in key focus areas
- Operation under the ISO 9001 quality management system, with additional ISO 17025 qualification for key laboratories
- Project execution at the Project Management Professional (PMP) level

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A INTRODUCTION

Generally accepted accounting principles (GAAP) require entities with property, plant, and equipment (PP&E) to amortize the cost of such assets over the period of time that they provide useful service. Determination of such periods of time (total service lives) is generally based on engineering studies, asset retirement statistics and the experience of other utilities with like assets. Total service lives are reviewed from time to time to ensure they are current.

The majority of electricity distributors in Ontario continue to use asset service lives originally prescribed by Ontario Hydro at least 20 years ago.

Prior to adoption of International Financial Reporting Standards (IFRS), GAAP in Canada permitted the use of asset service lives specified by the regulator. IFRS (without approval of a standard for Rate-regulated Activities) does not allow for the use of externally mandated depreciation rates. Ontario Energy Board (OEB) has stipulated that all Ontario's distributors are expected to adopt IFRS beginning in 2011. In order to be IFRS compliant, distributors must adopt useful life estimates that do not depend on the regulator and are supported by independent asset service life studies.

In addition IFRS requires the componentization of assets placed in service by distributors at a sufficient level of detail to recognize that portions of an overall asset may be replaced or refurbished during the life of the asset of which they are a component, while the overall life of the asset may be somewhat longer. For many distributors, the level of detail maintained in their fixed asset and depreciation records is already sufficient to meet the IFRS componentization requirements. Such distributors have typically broken their PP&E into parts and have established formal "plant retirement units" (scaled in anticipation that they could be retired from service part way through the life of the asset of which they are a part). For other distributors, additional breakout may be necessary in adopting IFRS.

Because of the myriad of possible asset and system configurations, there are no industry standard components or plant retirement units. Nonetheless, industry practice in Ontario has been common enough that there are expected to be normative collections of asset components and system design configurations that can enable a study of service lives to be performed on the most commonly found components and configurations.

The purpose of this Report is to assist utilities in making the transition to IFRS and to assist them with determining appropriate initial service lives for assets most commonly used in the distribution of electricity in Ontario, particularly in situations where they have not conducted their own study. This approach is considered an effective way to minimize the need and cost to Ontario consumers of a myriad of like studies by individual distributors.

The method of depreciation of PP&E used by Ontario distributors is the straight-line remaining service life method, and Kinectrics understands this will continue to be the method used under IFRS.

This study will assist distributors with the determination of suitable asset total service lives. Distributors must still evaluate whether the total service lives set out in this Report are completely applicable to their own utility. This evaluation includes assessing the applicability of utilization factors (UF) that affect the most likely values provided in the Report, determining whether adjustments need to be made to reflect their individual componentization circumstances, determining how much service life remains for each component as well as the amount, if any, of residual or scrap value that is expected on disposition/removal from service of the component. Such utility-specific work is not part of the work for which Kinectrics Inc was engaged.

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B OBJECTIVE AND SCOPE

B - 1 OBJECTIVE

The objective of this Report is to assist electricity distributors in Ontario in determining total service lives for typical electricity distribution system assets that they own.

The information contained in the Report is expected to further facilitate transfer of responsibility for determining asset total service lives to distributors as they transition to IFRS.

B - 2 SCOPE OF WORK

This Report identifies and describes commonly configured groups of assets forming most commonly found "components" and ascribes total service lives to such components. In addition, assets are assigned to one of the following "parent" systems:

- Overhead Lines (OH)
- Transformer and Municipal Stations (TS&MS)
- Underground Systems (UG)
- Monitoring and Control Systems (S)

For each of the assets and their components, this Report provides a useful life range and a typical useful life value within the range. To further assist distributors with selecting the depreciation periods most appropriate for their utility, the Report also assesses the importance of various factors that affect the typical useful life value.

Useful life is expressed as a specific number of years rounded off to the nearest multiple of 5, being the Typical Useful Life (TUL). As well, a lower and upper limit of number of years is provided, within which most situations could be expected to occur. These upper and lower limits are referred to as the Minimum Useful Life (MIN UL) and Maximum Useful Life (MAX UL) and are also rounded off to the nearest multiple of 5. The definition of these terms is provided in Subsection E - 1 of this Report.

The Report also indicates the typical Utilization Factors (UF) affecting the degree to which shorter or longer total services lives could be judged by a distributor in a particular circumstance to be more appropriate. These factors include Maintenance Practices, Environmental Conditions, Mechanical Loading, Electrical Loading, Operating Practices, and Non-Physical Factors such as obsolescence. A description of these factors is provided in Subsection E - 1of this Report.

The Report includes a summary of the statistical analysis that establishes a percentage of assets that will reach their end-of-life (EOL) between MIN UL and MAX UL in Subsection E - 6.

In addition, the Report provides a guideline regarding the typical depreciation periods used in Ontario for other utility assets that do not fall under any of the above "parent" systems, such as office equipment, computers, buildings, vehicles, and communication equipment. These assets are often referred to as Minor Assets or General Plant.

Kinectrics selected six Ontario distributors in collaboration with the Ontario Energy Board staff and met with these distributors to ascertain what they consider to be appropriate values for TUL, MIN UL and MAX UL, as well as factors that they felt impacted the TUL for each class of depreciable property. A class of depreciable property is that grouping of components that is appropriate to consider together for purposes of this study. Some such distributors had recently completed depreciation studies of their own, and all were prepared to assist with this work.

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C EXECUTION PROCESS

The project execution process entailed seven steps to ensure that the industry-based information compiled by Kinectrics includes all the relevant assets and components used by Ontario's Local Distribution Companies (LDCs). The procedure was as follows:

Step 1
Kinectrics established a list of asset groupings representative of the typical breakdown of assets for Ontario's LDCs. This list was based on Kinectrics familiarity with LDCs business practices, particularly as a result of having performed a number of studies in support of the IFRS transition initiative for a number of large LDCs. The asset breakdown presented in this Report should be regarded as a guideline as it is likely that LDCs will have a somewhat different asset breakdown based on their specific asset mix and existing accounting practices.

Step 2
Kinectrics provided further breakdown or componentization for some of the asset categories. This was also based on Kinectrics familiarity with LDCs business practices and, at the same time was assessed against the following two criteria:

1. A value of component is significant or material enough relative to the value of the asset of which it is a component.
2. A need to replace the component does not necessarily warrant replacement of the entire asset.

Step 3
Kinectrics compiled industry based useful life values for the assets and their components using different sources, including industry statistics, research studies and reports (either by individuals or working groups, such as CIGRE), and Kinectrics Inc past experience (see Section E-2).

The listing for each asset/component includes a minimum and maximum useful life range (MIN UL and MAX UL) as well as TUL and utilization factors, such as maintenance practices, environmental conditions, mechanical and electrical loading, etc. that have an impact on whether the actual life for a particular utility is longer or shorter than the typical life.

Step 4
Six LDCs of different sizes were engaged to provide input to the study. The selection was made considering variables such as asset mix and geographical location. The utilities had varying experience regarding assets grouping, breakdown and componentization. Kinectrics Inc met with these utilities directly and obtained and discussed their assessments of each of the useful life values and the influencing utilization factors for each asset.

Step 5
The typical lives for some assets/components were combined with the corresponding lives obtained from utility interviews as described in Section E - 4 of this Report for each of the asset categories/components to come up with the recommended TUL, as well as recommended MIN UL and MAX UL. The study work also summarized and displayed the qualitative assessment of the degree to which each Utilization Factor underwrites the choice of TUL and affects TUL and the range between MIN UL, and MAX UL.

Step 6
A Draft Report was prepared by Kinectrics and circulated for comment from the LDC community.

Step 7
This Final Report was prepared and submitted to the OEB incorporating adjustments in response to comments on the Draft Report.

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D DELIVERABLES

This Report is the primary deliverable to the Ontario Energy Board from this engagement for use by electricity distributors in Ontario. In particular, this Report includes:

1. An Executive Summary and Table of Contents.

2. A summary of the credentials of the consultant.

3. A description of the methods used to determine estimated total life and estimated ranges of the respective categories of the depreciable assets, as well as a description of the data sources relied upon.

4. A description of each asset category and component for which Kinectrics has determined a service life.

5. A reference table listing the asset categories and components for which a service life has been determined:

   i. a most likely service life for the component expressed in years (referred to as the typical useful life or TUL), and

   ii. a reasonable upper and lower limit stated in years for the service life of the component under various operating or environmental conditions (referred to as the minimum and maximum useful live or MIN UL and MAX UL, respectively)

   iii. a description of the factors that impact the useful life of each asset.

6. Implementation suggestions that Kinectrics considers useful for distributors to consider when implementing the service lives (these suggestions include utilization and maintenance factors and practices).

7. Other matters Kinectrics considers relevant including the definition of Useful Life, Factors Impacting Typical Useful Life and statistical evaluation of percentage of the asset population that is expected to fall between MIN UL and MAX UL.

Kinectrics also provided in Section G some conclusions about areas of need where distributors could improve the overall process of managing depreciation cost.

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E METHODOLOGY

This Section defines some of the terms used throughout this report and describes the methodology used to estimate typical useful life, its range between minimum and maximum values for the defined distribution assets categories and the utilization factors influencing useful life.

E - 1 DEFINITIONS

The definitions of Asset Categories and Components, Useful Life Ranges, Typical Useful Life and the Factors that impact Useful Life (both physical and non-physical in nature) are listed below.

Asset Categories
Asset categories refer to typical distribution system assets such as as station transformers, distribution transformers (overhead and underground), breakers, switches, underground cables, poles, vaults, cable chambers, etc. Some of the assets, such as power transformers, are complex systems and include a number of components.

Components
For the purposes of this study, component refers to the sub-category of an asset that meets both of the following criteria:

1. Its replacement value is material enough to track.
2. A need to replace the component does not necessarily warrant replacing the entire asset.

An *asset* may be comprised of more than one component, each with independent failure modes and degradation mechanisms that may result in a substantially different useful life than that of the overall asset. A component may also be managed under an independent maintenance and replacement schedule.

Typical Useful Life (TUL)

TUL is defined differently, depending on the asset category and component type, and can be categorized under one of the following three scenarios:

i. Assets Are Replaced Only When Failed

TUL= Age when most of the assets fail and are replaced and is equal to the asset's physical EOL (physical EOL is defined as an asset's inability to perform its functions as designed).

ii. Assets Are Replaced Due to Reasons Not Related to Their Performance

TUL = Typical age when assets are replaced before they reach their physical EOL due to reasons such as lack of spare parts or replacement assets, incompatibility with system requirements, external drivers (e.g., road widening, or PCB Regulation), or internal initiatives (e.g., carbon print reduction or voltage conversion).

iii. Assets are Replaced for Economic Reason

TUL = Typical age when assets reach their "economic life", i.e., although physical EOL is not reached, high risk of failure cost makes it economical to replace them.

Depending on the utility's circumstances, replace vs. refurbish strategy and type and age distribution of a particular asset category/component, TUL may reflect a combination of all three scenarios described above. The degradation mechanism is discussed for each asset studied in this report.

Useful Life Ranges

TUL falls between Minimal Useful Life (MIN UL) and Maximum Useful Life (MAX UL) which for the purposes of this report are defined as:

MIN UL = Age when a small percentage of assets reach their physical EOL, usually at the beginning section of the statistical "bath-tub curve", where failure rate starts increasing exponentially

MAX UL = Age when most of the assets reach their physical EOL, usually at the end section of the statistical "bath-tub curve", where failure rate increases exponentially

The exact percentage of assets/components that fail before reaching MIN UL or MAX UL varies from utility to utility as well as among different asset categories/components. Although MIN UL and MAX UL are most often related to physical EOL, in some cases the range is defined by economic or other reasons. In such cases, the range is usually less than when MIN UL and MAX UL are dictated by the physical EOL alone.

It is worth noting that an asset category can have a typical life that is equal to either the maximum or minimum life. This fact is simply an indication that the majority of the units within a population will be operational for either the minimum or maximum number of years; i.e. the statistical data is skewed towards either the maximum or minimum values. This could also happen, for example, when assets are replaced for economic reasons to alleviate failure risk cost.

A statistical analysis that estimates the percentage of assets/components whose useful lives are within the range defined by MIN UL and MAX UL is presented in Subsection E - 6 of this report.

The range in useful lives that are found in practice reflects differences in various factors described in the "Utilization Factors" subsection below.

Utilization Factors

For the purposes of this Report, the term Utilization Factors (UFs) refers to factors that are expected to affect TUL of assets and their components and to a certain extent MIN UL and MAX UL. The degree of their effect is qualitatively described as High (H), Medium (M), Low (L), or No Impact (NI). The following UFs were identified:

1. **Mechanical stress** refers to forces and loads applied to an asset that may lead to degradation over time, e.g. wind load, ice load, gravitational and spring forces on components, etc.

2. **Electrical loading** refers to stresses such as continuous loading, temporary overloading and exposure to short circuit fault current.

3. **Operating practices** refers to how frequently an asset is subject to operations (automatic or manual) that impact its useful life, e.g. reclosers, switch or breaker operations.

4. **Environmental conditions** include pollution, salt, acid rain, humidity, extreme temperature, and animals that are prevalent and cause long-term degradation over a period of time.

5. **Maintenance Practices** refers to how frequently and regularly Routine Inspection or Routine Testing/ Maintenance is performed on assets/components.

6. **Non-Physical Factors** refers to things that are not directly related to physical condition of assets, e.g. obsolescence, economic considerations related to life cycle cost management, increased rating requirements due to system growth, regulatory changes, construction activities, etc. These factors could lead to asset replacement even when assets can still perform as designed.

Each asset may be impacted by one or more of the UFs, resulting in different degradation rates for the same assets and/or components in different jurisdictions. Therefore, it is expected that some of the utility-specific total lives chosen will be different than the TULs provided in this Report based on the qualitative assessment of the above factors.

As part of the interview, each of the six utilities was asked to rank the degree to which each UF impacts the life of each of their assets. For each UF, a singular degree of impact value (H, M, L, NI), based on a composite of the rankings provided by the utilities, is reported. The degree of impact (DI) is determined by the following formulation:

$$DI = \frac{\sum_{m=1}^{6} \alpha_m (RS)}{\sum_{m=1}^{6} \alpha_m (RS_{\max})}$$

m Utility number. Six (6) utilities were interviewed.

RS Ranking Score. This is a numerical score assigned to the qualitative rakings of H, M, L, and NI (no impact).

Qualitative Ranking	Ranking Score (RS)
H	4
[illegible]	3
	1.5
NI (no impact)	0

α_m Data availability coefficient (1 when data is provided by utility, 0 otherwise).

RS_{max} Maximum possible Ranking Score. The maximum value is equal to the score of a qualitative ranking of "H"; in this case the numerical value is 4.

The numerical percentage of degree of impact (DI) is then translated into a singular, qualitative ranking as per the following:

Degree of Impact (%)	Qualitative Rating
< 10%	NI
10% – 44%	L
45% - 78%	M
79% - 100%	H

Consider, for example, the Mechanical Stress for Fully Dressed Concrete Poles. Three of six utilities provided qualitative rankings, as shown on the "Qualitative Ranking" column. The numerical scores for each of the rankings are shown on the "Ranking Score RS" column. The data availability coefficient and maximum ranking score are also shown.

Utility	Qualitative Ranking	Ranking Score RS	α	Maximum Ranking Score (RS_{max})
Utility 1	n/a	n/a	0	n/a
Utility 2	H	4	1	4
Utility 3	n/a	n/a	0	n/a
Utility 4	n/a	n/a	0	n/a
Utility 5	M	3	1	3
Utility 6	H	4	1	4

For the above data, the Degree of Impact (DI) = (0 + 1*4 + 0 + 0 + 1*3 + 1*4) / (0 + 1*4 + 0 + 0 + 1*4 + 1*4) = 92%. A score of 92% translates to a ranking of high (H). Thus, as per the utility interviews, Mechanical Stress has a high impact on the useful lives of concrete poles.

E - 2 INDUSTRY RESEARCH

Kinectrics compiled degradation and useful life data from several different sources to develop what Kinectrics refers to as the "industry" values for TUL, MIN UL and MAX UL in the tables provided in Section H – APPENDIX – DERIVATION OF USEFUL LIVES. These sources are:

- Industry statistics
- Information provided by manufacturers
- Research studies and reports by individuals and corporate entities, such as universities, utilities, research organizations, etc.
- Research studies conducted by working groups of international organizations such as CIGRE, EPRI, etc.
- Kinectrics applied its own extensive expertise in failure investigations conducted for many utilities across North America, knowledge gained from numerous completed Asset Condition Assessment project that involved determining appropriate EOL for different assets, testing of distribution assets and their components, and IFRS studies performed for many large Ontario LDCs.

All the sources are listed in Section J - REFERENCES of this Report.

E - 3 UTILITY INTERVIEWS

Kinectrics interviewed staff members from six utilities across Ontario. The utilities were selected in conjunction with OEB staff and the sample represents a good cross-section of Ontario's distributors based on their size, geographical location, and asset mix as follows:

- One utility from GTA
- One utility from the Niagara Escarpment Region
- One utility from South Western Ontario
- One utility from Eastern Ontario
- Two utilities from Northern Ontario

The interviews were focused on obtaining information from the utilities technical staff regarding:

- Appropriateness of the assets/components break down
- Utility-specific TUL, MIN UL and MAX UL
- Utilization factors affecting the above values

Actual asset failure information was not available so utility staff relied on existing age distribution information when available, hands-on field experience or budgetary forecasting experience to provide the required information. The utilities sampled had a good grasp of the challenge related to establishing realistic useful life and their responses were based on the mix of available data, actual experience and informed judgment.

E - 4 COMBINING INDUSTRY RESEARCH AND UTILITY INTERVIEW FINDINGS

Industry research was combined with interview results to ensure that the recommended values, although still based on the industry-wide experience, properly reflect Ontario's perspective.

The more utilities that provided input regarding a certain asset, the more weight utility input was given in arriving at the overall TUL, MIN UL and MAX UL as shown in the table below:

Number of Utility Inputs	Ontario Weight	Industry Weight
6	50%	50%
5	42%	58%
4	33%	67%
3	25%	75%
2	16%	84%
1	4%	96%

The overall values shown in the summary tables in Section F and H incorporate the logic described in the above table.

The summary of the results of combining both industry research and Ontario LDC survey findings is provided in Table F-1 of this Report for TUL, MIN UL and MAX UL along with summary assessments by the distributors of the impact of UFs on useful lives. A detailed description of degradation mechanism(s), TUL, MIN UL, MAX UL and UFs for each asset category and component is provided in Section H of this Report. Recommended ranges for the Minor Assets that do not fall under any of the "parent" systems are provided in the Table F-2.

E - 5 EXAMPLE OF USING THE REPORT

Following is an example demonstrating how an appropriate depreciation period could be selected by a utility for Power Transformers:

1. TUL from either Table F-1 in Section 0 or the detailed description in Section 12 of Section H- APPENDIX - DERIVATION OF USEFUL LIVES for the overall Fully Dressed Pole is 45 years, with MIN UL and MAX UL at 30 and 60 years, respectively.

2. The UFs are as follows:
   - Mechanical Stress – no impact
   - Electrical Stress – medium impact
   - Environmental Conditions – medium impact
   - Operating Practices – low impact
   - Maintenance Practices – low impact
   - Non-Physical Factors – no impact

3. A utility may select an appropriate depreciation period based on the specific UFs reflecting the actual utility conditions. For example, if electrical stress is not significant (lightly loaded transformer), environment in terms of pollution or weather extremes is not very harsh, the units are regularly maintained, and tap changers are operated not very frequently, the utility could select a depreciation period above the TUL but below MAX UL, say 50 years. Should the conditions and factors be more severe, the depreciation period chosen by the utility may be less than the TUL shown, (e.g., 40 years).

4. As more information is accumulated over time (e.g., several years of failure history), a utility may decide to adjust the depreciation period based on empirical information to better reflect its specific circumstances.

The decision on whether TUL should be the same as the one in the table or whether it should be shortened or prolonged and by how much is not an exact science and depends on the informed judgment of the utility's technical staff and the utility's approach to life cycle cost management.

Although the values provided in this study for the UFs are those that underwrite TUL in each case, statistical analysis described in Section E-6 suggests that there is between 67% and 91% probability that the selected depreciation period will fall within the prescribed range (i.e., between MIN UL and MAX UL). Therefore, it is possible that the selected depreciation period could be outside of the Min UL or Max UL provided in this report depending on the impact of the various UFs. In such cases, and particularly if the depreciation period is significantly longer or shorter than the recommended TUL, a utility's auditors and the OEB will likely require the utility to explain with more rigour the reasons for selecting the particular depreciation period.

E - 6 STATISTICAL ANALYSIS

Once Kinectrics determined the useful life values of TUL, MIN UL, and MAX UL using industry and Ontario LDC information, Kinectrics performed a statistical analysis to estimate what percentage of assets is expected to fall between MIN UL and MAX UL. A detailed description of the methodology is presented in APPENDIX I – PERCENT OF ASSETS IN THE USEFUL LIFE RANGE of this Report. The following assumptions were made in the analysis:

1. EOL distribution for all the assets is uni-modal with the peak potentially skewed towards MIN UL or MAX UL depending on the asset category/component.

2. The value corresponding to the peak of failure density function is the same as TUL.

3. In defining the useful life range, the MIN UL and MAX UL are within ($\sqrt{3}$ times standard deviation σ) from the mean value μ of the useful life distribution, regardless of where TUL is relative to the mean value μ.

4. For any specific asset category/component TUL always lies within the useful life range.

Based on these assumptions, the percentage of assets with useful life within the range between MIN UL and MAX UL is found to be equal to 91% for a normally distributed useful life (i.e., TUL is the same as the mean value). If the useful life distribution is not normal (i.e., TUL is not the same as the mean value) the percentage of assets within the range between MIN UL and MAX UL will be less than 91% but more than the minimum value of 67%.

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F SUMMARY OF RESULTS

Table F - 1 summarizes useful lives, and factors impacting those lives as developed by this report.

Table F - 1 Summary of Componentized Assets, Service Life and Factors

PARENT*	#	ASSET DETAILS			USEFUL LIFE			FACTORS **					
		Category| Component | Type			MIN UL	TUL	MAX UL	MC	EL	EN	OP	MP	NPF
OH	1	Fully Dressed Wood Poles	Overall		35	45	75	H	L	M	NI	L	L
			Cross Arm	Wood	20	40	55						
				Steel	30	70	95						
	2	Fully Dressed Concrete Poles	Overall		50	60	80	H	L	M	NI	L	NI
			Cross Arm	Wood	20	40	55						
				Steel	30	70	95						
	3	Fully Dressed Steel Poles	Overall		60	60	80	H	M	L	NI	L	NI
			Cross Arm	Wood	20	40	55						
				Steel	30	70	95						
	4	OH Line Switch			30	45	55	L	L	L	L	M	L
	5	OH Line Switch Motor			15	25	25	L	NI	L	L	M	L
	6	OH Line Switch RTU			15	20	20	NI	NI	L	L	L	M
	7	OH Integral Switches			35	45	60	L	M	M	M	L	H
	8	OH Conductors			50	60	75	M	L	M	NI	NI	L
	9	OH Transformers & Voltage Regulators			30	40	60	L	M	M	NI	NI	M
	10	OH Shunt Capacitor Banks			25	30	40	-	-	-	-	-	-
	11	Reclosers			25	40	55	L	L	L	M	L	M
TS & MS	12	Power Transformers	Overall		30	45	60	NI	M	M	L	L	NI
			Bushing		10	20	30						
			Tap Changer		20	30	60						
	13	Station Service Transformer			30	45	55	NI	L	M	L	NI	L
	14	Station Grounding Transformer			30	40	40	-	-	-	-	-	-
	15	Station DC System	Overall		10	20	30	NI	M	L	L	M	M
			Battery bank		10	15	15						
			Charger		20	20	30						
	16	Station Metal Clad Switchgear	Overall		30	40	60	L	L	M	M	M	M
			Removable Breaker		25	40	60						
	17	Station Independent Breakers			35	45	65	M	M	M	M	M	M
	18	Station Switch			30	50	60	M	L	M	M	M	L

* OH = Overhead Lines System **TS & MS = Transformer and Municipal Stations**
** MC = Mechanical Stress EL = Electrical Loading OP = Operating Practices EN = Environmental Conditions
MP = Maintenance Practices NPF=Non-Physical Factors
H=High M=Medium L=Low NI=No Impact

PARENT*	#	ASSET DETAILS		USEFUL LIFE			FACTORS **					
		Category| Component | Type		MIN UL	TUL	MAX UL	MC	EL	EN	OP	MP	NPF
TS & MS	19	Electromechanical Relays		25	35	50	NI	NI	NI	NI	NI	H
	20	Solid State Relays		10	30	45	NI	NI	NI	NI	NI	H
	21	Digital & Numeric Relays		15	20	20	NI	NI	NI	NI	NI	H
	22	Rigid Busbars		30	55	60	L	L	L	NI	NI	L
	23	Steel Structure		35	50	90	L	NI	M	NI	NI	L
UG	24	Primary Paper Insulated Lead Covered (PILC) Cables		60	65	75	L	L	M	L	NI	M
	25	Primary Ethylene-Propylene Rubber (EPR) Cables		20	25	25	NI	M	L	NI	NI	NI
	26	Primary Non-Tree Retardant (TR) Cross Linked Polyethylene (XLPE) Cables Direct Buried		20	25	30	M	M	M	L	L	L
	27	Primary Non-TR XLPE Cables In Duct		20	25	30	M	M	M	L	L	M
	28	Primary TR XLPE Cables Direct Buried		25	30	35	M	M	M	L	L	L
	29	Primary TR XLPE Cables In Duct		35	40	55	M	M	M	L	L	L
	30	Secondary PILC Cables		70	75	80	NI	L	L	NI	NI	H
	31	Secondary Cables Direct Buried		25	35	40	M	M	M	L	NI	NI
	32	Secondary Cables In Duct		35	40	60	M	M	M	L	NI	NI
	33	Network Transformers	Overall	20	35	50	NI	L	H	NI	NI	NI
			Protector	20	35	40						
	34	Pad-Mounted Transformers		25	40	45	L	M	M	NI	L	L
	35	Submersible/Vault Transformers		25	35	45	L	M	M	NI	L	L
	36	UG Foundations		35	55	70	M	NI	M	L	L	M
	37	UG Vaults	Overall	40	60	80	M	NI	M	L	L	L
			Roof	20	30	45						
	38	UG Vault Switches		20	35	50	L	L	L	L	L	NI
	39	Pad-Mounted Switchgear		20	30	45	L	L	H	L	L	L
	40	Ducts		30	50	85	H	NI	M	NI	NI	L
	41	Concrete Encased Duct Banks		35	55	80	M	NI	M	NI	NI	L
	42	Cable Chambers		50	60	80	M	NI	H	NI	L	NI
S	43	Remote SCADA		15	20	30	NI	NI	L	NI	L	H

* **TS & MS = Transformer and Municipal Stations** UG = Underground Systems **S = Monitoring and Control Systems**
** MC = Mechanical Stress EL = Electrical Loading OP = Operating Practices EN = Environmental Conditions
MP = Maintenance Practices NPF=Non-Physical Factors
H=High M=Medium L=Low NI=No Impact

Table F - 2 summarizes useful life ranges for Ontario's Local Distribution Companies' non-distribution assets. Table F - 2 contains assets that were not studied in detail in this analysis and represent recommended ranges based on the experience of Ontario LDCs interviewed. A further analysis of these assets is not considered necessary.

Table F - 2 Summary Useful Life of Minor Assets

#	ASSET DETAILS Category - Component - Type		USEFUL LIFE RANGE
1	Office Equipment		5-15
2	Vehicles	Trucks & Buckets	5-15
		Trailers	5-20
		Vans/Cars	5-10
3	Administrative Buildings		50-75
4	Leasehold Improvements		Lease dependent
5	Station Buildings	Station Building	50-75
		Parking	25-30
		Fence	25-60
		Roof	20-30
6	Computer Equipment	Hardware	3-5
		Software	2-5
7	Equipment	Power Operated	5-10
		Stores	5-10
		Tools, Shop, Garage Equipment	5-10
		Measurement & Testing Equipment	5-10
8	Communication	Towers	60-70
		Wireless	2-10
9	Residential Energy Meters		25-35
10	Industrial/Commercial Energy Meters		25-35
11	Wholesale Energy Meters		15-30
12	Current & Potential Transformer (CT & PT)		35-50
13	Smart Meters		5-15
14	Repeaters - Smart Metering		10-15
15	Data Collectors - Smart Metering		15-20

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G CONCLUSIONS

This Report provides reference information that will assist Ontario's electrical distribution utilities in selecting appropriate useful lives for typical distribution asset categories. The ultimate decision on what the appropriate useful lives are lies with utilities and they are expected to justify their selection based on the local circumstances vis-à-vis utilization factors that affect TUL and other relevant considerations such as empirical data and manufacturers recommendations.

This Report combines available industry information, Kinectrics expertise and survey results from 6 of Ontario's LDC. Thus, Kinectrics considers that the total service lives recommended are sufficiently reliable so that another independent expert would reasonably arrive at the same conclusion. Nevertheless, it is expected that for most asset categories/components TUL, and thus the selected depreciation period, will vary among utilities..,. The utility should be prepared and be able to provide a rationale for selecting a particular depreciation period based on the information in this Report and the utility's specific experience.

Asset categories and their componentization as presented in this report represent typical assets componentization in Ontario. In most cases utilities will only have a subset of the asset categories included in the Report. Furthermore, utilities may choose not to have some of the asset categories componentized as suggested in this Report and have depreciation tracked at the asset level.

In the course of our work Kinectrics identified several areas for improvement that, once addressed, should enhance distributors' ability to improve the accuracy of their determination of asset service lives. At the present time most distributors have limited data available on actual asset retirement history. One consequence of this is that the range of asset service lives from minimum to maximum tends to be broader that it would be if reliable asset retirement histories were available. To improve the overall process of managing depreciation cost, from this study Kinectrics concludes there is a need:

- For distributors to improve availability of asset retirement records that identify both the end of life and its causes (e.g., failures, non-physical factors (obsolescence), high risk of failure, etc).
- For ongoing comparison of the depreciation period selected with actual physical useful lives based on empirical evidence.
- To gather data to support probability of failure curves for assets that are run to failure.
- To consider whether there are other Utilization Factors that have significance and develop ways to quantify their impacts on Typical Useful Life.
- For distributors to acquire and maintain planned and corrective maintenance records in a manner that can be easily accessed and analyzed.
- To develop and maintain a record of assets replaced as a result of major projects (e.g., road widening or voltage conversion).

The depreciation periods selected are expected to be reviewed periodically and adjusted if and when required based on the knowledge and experience gained in the future.

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H APPENDIX - DERIVATION OF USEFUL LIVES

A results section has been created for each asset category. Each includes:

Description - The description of the asset category including componentization, design configurations, alternative design configurations and system hierarchy. For some assets their attributes such as type and material (e.g. wood poles) or interrupting mechanism (e.g. reclosers) were also mentioned. In such cases, although these attributes may result in useful lives being somewhat different, the useful lives information provided in this Report is for the overall asset category and Kinectrics recommends not breaking these asset categories down further based on their attributes.

1. Degradation Mechanism – A discussion of the degradation mechanism including end of life criteria. This describes physical EOL referred to in Section E-1 - DEFINITIONS.

2. Useful Life - The useful life values (MIN UL, TUL and MAX UL) for the asset and their respective components. This section presents both industry and survey values as well as the combined values.

3. Impact of Utilization Factors – This section discusses the factors (UFs) impacting useful life and includes qualitative degree of impact based on the utilities surveyed. If utilities considered the TUL to be impacted by a factor, they rated the magnitude of the impact on a scale of high, medium or low (displayed on the graph as red, orange and yellow, respectively). For the case where utilities felt that the factor has no impact on the TUL the space is left light gray. Finally, "No Response" is displayed as dark grey and signifies that one or more utility did not provide information for that asset.

Please refer to Table F - 1 for a summary of these results.

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1. Fully Dressed Wood Poles

1.1 Description

The asset referred to in this category is the fully dressed wood pole ranging in size from 30 to 75 feet. This includes the wood pole, cross arm, bracket, insulator, cutouts, arresters, and anchor and guys. Wood poles are typically the most common form of support for overhead distribution feeders and low voltage secondary lines.

1.1.1 Componentization Assumptions

For the purposes of this report, the Fully Dressed Wood Poles asset category has been componentized so that the cross arm can be regarded as a separate component. Therefore the Fully Dressed Wood Pole has overall useful life values based on the useful life of the pole itself, and useful life values for the cross arm component.

The most significant component of this asset is the wood pole itself. The wood species predominately used for distribution systems are Red Pine, Jack Pine, and Western Red Cedar (WRC), either butt treated or full length treated. Smaller numbers of Larch, Fir, White Pine and Southern Yellow Pine have also been used. Preservative treatments applied prior to 1980, range from none on some WRC poles, to butt treated and full length Creosote or Pentachlorophenol (PCP) in oil. The present day treatment, regardless of species, is CCA-Peg (Chromated Copper Arsenate, in a Polyethylene Glycol solution). Other treatments such as Copper Naphthenate and Ammoniacal Copper Arsenate have also been used, but these are relatively uncommon.

1.1.2 System Hierarchy

Fully Dressed Wood Poles are considered to be a part of the Overhead Lines asset grouping.

1.2 Degradation Mechanism

The end of life criteria for wood poles includes loss of strength, functionality, or safety (typically due to rot, decay, or physical damage). As wood is a natural material the degradation processes are somewhat different from those which affect other physical assets on the electricity distribution systems. The critical processes are biological, involving naturally occurring fungi that attack and degrade wood, resulting in decay. The nature and severity of the degradation depends both on the type of wood and the environment. Some fungi attack the external surfaces of the pole and some the internal heartwood. Therefore, the mode of degradation can be split into either external rot or internal rot. Wood poles can also be degraded by damage inflicted by woodpeckers, and insects such as carpenter ants. As a structural item the sole concern when assessing the condition for a wood pole is the reduction in mechanical strength due to degradation or damage.

1.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Fully Dressed Wood Poles are displayed in Table 1-1.

Table 1-1 Useful Life Values for Fully Dressed Wood Poles

ASSET COMPONENTIZATION		USEFUL LIFE (years)		
		MIN UL	TUL	MAX UL
Overall		35	45	75
Cross Arm	Wood	20	40	55
	Steel	30	70	95

1.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Fully Dressed Wood Poles. All six of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Fully Dressed Wood Poles (Figure 1-1). For the cross arm component, five of the Utilities gave MIN UL, TUL and MAX UL Values for Wood Cross Arms (Figure 1-2) and two of the Utilities gave MIN UL, TUL and MAX UL Values for Steel Cross Arms (Figure 1-3).

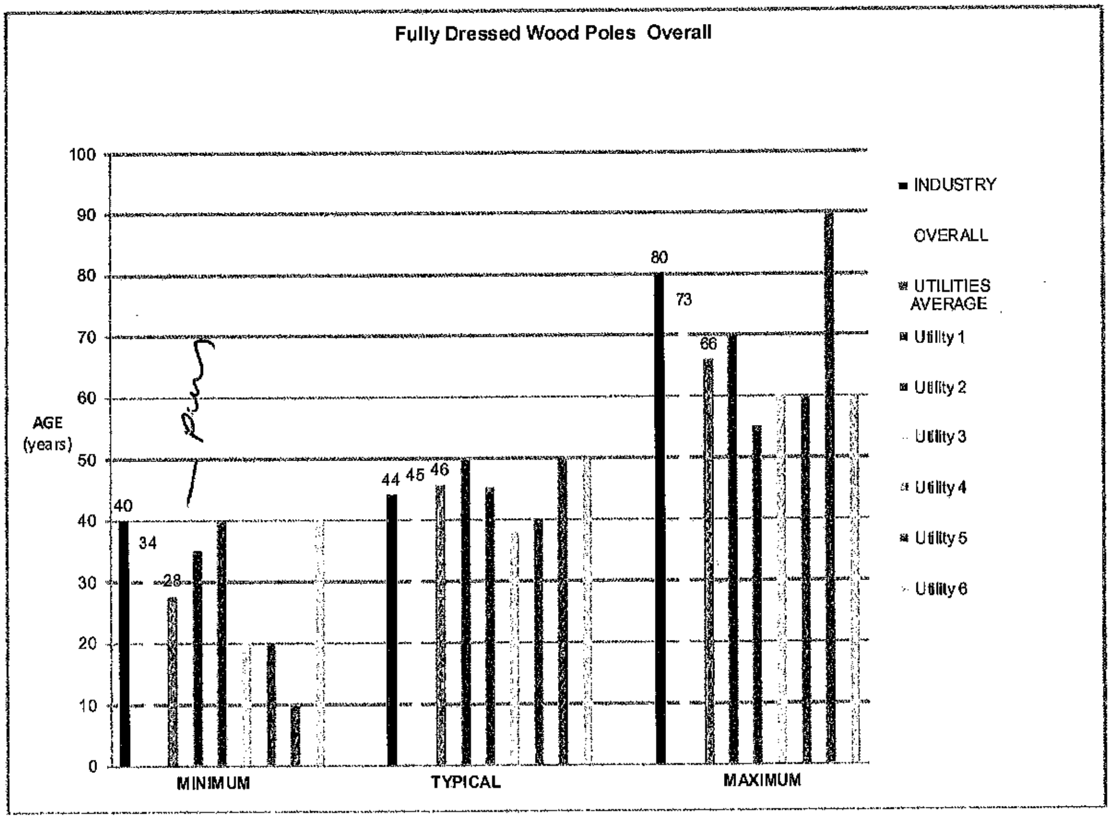


Figure 1-1 Useful Life Values for Fully Dressed Wood Poles

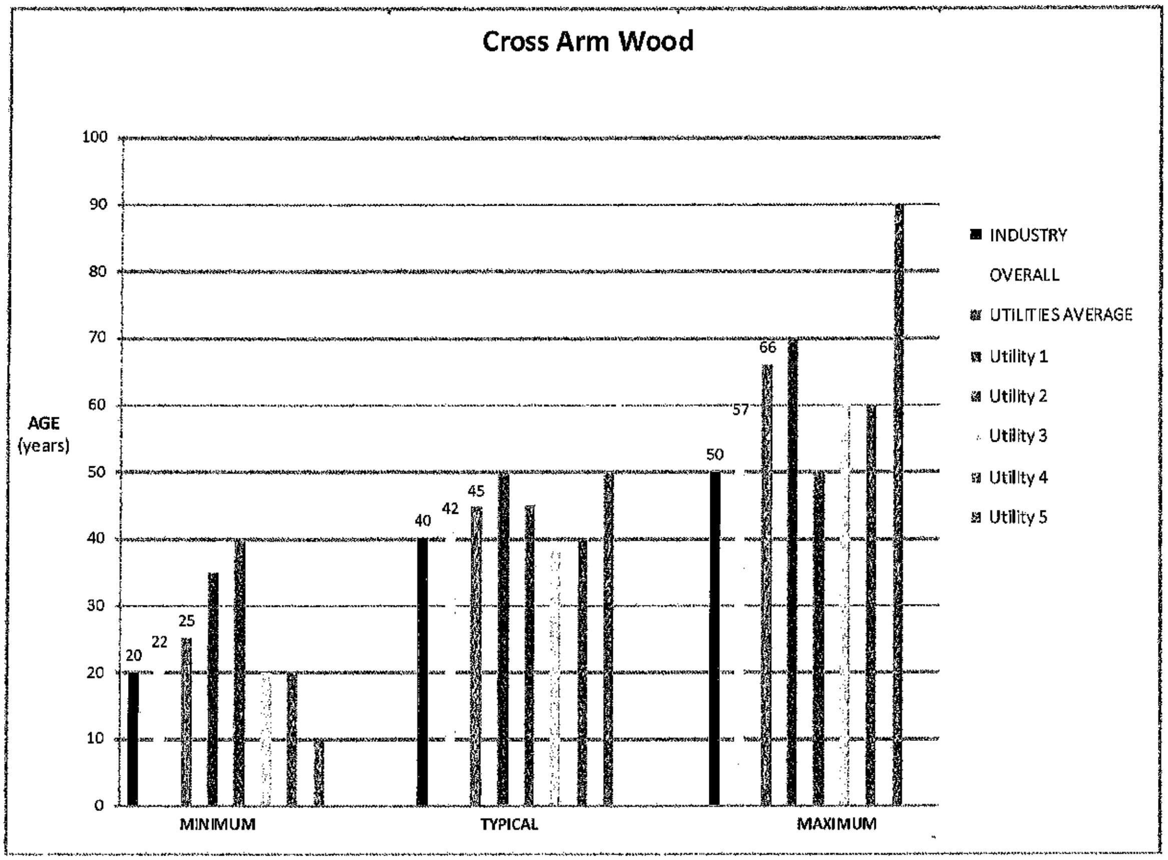


Figure 1-2 Useful Life Values for Fully Dressed Wood Poles – Cross Arm – Wood

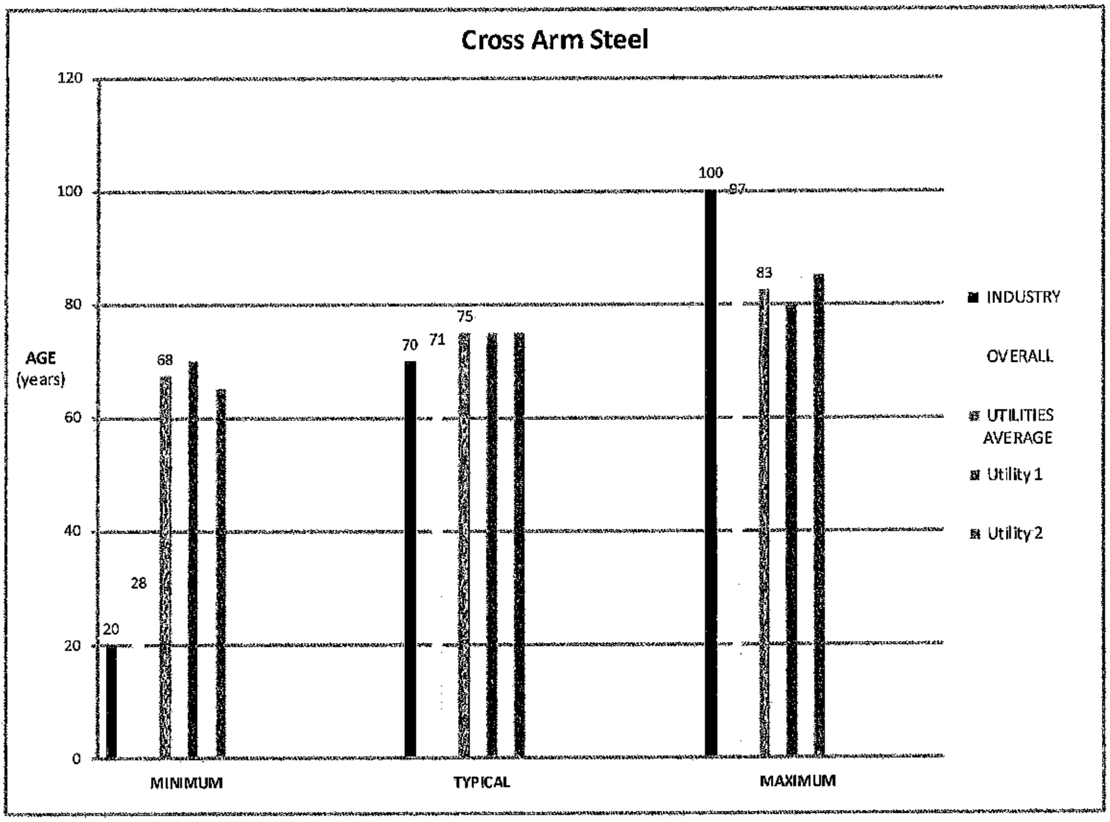


Figure 1-3 Useful Life Values for Fully Dressed Wood Poles – Cross Arm - Steel

1.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Fully Dressed Wood Poles are displayed in Table 1-2.

Table 1-2 - Composite Score for Fully Dressed Wood Poles

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	100%	13%	75%	0%	19%	31%
Overall Rating*	H	L	M	NI	L	L

* H = High Impact M = Medium Impact L = Low Impact NI = No Impact

1.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Fully Dressed Wood Poles. All six of the interviewed utilities provided their input regarding the UFs for Fully Dressed Wood Poles (Figure 1-4). The UFs impacts were the same for poles and cross-arms.

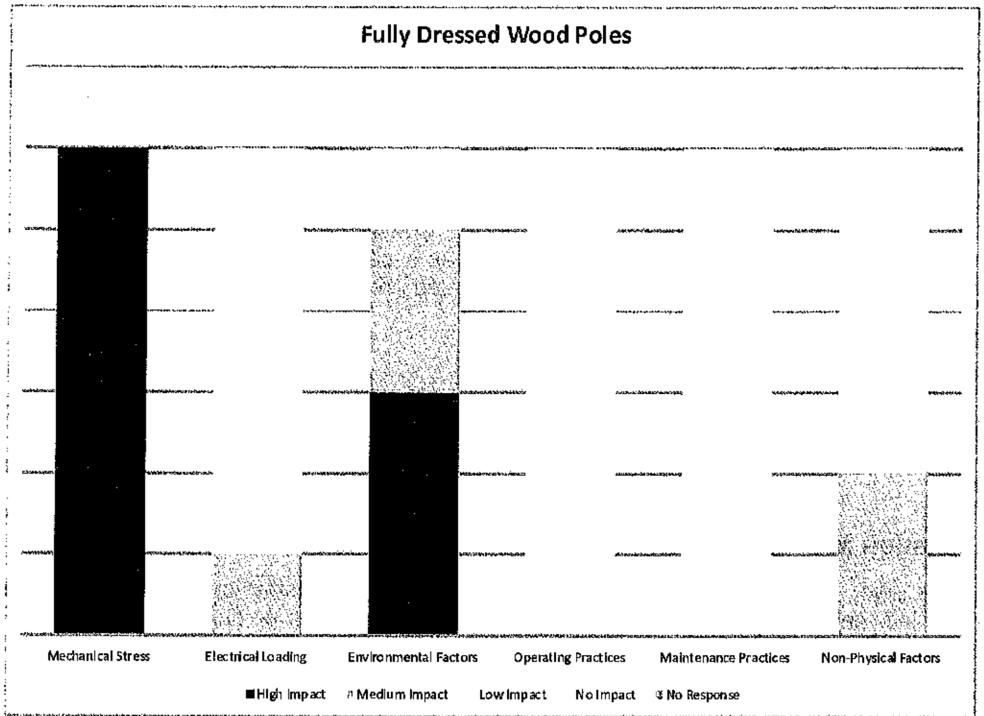


Figure 1-4 Impact of Utilization Factors of the Useful Life of Fully Dressed Wood Poles

2. Fully Dressed Concrete Poles

2.1 Description

The asset referred to in this category is the fully dressed concrete pole ranging in size from 30 to 75 feet. This includes the concrete pole, cross arm, bracket, insulator, cutouts, arresters, and anchor and guys. Concrete poles are a common form of support for overhead distribution feeders particularly in urban utilities.

2.1.1 Componentization Assumptions

For the purposes of this report, the Fully Dressed Concrete Poles asset category has been componentized so that the cross arm can be regarded as a separate component. Therefore the Fully Dressed Concrete Pole has an overall useful life value based on the useful life of the pole itself, and also a useful life value for the cross arm component.

2.1.2 System Hierarchy

Fully Dressed Concrete Poles are considered to be a part of the Overhead Lines asset grouping.

2.2 Degradation Mechanism

Concrete poles age, as do other concrete structures, by mechanisms such as moisture ingress, freeze/thaw cycles, and chemical erosion. Moisture ingress into cracks or concrete pores can result in freezing during the winter and damage to concrete surface. Road salt spray can further accelerate the degradation process and lead to concrete spalling. Typical concrete mixes employ a washed-gravel aggregate and have extremely high resistance to downward compressive stresses (about 3,000 lb/sq in); however, any appreciable stretching or bending (tension) will break the microscopic rigid lattice, resulting in cracking and separation of the concrete. The spun concrete process used in manufacturing poles prevents moisture entrapment inside the pores. Spun, pre-stressed concrete is particularly resistant to corrosion problems common in a water-and-soil environment.

2.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Fully Dressed Concrete Poles are displayed in Table 2-1.

Table 2-1 Useful Life Values for Fully Dressed Concrete Poles

ASSET COMPONENTIZATION		USEFUL LIFE (years)		
		MIN UL	TUL	MAX UL
Overall		50	60	80
Cross Arm	Wood	20	40	55
	Steel	30	70	95

2.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Fully Dressed Concrete Poles. Two of the interviewed utilities gave MIN UL Values and three of the interviewed utilities gave TUL and MAX UL Values for Fully Dressed Concrete Poles (Figure 2-1 Useful Life Values for Fully Dressed Concrete Poles). For the cross arm component, refer to Section 1.3.1 for Fully Dressed Wood Poles.

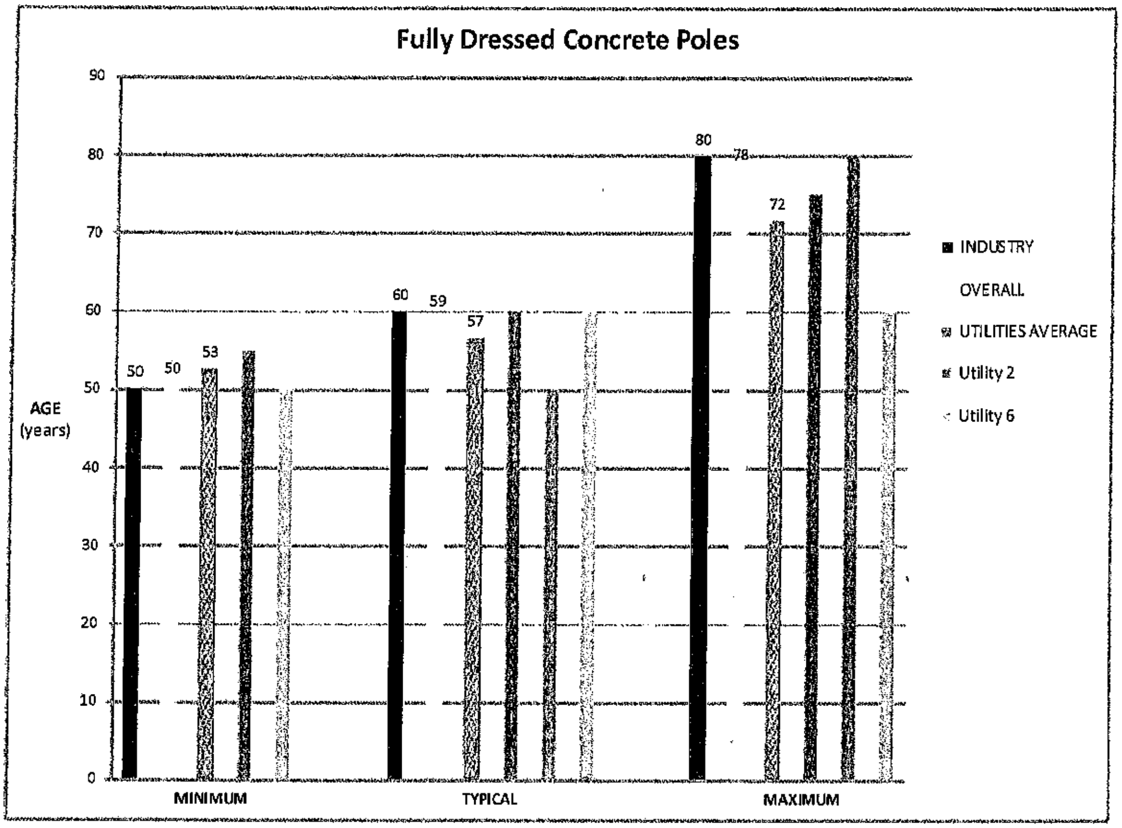


Figure 2-1 Useful Life Values for Fully Dressed Concrete Poles

2.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Fully Dressed Concrete Poles are displayed in Table 2-2.

Table 2-2 - Composite Score for Fully Dressed Concrete Poles

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	92%	25%	58%	0%	13%	0%
Overall Rating*	H	L	M	NI	L	NI
* H = High Impact M = Medium Impact L = Low Impact NI = No Impact						

2.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Fully Dressed Concrete Poles. Three of the interviewed utilities provided their input regarding the UFs for Fully Dressed Concrete Poles (Figure 1-42).

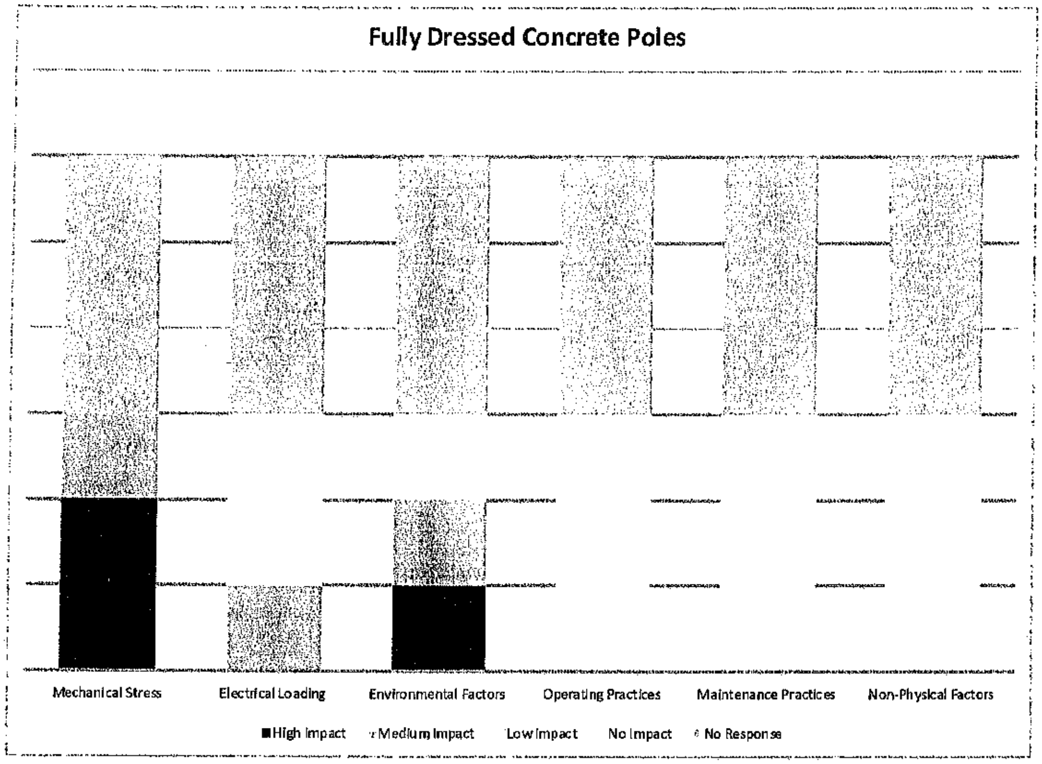


Figure 2-2 Impact of Utilization Factors on the Useful Life of Fully Dressed Concrete Poles

3. Fully Dressed Steel Poles

3.1 Description

The asset referred to in this category is the fully dressed steel pole ranging in size from 30 to 75 feet. This includes the steel pole, cross arm, bracket, insulator, cutouts, arresters, and anchor and guys. Steel poles are an alternative form of support for some overhead distribution feeders, used primarily by urban distribution utilities.

3.1.1 Componentization Assumptions

For the purposes of this report, the Fully Dressed Steel Poles asset category has been componentized so that the cross arm can be regarded as a separate component. Therefore the Fully Dressed Steel Pole has overall useful life values based on the useful life of the pole itself, and separate useful life values for the cross arm component.

3.1.2 System Hierarchy

Fully Dressed Steel Poles are considered to be a part of the Overhead Lines asset grouping.

3.2 Degradation Mechanism

The degradation of directly buried steel poles is mainly due to steel corrosion in-ground and at the ground line. In-ground situations are vastly different from one installation to anther because of the wide local variations in soil chemistry, moisture content and conductivity that will affect the way coated or uncoated steel will perform in the ground. There are two issues that determine the life of buried steel. The first is the life of the protective coating and the second is the corrosion rate of the steel. The item can be deemed to have failed when the steel loss is sufficient to prevent the steel performing its structural function. Where polymer coatings are applied to buried steel items, the failures are rarely caused by general deterioration of the coating. Localized failures due to defects in the coating, pin holing or large-scale corrosion related to electrolysis are common causes of failure in these installations. Metallic coatings, specifically galvanizing, and to a lesser extent aluminum, fail through progressive consumption of the coating by oxidation or chemical degradation. The rate of degradation is approximately linear, and with galvanized coatings of known thickness, the life of the galvanized coating then becomes a function of the coating thickness and the corrosion rate.

3.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Fully Dressed Steel Poles are displayed in Table 3-1.

Table 3-1 Useful Life Values for Fully Dressed Steel Poles

ASSET COMPONENTIZATION		USEFUL LIFE (years)		
		MIN UL	TUL	MAX UL
Overall		60	60	80
Cross Arm	Wood	20	40	55
	Steel	30	70	95

3.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Fully Dressed Steel Poles. Two of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX

UL) Values for Fully Dressed Steel Poles (Figure 3-1). For the cross arm component, refer to Section 1.3.1 for Fully Dressed Wood Poles.

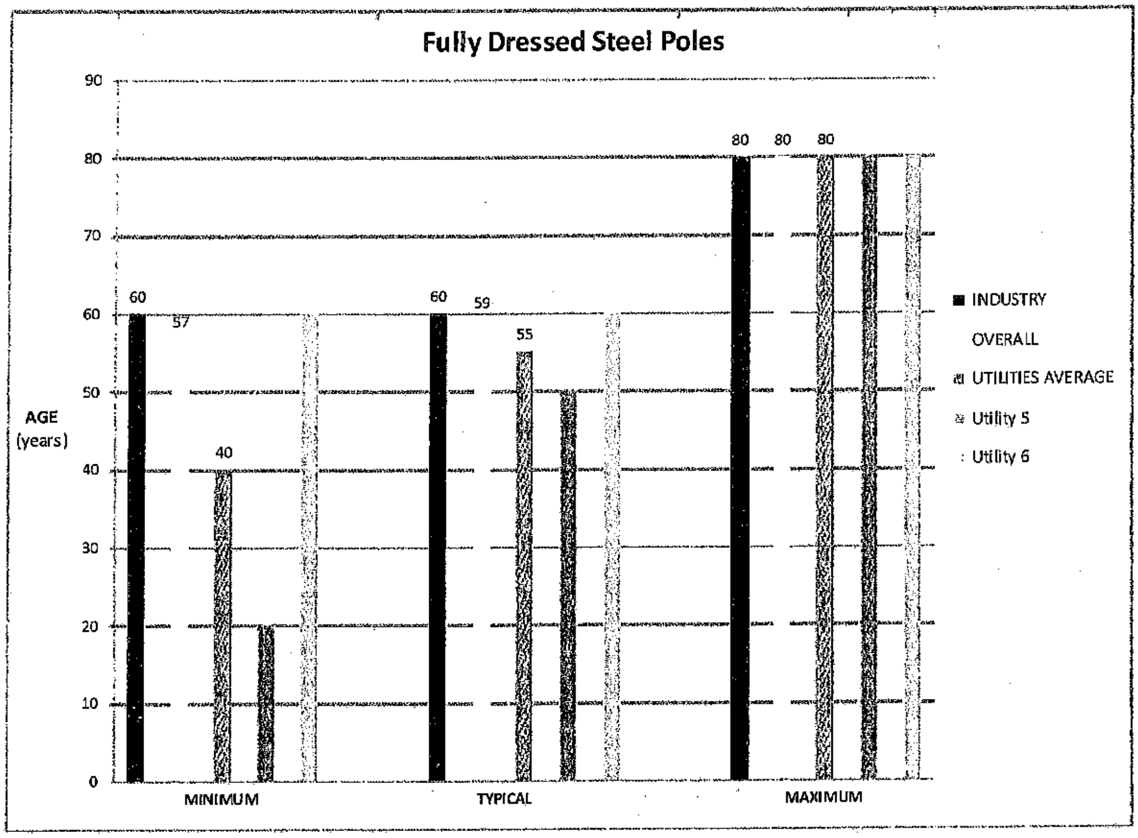


Figure 3-1 Useful Life Values for Fully Dressed Steel Poles

3.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Fully Dressed Steel Poles are displayed in Table 3-2.

Table 3-2 - Composite Score for Fully Dressed Steel Poles

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	88%	56%	38%	0%	19%	0%
Overall Rating*	H	M	L	NI	L	NI

* H= High Impact M = Medium Impact L = Low Impact NI = No Impact

3.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Fully Dressed Steel Poles. Two of the interviewed utilities provided their input regarding the UFs for Fully Dressed Steel Poles (Figure 1-42).

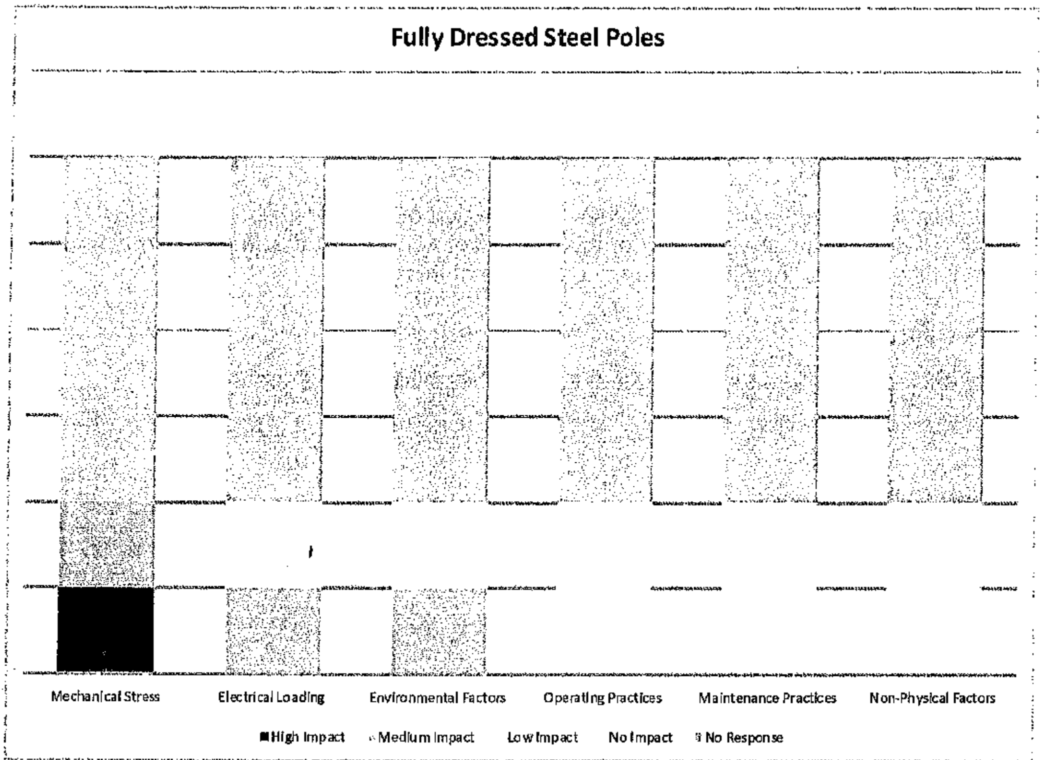


Figure 3-2 Impact of Utilization Factors on the Useful Life of Fully Dressed Steel Poles

4. Overhead Line Switch

4.1 Asset Description

This asset class consists of overhead line switches, focusing primarily on 3-phase outdoor pole-mounted switches but also including in-line switches. The primary function of switches is to allow for isolation of line sections or equipment for maintenance, safety or other operating requirements. The operating mechanism can be either a manual gang operating linkage or a simple hook stick.

4.1.1 Componentization Assumptions

For the purposes of this report, the Overhead Line Switch asset category has not been componentized.

4.1.2 Design Configuration

There are several types of Overhead Line Switches. For the purposes of this report, the types are air, oil, vacuum and gas (SF6). Also for the purpose of this study it is considered that the switch type does not make a significant difference to the degradation or useful life of this asset.

4.1.3 System Hierarchy

Overhead Line Switch is considered to be a part of the Overhead Lines asset grouping.

4.2 Degradation Mechanism

The main degradation processes associated with overhead line switches include the following, with rate and severity depending on operating duties and environment:

- Corrosion of steel hardware or operating rod
- Mechanical deterioration of linkages
- Switch blades falling out of alignment
- Loose connections
- Insulators damage

The rate and severity of these degradation processes depends on a number of inter-related factors including the operating duties and environment in which the equipment is installed. In most cases, corrosion or rust represents a critical degradation process. The rate of deterioration depends heavily on environmental conditions in which the equipment operates. Corrosion typically occurs around the mechanical linkages of these switches. Corrosion can cause seizing. When lubrication dries out, the switch operating mechanism may seize making the disconnect switch inoperable. In addition, when blades fall out of alignment, excessive arcing may result. While a lesser mode of degradation, air pollution also can affect support insulators. Typically, this occurs in heavy industrial areas or where road salt is used.

4.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Overhead Line Switch are displayed in Table 4-1.

Table 4-1 Useful Life Values for Overhead Line Switch

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
OH Line Switch	30	45	55

4.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Overhead Line Switch. All six of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Overhead Line Switch (Figure 4-1).

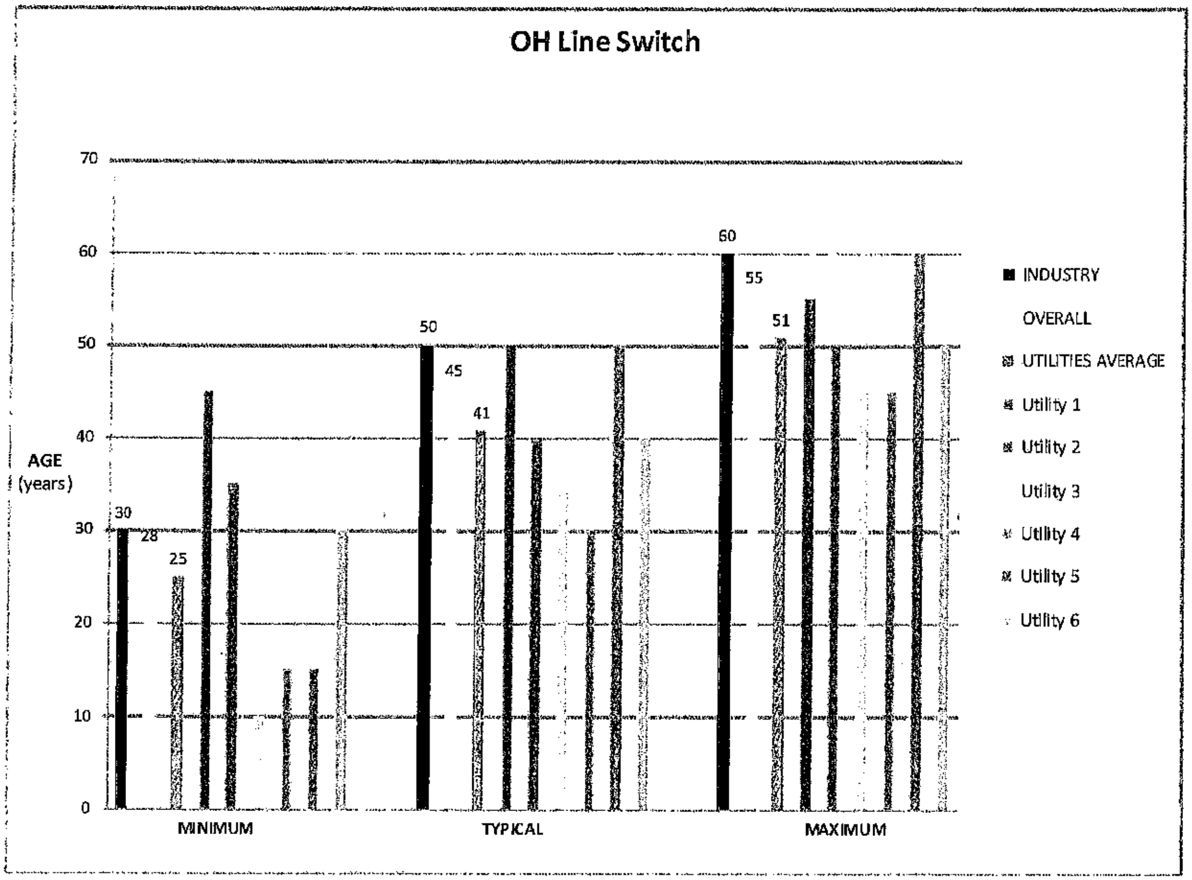


Figure 4-1 Useful Life Values for Overhead Line Switch

4.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Overhead Line Switch are displayed in Table 4-2.

Table 4-2 - Composite Score for Overhead Line Switch

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	35%	25%	35%	44%	65%	42%
Overall Rating*	L	L	L	L	M	L

* H = High Impact   M = Medium Impact   L = Low Impact   NI = No Impact

4.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Overhead Line Switch. All six of the interviewed utilities provided their input regarding the UFs for Overhead Line Switches (Figure 1-42).

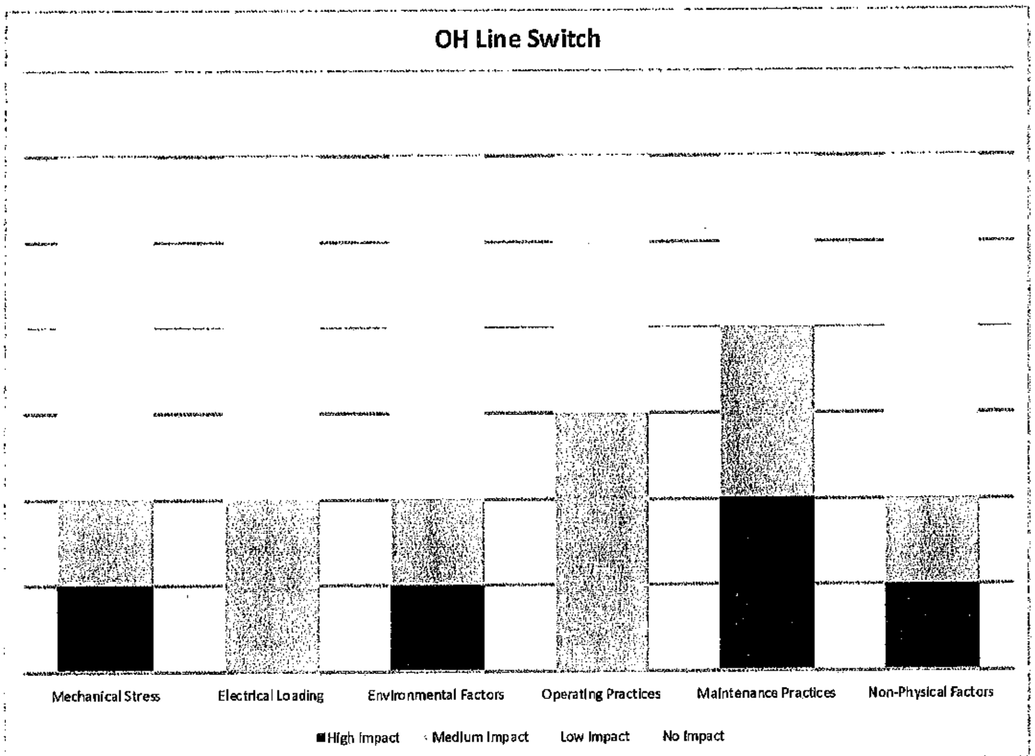


Figure 4-2 Impact of Utilization Factors on the Useful Life of Overhead Line Switch

5. Overhead Line Switch Motor

5.1 Asset Description

This asset class consists of the motor component of overhead line three-phase, gang operated switches. The primary function of switches is to allow for isolation of line sections or equipment for maintenance, safety or other operating requirements. .

5.1.1 Componentization Assumptions

For the purposes of this report, the Overhead Line Switch Motor asset category has not been componentized.

5.1.2 System Hierarchy

Overhead Line Switch Motor is considered to be a part of the Overhead Lines asset grouping.

5.2 Degradation Mechanism

The main degradation processes associated with local motor for operating overhead switches include the following:

- Corrosion of the housing
- Mechanical deterioration of linkages and bearings
- Loose connections
- Winding deterioration

The rate and severity of degradation are a function on operating duties and environment.

5.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Overhead Line Switch Motor are displayed in Table 5-1.

Table 5-1 Useful Life Values for Overhead Line Switch Motor

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
OH Line Switch Motor	15	25	25

5.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Overhead Line Switch Motor. Four of the interviewed utilities gave Minimum and Maximum Useful Life (Min UL and MAX UL) Values and five of the interviewed utilities gave TUL Values for Overhead Line Switch Motor (Figure 5-1).

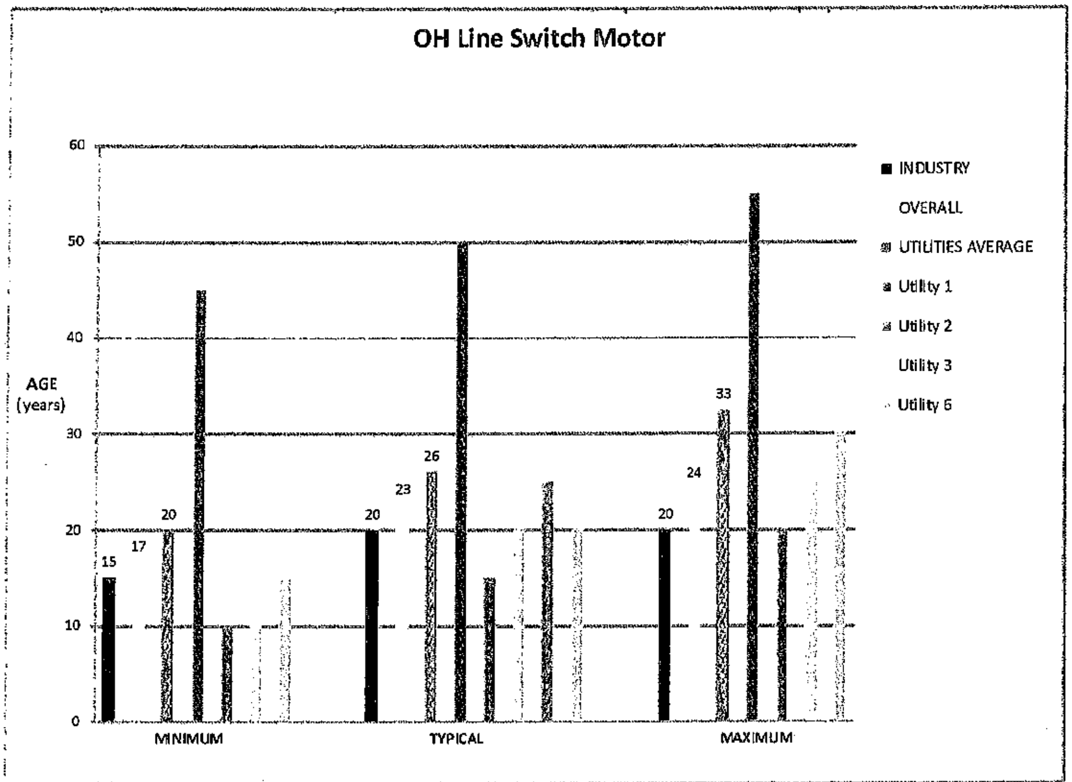


Figure 5-1 Useful Life Values for Overhead Line Switch Motor

5.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Overhead Line Switch Motor are displayed in Table 5-2.

Table 5-2 - Composite Score for Overhead Line Switch Motor

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	35%	0%	20%	30%	50%	33%
Overall Rating*	L	NI	L	L	M	L

* H= High Impact M = Medium Impact L = Low Impact NI = No Impact

5.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Overhead Line Switch Motor. Five of the interviewed utilities provided their input regarding the UFs for Overhead Line Switch Motors (Figure 1-42).

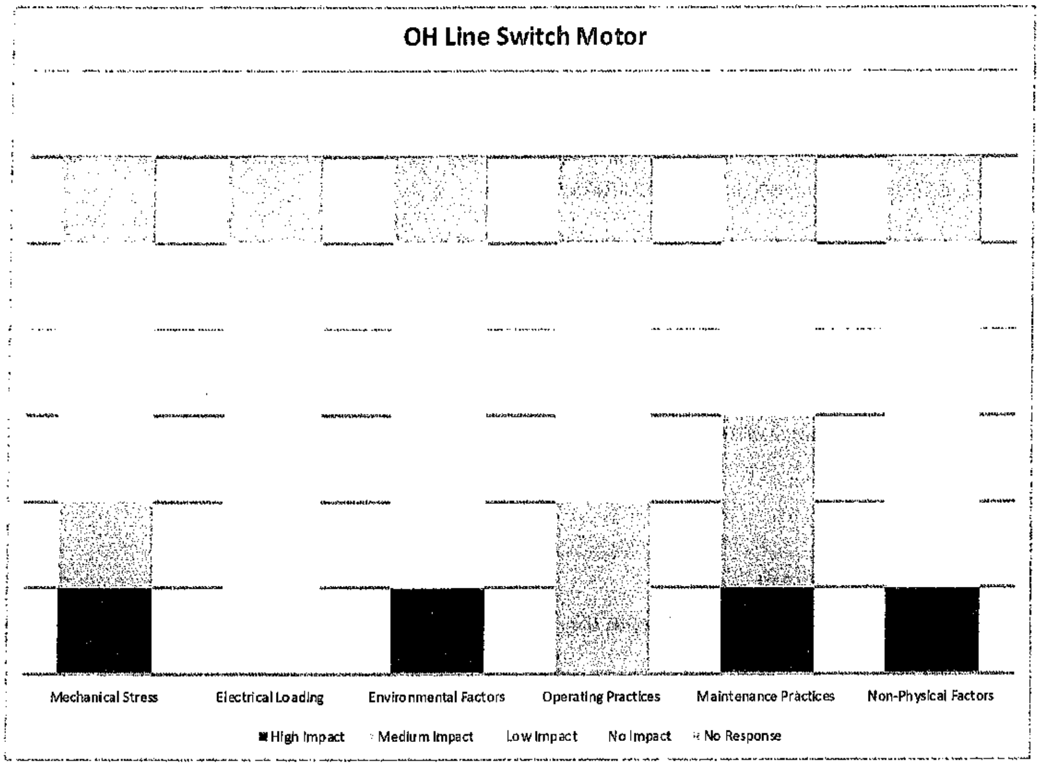


Figure 5-2 Impact of Utilization Factors on the Useful Life of Overhead Line Switch Motor

6. Overhead Line Switch Remote Terminal Unit

6.1 Asset Description

This asset class consists of remote terminal unit (RTU) component of overhead line three-phase, gang operated switches. The primary function of switches is to allow for isolation of line sections or equipment for maintenance, safety or other operating requirements.

6.1.1 Componentization Assumptions

For the purposes of this report, the Overhead Line Switch Remote Terminal Unit asset category has not been componentized.

6.1.2 System Hierarchy

Overhead Line Switch Remote Terminal Unit is considered to be a part of the Overhead Lines asset grouping.

6.2 Degradation Mechanism

The main degradation processes associated with the remote terminal units include the following:

- Corrosion of the housing
- Contamination of the circuitry
- Loose connections
- Failure of electronic components

The rate and severity of degradation are a function on operating duties and environment.

6.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Overhead Line Switch Remote Terminal Unit are displayed in Table 6-1.

Table 6-1 Useful Life Values for Overhead Line Switch Remote Terminal Unit

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
OH Line Switch RTU	15	20	20

6.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Overhead Line Switch Remote Terminal Unit. Four of the interviewed utilities gave Typical and Maximum Useful Life (TUL and MAX UL) Values and five of the interviewed utilities gave MIN UL Values for Overhead Line Switch Remote Terminal Unit (Table 6-1).

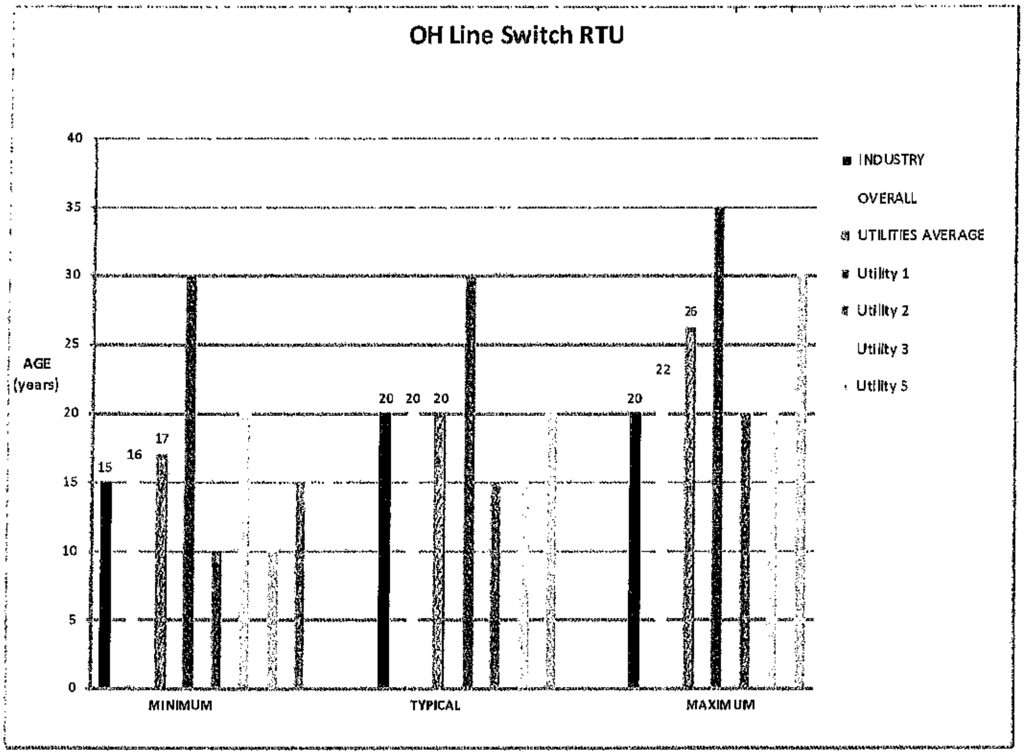


Figure 6-1 Useful Life Values for Overhead Line Switch Remote Terminal Unit

6.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Overhead Line Switch Remote Terminal Unit are displayed in Table 6-2.

Table 6-2 - Composite Score for Overhead Line Switch Remote Terminal Unit

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	0%	0%	28%	15%	30%	75%
Overall Rating*	NI	NI	L	L	L	M

* H = High Impact   M = Medium Impact   L = Low Impact   NI = No Impact

6.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Overhead Line Switch Remote Terminal Unit. Five of the interviewed utilities provided their input regarding the UFs for Overhead Line Switch RTUs (Figure 1-4).

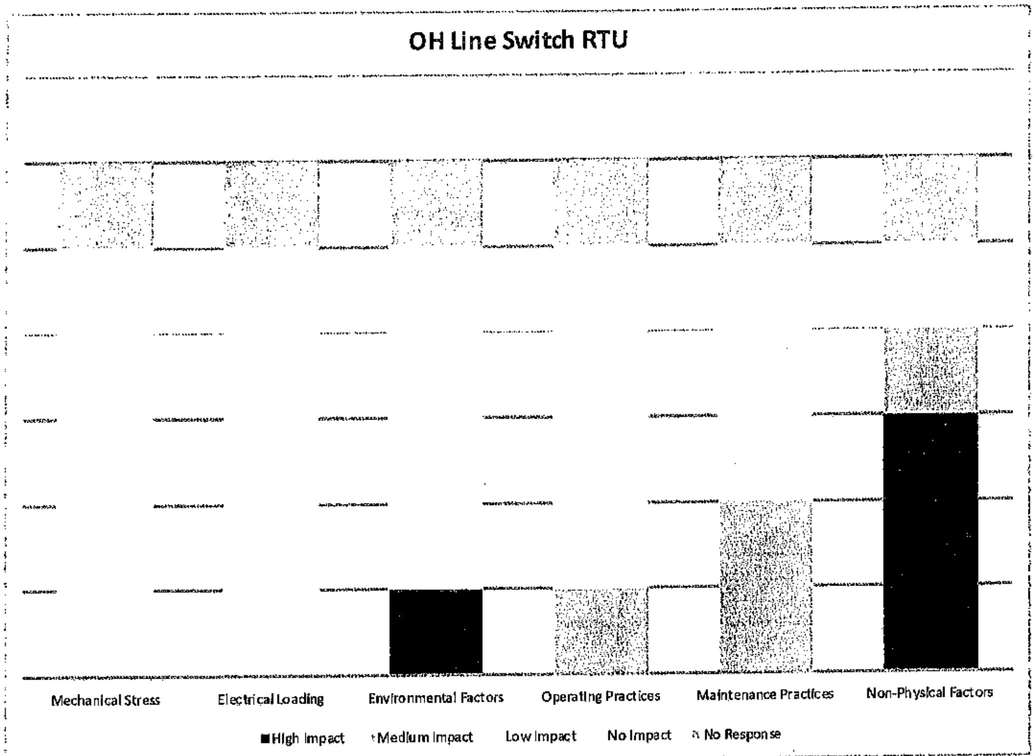


Figure 6-2 Impact of Utilization Factors on the Useful Life of Overhead Line Switch Remote Terminal Unit

7. Overhead Integral Switch

7.1 Asset Description

This asset class consists of integral switches. Integral switches are considered to be overhead line switches with integrated remotely operable opening and closing mechanisms and communication capability that can receive signals from and be monitored by a SCADA system. These units include the switch, communications, and RTU. As with other line switches, this asset allows for the isolation of overhead line sections or equipment for maintenance, safety, and any other operating requirements.

7.1.1 Componentization Assumptions

For the purposes of this report, the Overhead Integral Switch asset category has not been componentized.

7.1.2 System Hierarchy

Overhead Integral Switch is considered to be a part of the Overhead Lines asset grouping.

7.2 Degradation Mechanism

The main degradation processes associated with line switches include those associated with the switch, motor and communication circuitry:

- Corrosion of the housing, hardware and linkages
- Mechanical deterioration of linkages and bearings
- Loose connections
- Motor winding deterioration
- Contamination of the circuitry
- Failure of electronic components
- Switch blades falling out of alignment
- Insulators damage

7.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Overhead Integral Switch are displayed in Table 7-1.

Table 7-1 Useful Life Values for Overhead Integral Switch

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
OH Integral Switches	35	45	60

7.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Overhead Integral Switch. Three of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Overhead Integral Switch (Figure 7-1).

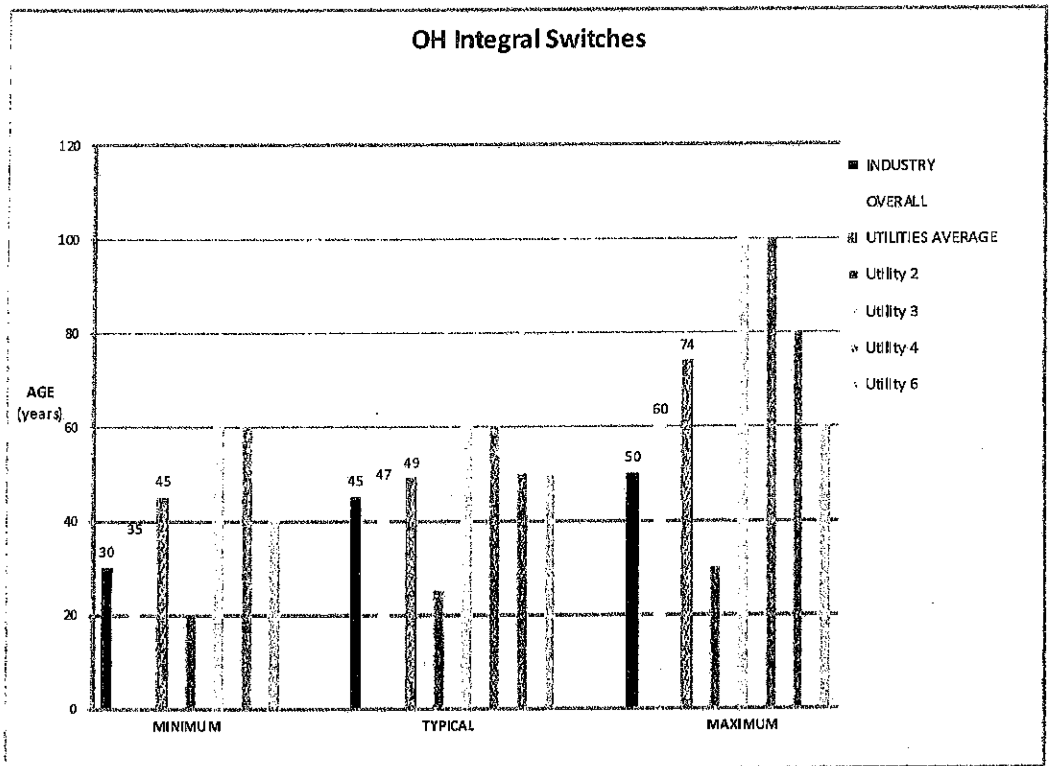


Figure 7-1 Useful Life Values for Overhead Integral Switch

7.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Overhead Integral Switch are displayed in Table 7-2.

Table 7-2 - Composite Score for Overhead Integral Switch

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	13%	50%	46%	67%	25%	100%
Overall Rating*	L	M	M	M	L	H
* H = High Impact	M = Medium Impact		L = Low Impact		NI = No Impact	

7.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Overhead Integral Switch. Three of the interviewed utilities provided their input regarding the UFs for Overhead Integral Switches (Figure 1-42).

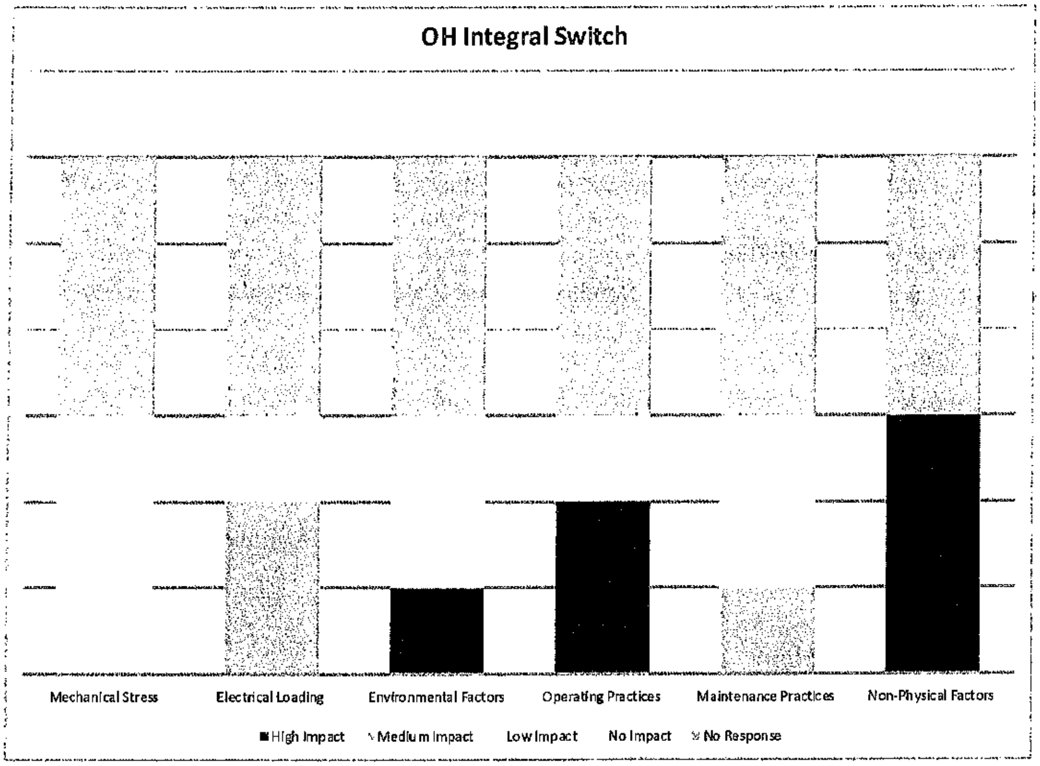


Figure 7-2 Impact of Utilization Factors on the Useful Life of Overhead Integral Switch

8. Overhead Conductors

8.1 Asset Description

Overhead conductors along with structures that support them constitute overhead lines or feeders that distribute electrical energy to customers from the distribution or transmission station. These conductors are sized to carry a specified maximum current and to meet other design criteria, i.e. mechanical loading.

8.1.1 Componentization Assumptions

For the purposes of this report, the Overhead Conductors asset category has not been componentized.

8.1.2 Design Configuration

There are several types of Overhead Line Switches. For the purposes of this report, the types are aluminum conductor steel reinforced (ACSR), all aluminum conductor (AAC), and copper.

8.1.3 System Hierarchy

Overhead Conductors is considered to be a part of the Overhead Lines asset grouping.

8.2 Degradation Mechanism

To function properly, conductors must retain both their conductive properties and mechanical (i.e. tensile) strength. Aluminum conductors have three primary modes of degradation: corrosion, fatigue and creep. The rate of each degradation mode depends on several factors, including the size and construction of the conductor, as well as environmental and operating conditions. Most utilities find that corrosion and fatigue present the most critical forms of degradation.

Generally, corrosion represents the most critical life-limiting factor for aluminum-based conductors. Visual inspection cannot detect corrosion readily in conductors. Environmental conditions affect degradation rates from corrosion. Both aluminum and zinc-coated steel core conductors are particularly susceptible to corrosion from chlorine-based pollutants, even in low concentrations.

Fatigue degradation presents greater detection and assessment challenges than corrosion degradation. In extreme circumstances, under high tensions or inappropriate vibration or galloping control, fatigue can occur in very short timeframes. However, under normal operating conditions, with proper design and application of vibration control, fatigue degradation rates are relatively slow. Under normal circumstances, widespread fatigue degradation is not commonly seen in conductors less than 70 years of age. Also, in many cases detectable indications of fatigue may only exist during the last 10% of a conductor's life.

In designing distribution lines, engineers ensure that conductors have adequate rated tensile strength (RTS) to withstand the heaviest anticipated weather loads. The tensile strength of conductors gradually decreases over time. When conductors experience unexpectedly large mechanical loads and tensions, they begin to undergo permanent stretching with noticeable increases in sagging.

Overloading lines beyond their thermal capacity causes elevated operating temperatures. When operating at elevated temperatures, aluminum conductors begin to anneal and lose tensile strength. Each elevated temperature event adds further damage to the conductor. After a loss of 10% of a conductor's RTS, significant sag occurs, requiring either re-sagging or replacement of the conductor.

Phase to phase power arcs can result from conductor galloping during severe storm events. This can cause localized burning and melting of a conductor's aluminum strands, reducing strength at those sites and potentially leading to conductor failures. Visual inspection readily detects arcing damage.

Other forms of conductor damage include:

- Broken strands (i.e., outer and inners)
- Strand abrasion
- Elongation (i.e., change in sags and tensions)
- Burn damage (i.e., power arc/clashing)
- Birdcaging

The degradation of copper wire is mostly due to corrosion. Oxidization gives copper a high resistance to corrosion. Derivatives of chlorine and sulfur contained in coastal atmospheres start the oxidation by forming a blackish or greenish film. The film is very dense, has low solubility, high electric resistance and high resistance to chemical attack and to corrosion. Despite this, mechanical vibrations, abrasion, erosion and thermal variations may cause fissures and faults in this layer. When this happens, the metal is uncovered and corrosion may occur. Also electrolytes with low chlorine content could enter, causing a change in the chemical passivity. This may also be the result of a deficit of oxygen which would make the area anodic and rapidly accelerate corrosion.

Note that the weather protection and insulation on the Cables is for improving reliability of the distribution system as opposed to improving the useful life of this asset. The conductive properties of the wire are what degradation impacts, although Utilities may choose to replace weather protected cables if called for by their own system reliability practices.

8.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Overhead Conductors are displayed in Table 8-1.

Table 8-1 Useful Life Values for Overhead Conductors

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
OH Conductors	50	60	75

8.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Overhead Conductors. Four of the interviewed utilities gave Minimum (Min UL) Values and five of the interviewed utilities gave TUL and MAX UL Values for Overhead Conductors (Figure 8-1).

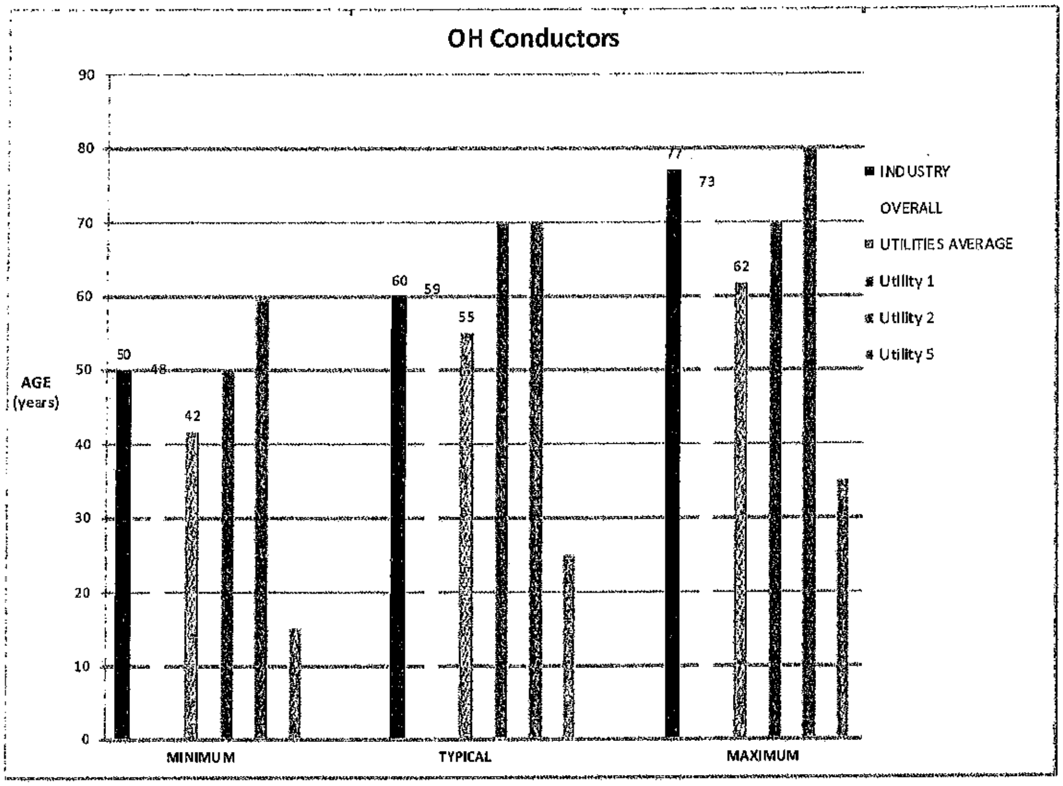


Figure 8-1 Useful Life Values for Overhead Conductors

8.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Overhead Conductors are displayed in Table 8-1.

Table 8-2 Composite Score for Overhead Conductors

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	50%	38%	65%	0%	8%	28%
Overall Rating*	M	L	M	NI	NI	L
* H= High Impact M = Medium Impact L = Low Impact NI = No Impact						

8.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Overhead Conductors. Five of the interviewed utilities provided their input regarding the UFs for Overhead Conductors (Figure 1-42).

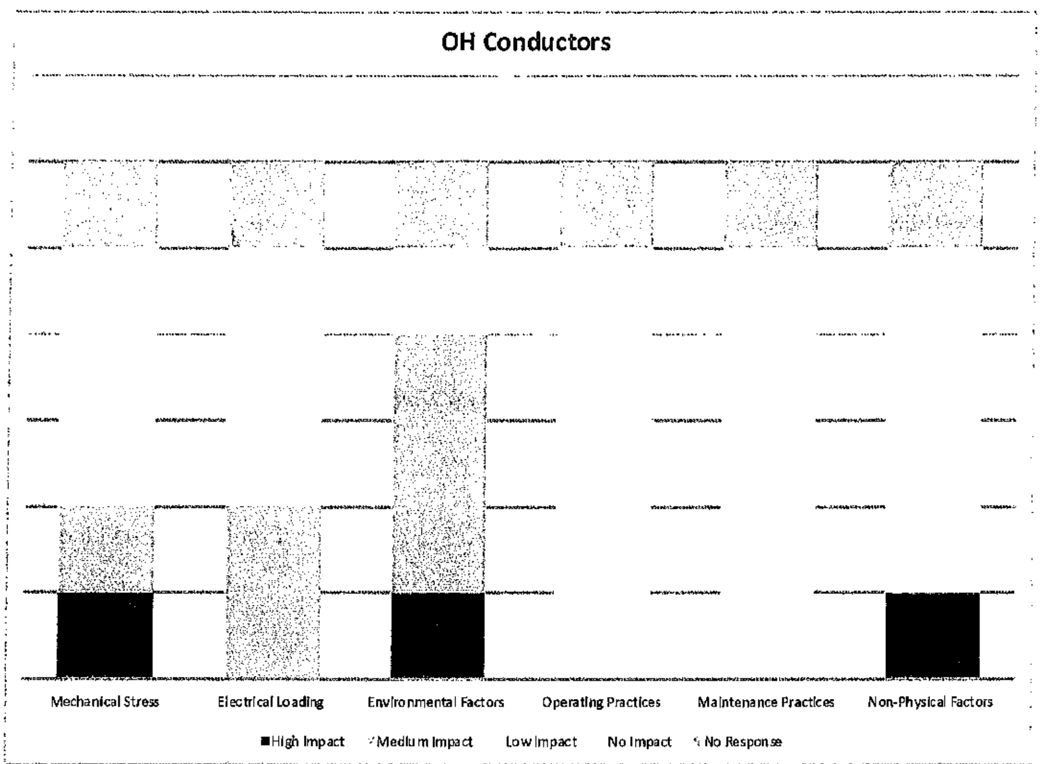


Figure 8-2 Impact of Utilization Factors on the Useful Life of Overhead Conductors

9. Overhead Transformers and Voltage Regulators

9.1 Asset Description

Distribution pole top transformers change sub-transmission or primary distribution voltages to secondary voltages such as 120/240 V or other common voltages for use in residential and commercial applications.

9.1.1 Componentization Assumptions

For the purposes of this report, the Overhead Transformers and Voltage Regulators asset category has not been componentized.

9.1.2 Design Configuration

For the purposes of this report, Overhead Transformers and Voltage Regulators refers to both single phase and three phase Transformers.

9.1.3 System Hierarchy

Overhead Transformers and Voltage Regulators is considered to be a part of the Overhead Lines asset grouping.

9.2 Degradation Mechanism

It has been demonstrated that the life of the transformer's internal insulation is related to temperature-rise and duration. Therefore, transformer life is affected by electrical loading profiles and length of time in service. Other factors such as mechanical damage, exposure to corrosive salts, and voltage and current surges also have a strong effect. Therefore, a combination of condition, age and load based criteria is commonly considered in determining the useful remaining life of distribution transformers.

The impacts of loading profiles, load growth, and ambient temperature on asset condition, loss-of-life, and life expectancy can be assessed using methods outlined in ANSI/IEEE Loading Guides. This also provides an initial baseline for the size of transformer that should be selected for a given number and type of end users to obtain optimal life.

The life of the voltage regulator's internal insulation is related to temperature-rise and duration. Therefore, voltage regulator life is affected by electrical loading profiles and length of time in service. Other factors such as mechanical damage, exposure to corrosive salts, and voltage and current surges also have a strong effect. Therefore, a combination of condition, age and load based criteria is commonly considered in determining the useful remaining life of voltage regulators.

The impacts of loading profiles, load growth, and ambient temperature on asset condition, loss-of-life, and life expectancy can be assessed. There is also the operating practice affect on voltage regulators in terms of the number of operations that it is required to perform on a daily basis.

9.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Overhead Transformers and Voltage Regulators are displayed in Table 9-1.

Table 9-1 Useful Life Values for Overhead Transformers and Voltage Regulators

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
OH Transformers	30	40	60

9.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Overhead Transformers and Voltage Regulators. All six of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Overhead Transformers and Voltage Regulators (Figure 9-1).

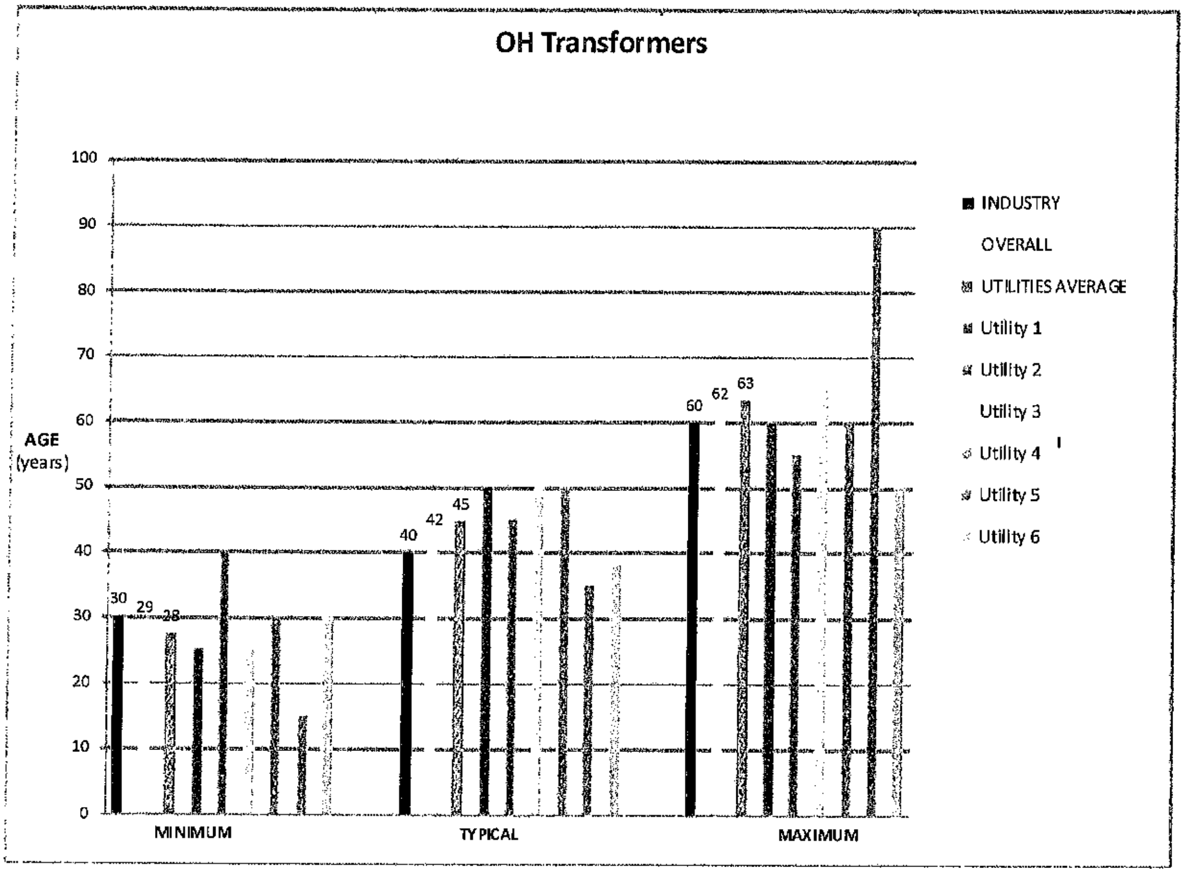


Figure 9-1 Useful Life Values for Overhead Transformers and Voltage Regulators

9.4 Impact of Utilization Factors

Based on the Utility Interviews the composite score and overall impact (high medium, low), if any, of each factor on the typical useful life of Overhead Transformers and Voltage Regulators are displayed in Table 9-2.

Table 9-2 - Composite Score for Overhead Transformers and Voltage Regulators

	Utilization Factors					
	Mechanical Stress	Electrical Loading	Environmental Factors	Operating Practices	Maintenance Practices	Non-Physical Factors
Composite Score	13%	65%	56%	0%	6%	58%
Overall Rating*	L	M	M	NI	NI	M

* H = High Impact M = Medium Impact L = Low Impact NI = No Impact

9.4.1 Utility Interview Data

This section displays the data used to determine the composite score and overall impact (high, medium, low) of each factor on the typical useful life of Overhead Transformers and Voltage Regulators. All six of the interviewed utilities provided their input regarding the UFs for Overhead Transformers (Figure 1-42).

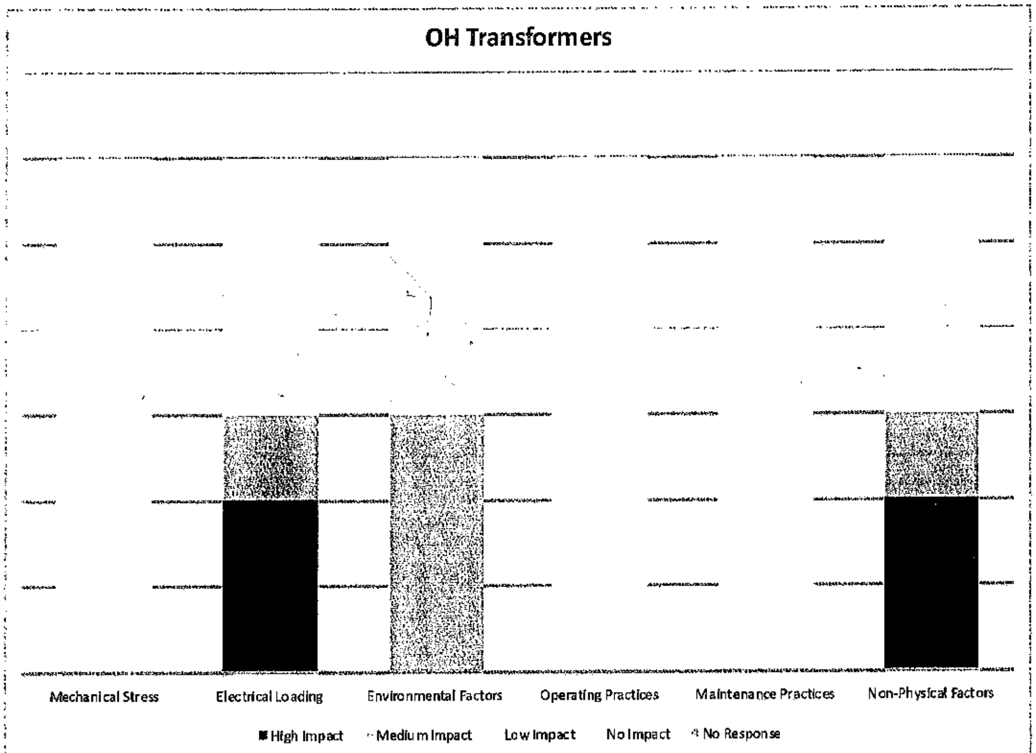


Figure 9-2 Impact of Utilization Factors on the Useful Life of Overhead Transformers and Voltage Regulators

10. Overhead Shunt Capacitor Banks

10.1 Asset Description

This asset category refers to pole mounted shunt capacitor banks and their supporting hardware. The capacitor bank also includes the control switches and devices, fuse cutout, surge arrester and in some cases current-limiting fuses. Shunt capacitors regulate voltage in distribution systems, and provide reactive compensation.

10.1.1 Componentization Assumptions

For the purposes of this report, the Overhead Shunt Capacitor Banks asset category has not been componentized.

10.1.2 System Hierarchy

Overhead Shunt Capacitor Banks is considered to be a part of the Overhead Lines asset grouping.

10.2 Degradation Mechanism

The major degradation of overhead capacitor banks is related to the capacitors themselves. They are exposed to detrimental environmental factors including: extreme temperatures, contamination, birds etc. They also experience steady state, transient and dynamic over voltage conditions. The switching devices add an additional stress to the capacitors. These environmental conditions, electrical loading and operating practices cause non-reversible degradation of the insulation in capacitor units and external insulation.

Fuse and bushing degradation result primarily from the failure of seals (hence moisture seeps in). Based on the surrounding environmental conditions this may cause corrosion of the capacitor units and support frame. Internal degradation can also occur in insulators.

10.3 Useful Life

Based on the Industry Values and Utility Interviews the Useful Life Values, Minimum (MIN UL), Typical (TUL) and Maximum (MAX UL) for Overhead Shunt Capacitor Banks are displayed in Table 10-1 Useful Life Values for Overhead Shunt Capacitor Banks

Table 10-1 Useful Life Values for Overhead Shunt Capacitor Banks

ASSET COMPONENTIZATION	USEFUL LIFE		
	MIN UL	TUL	MAX UL
OH Shunt Capacitor Banks	25	30	40

10.3.1 Useful Life Data

This section displays the data used to determine the Useful Life Values for Overhead Shunt Capacitor Banks. None of the interviewed utilities gave Minimum, Typical and Maximum Useful Life (MIN UL, TUL and MAX UL) Values for Overhead Shunt Capacitor Banks (Figure 10-1).

I APPENDIX – PERCENT OF ASSETS IN THE USEFUL LIFE RANGE

This Appendix describes the statistical analysis that was performed to estimate the percentage of assets that fall within the useful life range (MIN UL – MAX UL). Note that the values of MIN UL and MAX UL were determined using industry research and utility interviews. The statistical analysis estimates the percentage of an a asset population that will fall in the useful life range. The following is discussed:

- Review of definitions
- Assumptions used in useful life analysis
- Useful life range coverage
- Sample calculation of useful life range

Definitions used in Useful Life Analysis for Utility Asset Groups

End-of-life - An asset reaches its end-of-life when it is considered unable to perform its functions as designed physically.

Useful Life Range (MIN UL – MAX UL) - The asset life range that covers the end-of-life year data for the majority of the population in a specific asset group.

Typical useful life (TUL) - The value that corresponds to the peak of failure probability density function (useful life distribution function in this project) for a specific asset category, assuming the failure distribution is of unimodal type (i.e. with only one global maximum).

In mathematics, this value is called the mode. It is the value of end-of-life year datum that is most likely to be sampled at a single sampling, or the value that appears most frequently at a group sampling.

Mean useful life (μ) - Probability weighted average value. It is the arithmetic average value of the end-of-life year data for a group of sampled assets, provided that the sample size is sufficiently large and representative.

Minimum useful life (MIN UL) - The lower set value of useful life range. It refers to the age when a small percentage of assets reaches the physical end-of-life. In this project, it is defined as

$$\text{MIN UL} = \mu - k\sigma \qquad \text{(Equation 1)}$$

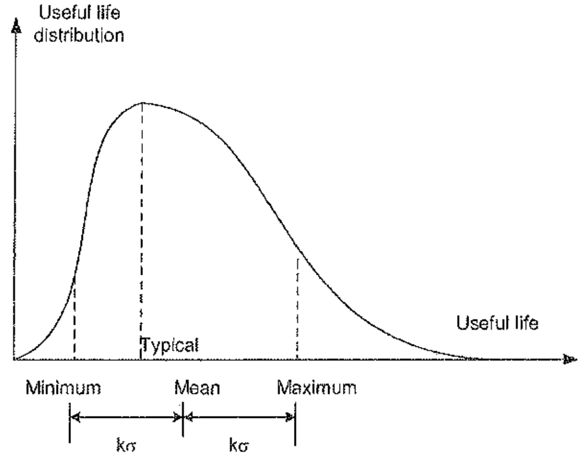
Where $k = \sqrt{3}$ (defined in later section)
σ standard deviation of useful life distribution

Maximum useful life (MAX UL)

The upper set value of useful life range. It refers to the age when most of assets reach the physical end-of-life. In this project, it is defined as

$$\text{MAX UL} = \mu + k\sigma \qquad \text{(Equation 2)}$$

Where $k = \sqrt{3}$ (defined in later section)
σ standard deviation of useful life distribution



Assumptions in Useful Life Analysis for Utility Asset Groups

To facilitate the analysis on useful life range coverage for utility asset groups, the following assumptions are made based on the information obtained during utility interviews as well as the character of various types of asset groups.

A. In a utility, there are always some asset groups that have their useful life distribution curve severely skewed to the either end of useful life range.

B. For all asset categories, the useful lives distribution is such that the mean (μ) is within k x standard deviation (σ) from MIN UL and MAX UL, regardless of where TUL is relative to the mean (μ).

C. For any specific asset group, the typical useful life is always captured within the useful life range.

D. For some asset groups, the typical values coincide with either minimum or maximum useful life values.

Assumption A is based on the fact that, due to different degradation mechanisms and operation modes, some of the asset groups have some predominant factors than exclusively determine the probability of failure of the asset group, thus making the asset end-of-life not follow normal distribution or other symmetrical distributions.

Assumption B is expanded from the special case where the asset end-of-life follows normal distribution. Under such condition, a utility needs to assign the same k coefficient to ensure that there is always a fixed percentage of asset population that is covered by the useful life range, regardless of how much the standard deviation is. If it is agreed that the same k coefficient is also adopted for the non symmetrical distribution, assumption B can be validated.

Assumptions C and D are validated by the results of interviews with various utilities.

In mathematics, it can be proven that the difference between the mean and the mode of a unimodal distribution is less than or equal to the square root of three times the standard deviation ($\sqrt{3}\sigma$).

With assumptions A, B and C, it can be concluded that the k coefficients should be greater than or equal to $\sqrt{3}$, applicable to all the asset groups.

With all the above assumptions validated, it is reasonable to conclude that the useful life range provided by utilities is within the interval between $\mu - \sqrt{3}\sigma$ and $\mu + \sqrt{3}\sigma$.

Useful Life Range Coverage

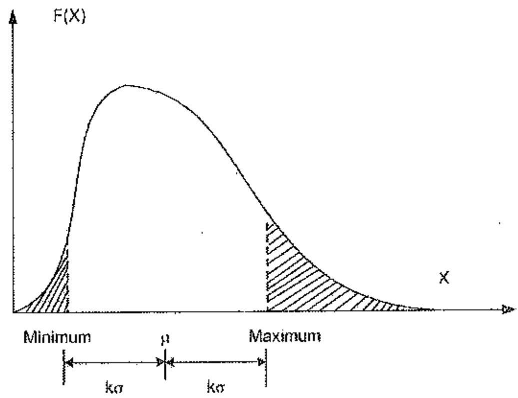
For any uni-modal useful life distribution, the coverage of a specific useful life range can be calculated using Chebyshev's inequality.

Chebyshev's Inequality

Let *X* be a random variable with mean value μ and finite variance σ^2. Then for any real number $k > 1$,

$$\Pr(|X-\mu| \geq k\sigma) \leq \frac{1}{k^2}$$

where the above inequality refers to the probability of the shadowed area in the following diagram.



Therefore the coverage of a useful life range is $1-1/k^2$.
For the useful life range specified in the previous section, it can be estimated that the range covers at least $1-\frac{1}{(\sqrt{3})^2} = 66.7\%$ of the whole population.

In case the useful life distribution is close to normal distribution for some asset groups, the percentage of data covered by the useful life range is determined by:

$$\Pr(|X-\mu| \leq k\sigma) = erf\left(\frac{k}{\sqrt{2}}\right)$$

Where erf is the error function defined as

$$erf(x) = \frac{2}{\sqrt{\pi}}\int_0^x e^{-t^2}\,dt$$

At $k = \sqrt{3}$, it can be calculated that the useful life range covers $erf\left(\frac{\sqrt{3}}{\sqrt{2}}\right) = 91.7\%$ of the whole population.
In general, the percentage of the whole population covered by the useful life range defined in this study is between 66.7% and 91.7%.

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