2014 Asset Management Plan

Annual Planning Report

2014 Asset Management Plan

Annual Planning Report

Executive Summary

Hydro Ottawa's Assets are the physical objects which transform, monitor and ultimately transmit electricity to the customer. This equipment not only fulfills the essential role of distributing electricity, but also acts as the barrier and protection that allows this potentially hazardous product to be transported through public spaces safely and reliably.

Large segments of the system were constructed in the 1960s, 70s and 80s – as most assets have a lifespan on the order of 50 years, a considerable proportion of the system is approaching or has exceeded the anticipated end-of-life. The increased potential of failure posed by these aging assets will, without intervention, impact the organization's ability to guard worker and public safety, maintain system reliability and protect organizational strength in the future.

> *By 2033, Plant Failure will account for 39% of available labour-hours if the current annual replacement levels are not increased.*

The Physical Asset Management Plan was created to provide strategic guidance on the replacement and investment forecasts, manage priorities and identify process gaps. The current recommendation for the annual sustainment budget to replace equipment and manage failures is to be increased to $72 million in the next 10 years. The recommended budgetary increase is based on the forecasted system need in order to maintain or reduce the rate of failures of the major distribution assets, and manage known equipment issues affecting Health and Safety. The asset failure forecasts have been developed utilizing equipment demographics, inspection data, and failure records.

The financial impacts of the proposed investment increases are significant, yet, so too are the risks of simply maintaining the status quo. System wide forecasts indicate that at the current investment levels, asset failure rates will continue to rise having a direct impact on service reliability and labour resources. At current investment levels it is anticipated that Plant Failure labour associated with the distribution system alone will increase to 320% of current levels by 2033, equivalent to 39% of the current labour resources. This increase in labour will impact the ability to complete planned work. The increase in failed equipment will also result in a 48% increase in Defective Equipment SAIFI by 2033. Furthermore, the elevated density of assets in poor condition will increase the potential for unrecoverable events in the case of high climatic stress (i.e. heat waves or severe storms), significantly impacting system reliability and corporate image. The deferral of these increases will lead to a growing annual burden while achieving the same result.

While the identified increase in funding may not be immediately achievable, progress towards this goal is essential in maintaining system performance.

Contents

1 Background

1.1 Purpose of the Plan

The intention of the Asset Management Plan (AMP) is to document the asset management practices used by Hydro Ottawa Limited (HOL) as part of an optimized lifecycle strategy for distribution assets. The objectives of the AMP are to demonstrate that the assets deliver the required functions at the desired level of performance and that this level of performance is sustainable for the foreseeable future while staying within the targeted levels of risk.

The AMP is a key component of the planning process. Addressed in the plan are the financial, technical, and management elements needed for making sound innovative or best practice asset management decisions.

The plan looks ahead 20 years from January 1st 2014. The main focus is on the first three to five years – for this period most of the planned projects have been identified. Beyond this period, analysis is more indicative. Based on long term trends, current asset demographics, known asset issues or needs on the system, it is likely that new and planned projects will change in the latter half of the forecasted period.

The AMP is also a technical management tool that provides extensive detail to be used on a day-to-day basis by HOL employees to demonstrate responsible stewardship of network assets.

The plan focuses on optimizing the lifecycle costs for each network asset group (including creation, operation, maintenance, renewal and disposal) to meet reliability service targets and future demand. Each year, the aim is to improve the plan by taking advantage of new information and changing technology. These innovations help to maintain the ranking as one of the most reliable and efficient electricity networks in the province of Ontario.

Hydro Ottawa Limited's distribution system assets range in age from new to over 50 years old. The management of these assets is critical to providing safe, reliable and efficient electricity distribution services to its customers.

2 Performance & Statistics

Hydro Ottawa tracks information on its distribution assets in order to monitor areas of growth and assess performance of the distribution system. This section will provide information on system demographics and the impacts of equipment failures on the environment and the customer.

2.1 System Asset Statistics

Although Hydro Ottawa's service area has remained constant, the distribution system continues to expand and evolve. System expansions of trunk feeders from new or existing substations are typically designed in an overhead configuration, especially in suburban areas. However, the majority of new subdivisions are constructed by the developer using an underground system design. The growth in underground equipment is reflective of these developments.

The demographics of overhead transformers are decreasing due to the amalgamation of transformers when a replacement occurs. The conversion away from electric heat has reduced the load on these units and has allowed for more customers to be supplied by a single transformer.

The number of station transformers is increasing as new substations are being constructed to meet the growing capacity needs. There continues to be some reduction in the number of sub-transmission transformers due to voltage conversion projects of substations that have reduced load.

Table 2.1 - System Demographics

	2009	2010	2011	2012	2013
Service Area (km^2)	1,104	1,104	1,104	1,104	1,104
Total Circuit Length (km)	5,386	5,414	5,606	5,658	5,720
O/H Circuit	2,709	2,693	2,916	2,923	2,926
U/G Circuit	2,677	2,721	2,690	2,735	2,794
Total Number of Poles	48,699	48,574	48,380	48,298	47,978
Distribution Transformers	40,525	42,516	42,970	43,689	44,402
O/H	17,393	17,228	16,801	16,617	16,424
U/G & Vaults	17,475	17,228	18,376	18,785	19,189
Stores + Missing Serial Number	5,657	7,470	7,793	8,287	8,789
Substation Transformers	166	170	170	171	170
Transmission	25	27	27	28	28
Sub-Transmission	141	143	143	143	142
Total Number of U/G chambers	3,006	3,082	3,268	3,167	3,399

2.2 Asset Failure Rates

Asset failure rates provide indication of the adequacy of proactive replacement programs to manage asset failures. Historical asset failures are shown in Table 2.2. Both overhead and underground distribution transformers and PILC cable are indicating an increasing trend. These increases may signify the need to increase replacement rates.

Table 2.2 - Asset Failure

	2009	2010	2011	2012	2013
Poles	46	29	74	41	76
Distribution Transformers (UG)	63	51	80	116	96
Distribution Transformers (OH)	49	52	71	84	61
***U/G Cable – PILC (m)**	975	1110	1332	2912	3487
U/G Cable – XLPE (m)	485	408	373	97	191
Station Transformers	5	0	2	0	6

*Note that a failed PILC cable requires repair from device to device accounting for the large number of meters replaced.

2.3 Asset Impact on Health and Safety & Environment

Hydro Ottawa reports to the Ministry of the Environment information on oil spilled and the cost of remediation. In 2009, a large amount of mineral oil was released due to the failure at Beacon Hill substation. Recent trends are seeing more leaking residential padmount transformers which have increased the cost of remediation. This emphasizes the importance of active inspection and replacement of padmount transformers to mitigate this environmental impact.

TABLE 2.3 - PUBLIC SAFETY CONCERN & OIL SPILLS

		2009	2010	2011	2012	2013*
Public Safety	**Public Safety Concern (PSCs)**	5	9	4	2	6
Oil Spills	**Annual Oil Spilled (L)**	10,374	1,262	1,225	3,249	5,828
	Annual Oil Clean up	$181,344	$377,788	$563,245	$464,972	$647,081.68

*Note that 2013 Oil Spills have not yet all been invoiced, as of May 7th, 2014.

2.4 Asset Impact on Customer Service

Asset failures impact the ability to provide reliable customer service to different extents. The impact of asset failures on system reliability is currently on an upward trend. The specific assets which are contributing to this trend include U/G Cable Attachments, Station Switchgear, O/H and U/G Transformers, and Poles. An increased or more targeted asset replacement may be required to manage these assets such that they do not adversely impact system reliability performance.

Table 2.4 - Defective Equipment Contribution to SAIFI

(customer interruptions per 100 customers served)

	2009	2010	2011	2012	2013
U/G Cable - Polymer	2	5	10	4	2
Insulator	3	2	7	0.3	0.1
Station Switchgear	1	2	5	0	3
O/H Switchgear	9	4	4	3	6
U/G Cable Attachment	1	2	3	2	5
Station Transformer	1.4	1.2	1.2	2	0
U/G Switchgear	0	1	1	7	0.1
U/G Cable - PILC	0.2	0.7	0.6	0.6	1.5
O/H XFRM	0	0	0	1	2
Pole	1	0	0	1	4
U/G XFRM	2	1	0	3	3
Other	7	6	9	6	5
Total	**28**	**25**	**41**	**30**	**32**

3 Outlook

Forecasted investment required to manage Hydro Ottawa's distribution assets over the next 20 years is shown in Figure 3.1. Without these increases, average annual asset failure costs will continue to rise. These increased failures bring with them impacts to system reliability and worker & public safety as well as directly impacting failure costs and labour resourcing.

The forecasted asset failure costs, distribution failure labour requirements, and system reliability impact at current and proposed investment levels are shown in Figure 3.2, Figure 3.3 & Figure 3.4, respectively.

These forecasts indicate that the expected annual average year to year failure rates and associated costs can and are expected to vary significantly. If the failure rates are allowed to continue to rise, the financial and labour impacts year-to-year will considerably impact the ability to manage financial performance and crew scheduling.

While the increases indicated are significant, the deferral of these investments will raise failure rates as well as increase the required annual investment needed in future years to achieve the same results.

FIGURE 3.1 - FORECASTED ASSET REPLACEMENT NEEDS

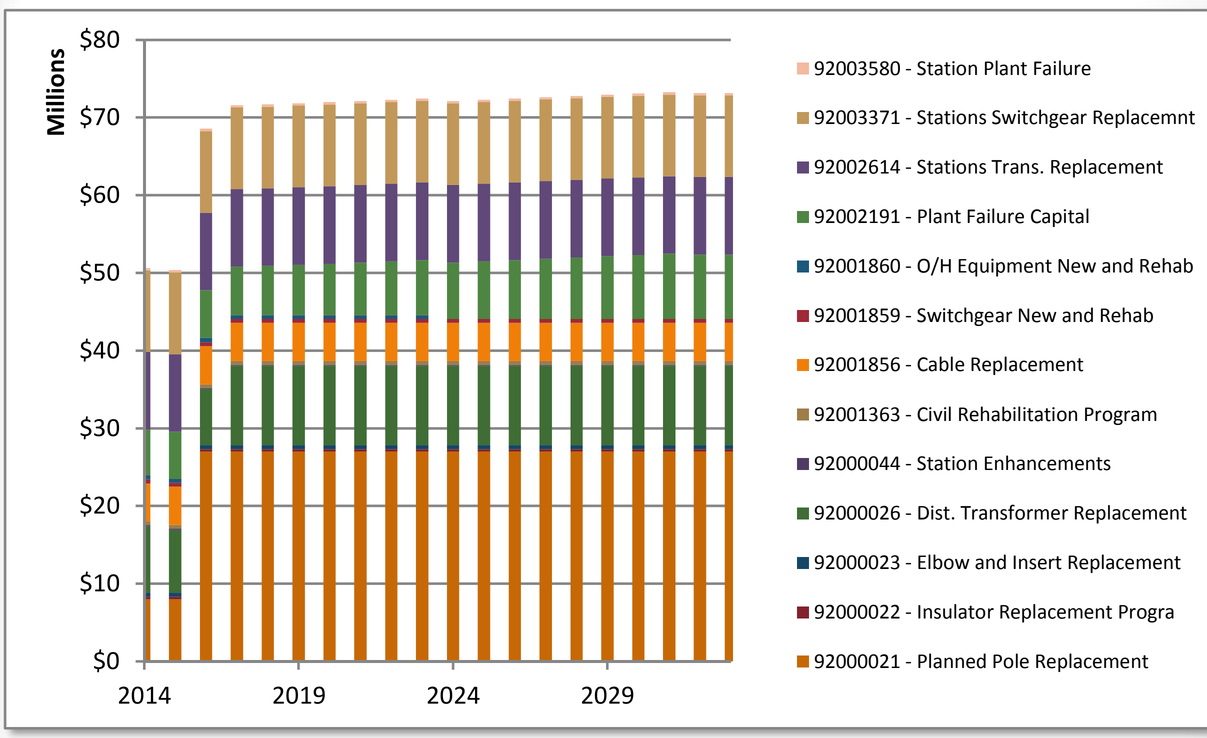


FIGURE 3.2 - FORECASTED ASSET FAILURE COSTS

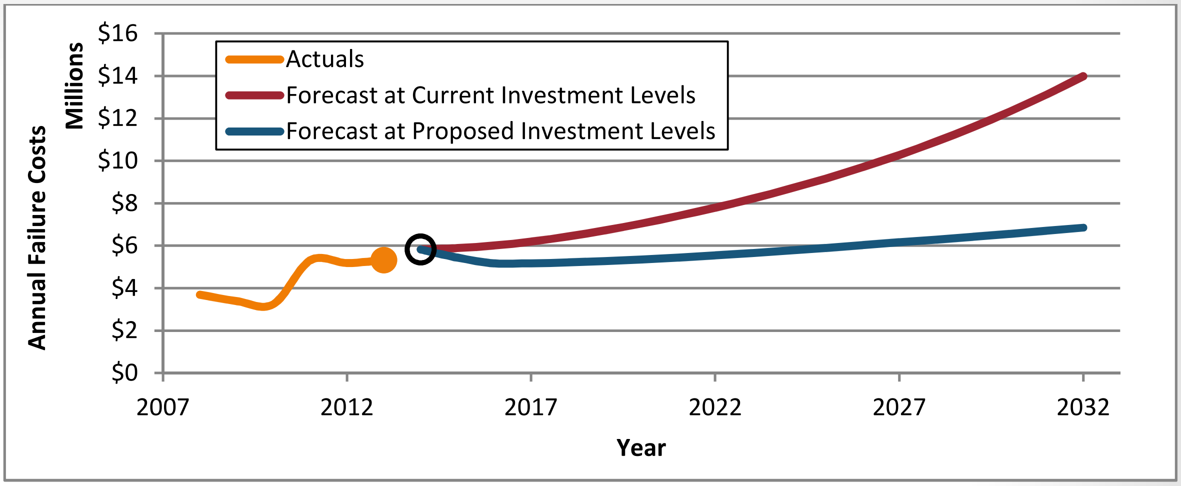


FIGURE 3.3 - FORECASTED DISTRIBUTION PLANT FAILURE LABOUR RESOURCE REQUIREMENTS

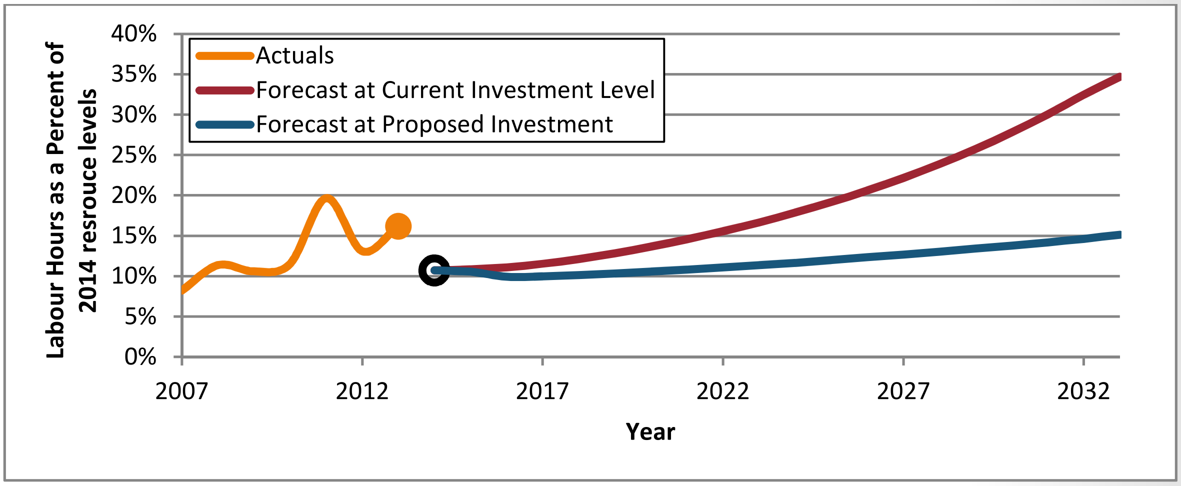
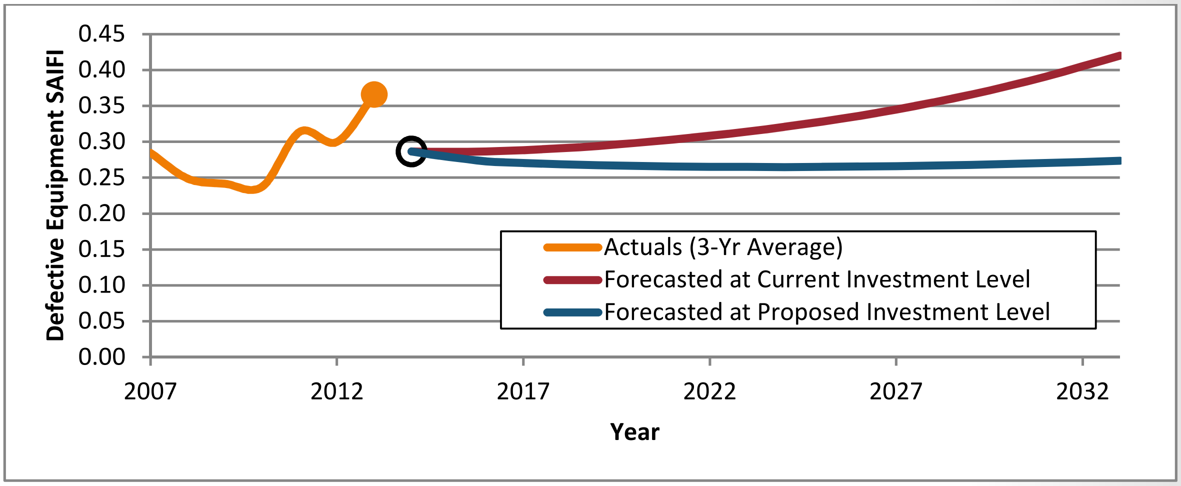


FIGURE 3.4 - FORECASTED DEFECTIVE EQUIPMENT SAIFI



4 Asset Financial Life-Cycle

A change of practice occurred in 2011, which required Hydro Ottawa to review the useful life of all asset classes for purposes of financial depreciation. Prior to 2011 an OEB standard set of asset lives for electrical utilities had been used. The evaluation of technical life span of assets focuses on the failure of assets rather than the broader question of asset retirement, and as such does not consider assets retired from service for external reasons, such as capacity upgrades, relocations, and vehicle collisions. It also does not accurately account for significant environmental changes or changes in use or loading. The AMP focus on end-of-life failure provides appropriate models for forecasting proactive asset replacement requirements, but typically results in higher average age than would be appropriate for asset depreciation.

Age at retirement has not been collected historically which creates a challenge in assessing appropriate financial useful lives for assets. The process for determining Hydro Ottawa's IFRS Useful Lives started late in 2008. Existing information regarding asset failure rates was used to determine technical lives from the 2005 Asset Management Plan (AMP), along with 2006/2007 asset management analysis and information, and industry technical reports. In order to develop appropriate commercial useful lives, the AMP technical analysis together with experience and professional judgment were utilized to consider existing and future issues that are pertinent to Hydro Ottawa's asset operational conditions which are unique from other utilities in Ontario. This is primarily due to weather including violent lightning storms, cold sustained temperatures and heavy snowfall, but is also due to high salt use on Ottawa streets causing contamination spray on Hydro Ottawa plant.

Hydro Ottawa has begun to consistently collect and review age at retirement data. As the pool of available data grows, regular review of the current financial useful lives (see Table 4.1) will continue to ensure they are consistent with the current HOL experience.

Table 4.1 - Financial Useful Life of Select Distribution Assets

Cost Code	Asset	IFRS Life (years)
5900	Stn. Equip. > 50 kV Other	20
5910	Station Switchgear >50kV	40
5920	Station transformers >50 kV	45
5930	Wholesale Meters >50 kV	15
6100	Stn. Equip. <50kV Other	20
6110	Station Switchgear <50kV	40
6120	Station transformers <50 kV	45
6130	Wholesale Meters< 50kV	15
6500	SCADA RTU, Relays, Com Equipment	15
6700	U/G Polymer Insulated Cable	35
6710	U/G Switchgear & Reclosers	25
6720	Vault Switchgear and Reclosers	30
6730	U/G PILC Cable	60
6900	U/G Conduit and cable chambers	40
7500	Line Transformers O/H & U/G	30
7510	Line Transformers Vault	35
8100	O/H Insulator & Conductors	45
8110	O/H Switchgear and Reclosers	25
8300	Poles, Towers, Fixtures	45
8500	Services	40

5 Asset Management Framework

Asset replacement projects are mainly driven by increasing demand from new developments and load intensification from existing developments. The remaining projects are developed through the management of assets to minimize health and safety concerns, reduce environmental impact and improve reliability. Assets are managed as a result of records that indicate type, age, location, maintenance, inspection results and industry best practices.

Hydro Ottawa develops an annual list of projects in advance of each year to ensure all aspects of the projects are known and documented. This allows for maximized construction efficiency each year. In an effort to further advance efficiencies, Hydro Ottawa has begun preparing annualized lists of projects as far out as 2020. The consequence of all projects are assessed for their potential risks and analysed to mitigate known risks and maximize cost versus benefits. Business cases are prepared for large projects to justify the project objective from various alternatives including costs, associated risks and benefits of each.

5.1 Risk Assessment

Risk is defined as the combination of the probability of an event and its consequence. Project risk is evaluated through the consideration of the probability and consequence, for potential events which may occur if the investment is not undertaken. Event probability is specified either as a certainty or a variable associated with a state of a system element. The probability of an event is defined based on existing HOL process/evaluation or through sound engineering judgment.

Hydro Ottawa assesses risk based on four objectives: Health and Safety, Environment, Reliability and Customer Impact and Asset Management. Each of these categories is given a measure based upon a seven step scale from “None” to “Severe”. The scale measure describes the potential consequences of delaying the project.

5.1.1 Health and Safety

The risks associated with health and safety are reviewed to establish concerns with public safety and employee safety. The assessment scales from the certainty that someone could not be injured to the possibility of fatality as a result of delaying the project.

5.1.2 Environment

Oil is a fundamental cooling and interrupting medium found in several of the asset classes. Perforated or deteriorating equipment can result in oil spills into the environment. The risk assessment evaluates all assets in the project and establishes the potential volume of oil that could be spilt into the environment as a result of delaying the project.

5.1.3 Reliability and Customer Impact

A risk evaluation is completed to determine how a project will impact reliability and affect customer experience. Specifically the evaluation looks at the assets associated with delaying the project to determine the following:

- The number of customers that will be affected by a failed asset (SAIFI)
- The duration in which it will take to restore all customers after a failed asset (SAIDI)
- How outages will affect the feeder score for number of sustained outages it experiences (FEMI)
- How customers will be impacted by voltage quality and the possibility of voltage variances that cause damage to customer equipment
- How customers will be impacted by harmonics and the possibility of power variances that cause damage to customer equipment

5.1.4 Asset Management

Risks associated with the management of assets due to delaying a project include:

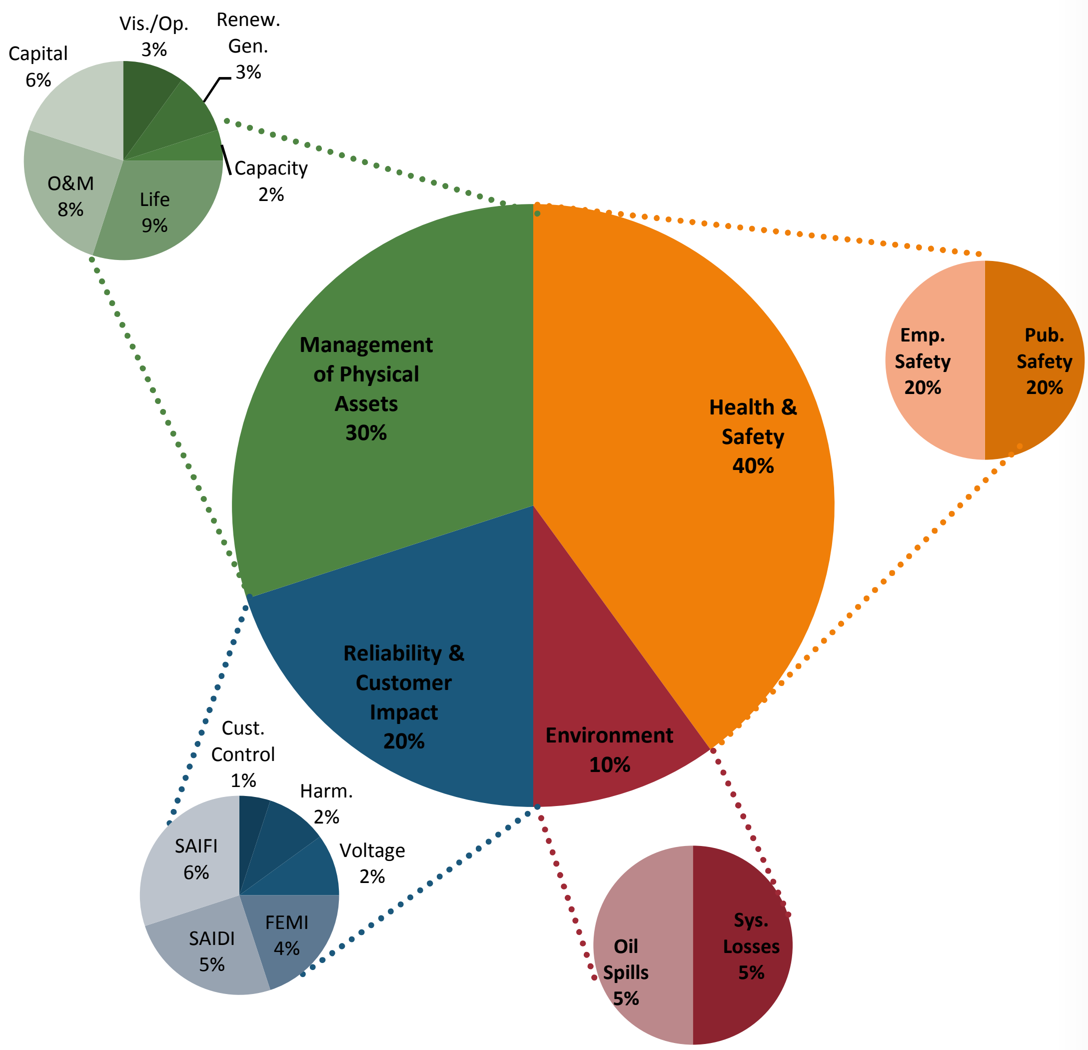
- Increasing operating and maintenance costs of assets
- Impact of loading assets over their rated capacity limits
- Continued deterioration of the condition of the assets
- Operation of the asset past its intended useful life

5.2 Consequence Scoring and Prioritization

The consequence as it pertains to each measure is assessed on a linear scale. This scale covers the range of impact from *"None" to "Severe"* with an associated score of 0 to 6, respectively. The weighted score is used to rank both the priority of a measure and its impact; a measure which has a relatively low impact on its associated initiative will also have a lower weighting.

Each of the four risk objectives has an associated weight, which reflects the organizational prioritization of that objective and, as such, the associated weighting must be endorsed by the Hydro Ottawa Limited Executive. The current objective weightings are summarized in Figure 5.1.

FIGURE 5.1 – ASSET MANAGEMENT OBJECTIVE RATINGS



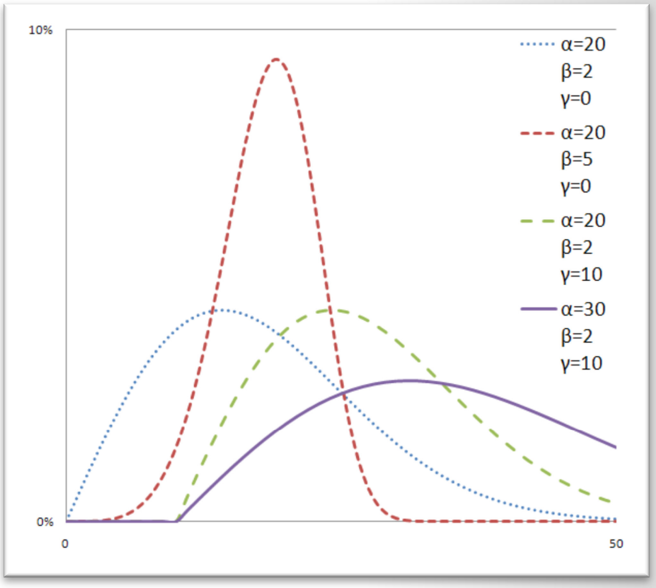
System investments are prioritized to maximize the benefit (i.e. risk score per dollar of investment). This cost/benefit ratio is calculated as the present value of the project cost (maximum 5 year window) over the 5 year present value of the project risk score. Investments are then prioritized based on ranking of this cost/benefit ratio. Projects with the lowest cost/benefit ratio are given higher priority over those with higher cost/benefit ratios.

While it is preferred for all investments to be selected based on this prioritization, non-discretionary investments will arise typically due to external drivers. When such investments occur they should have reasoning clearly documented and they must be scored so that the impact to objectives is clearly understood and communicated.

5.3 Asset Replacement Projections

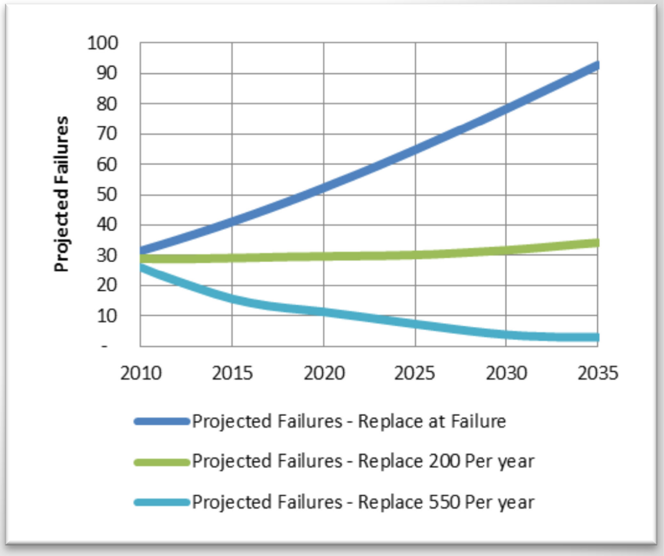
In order to project future replacement rates within asset classes and across asset replacement categories, Hydro Ottawa looks at the probability of failure of each asset class. Determining the probability of failure for an asset class allows for optimal replacement rates scenarios to be created which can be adjusted based on the amount of risk the utility is willing to take on.

Hydro Ottawa uses the Weibull analysis method for estimating the expected end-of-life of different asset classes. The Weibull analysis is a statistical method that provides realistic probability of failure curves which accurately models the lifecycle of non-repairable equipment.



In order to create these curves, the Weibull analysis requires asset information on the age demographics, population, and time to failure. Hydro Ottawa uses its own data to produce these curves to reflect past experience. Due to the variations in the availability of this data, curve fitting analytics is used to estimate data.

Once failure curves are produced, scenarios are created to show the impact of run-to-failure vs. active replacement. Optimal replacement scenarios can also be determined in order to maintain or minimize future failures.



2014 Asset Management Plan

6 Distribution Asset Lifecycle Management

6.1 Distribution Poles

The Hydro Ottawa overhead distribution system is supported both electrically and mechanically by a system of poles and fixtures. The reliability and safety of the overhead distribution is contingent on the performance of these poles and fixtures.

Hydro Ottawa owns and/or operates plant on approximately 60,000 wood poles. In addition, Hydro Ottawa owns approximately 537 alternative material poles including composite, concrete and metal. The current planned replacement program focuses on the wood poles on which Hydro Ottawa operates due to the age and quantity of these assets. Pole replacement projects are medium to low complexity with an average cost of approximately $15,000 to $30,000 per pole.

The wood pole asset base consists of both Hydro Ottawa owned poles as well as those that are owned by a third party on which Hydro Ottawa is a tenant. As both types of poles support Hydro Ottawa circuits and are fundamental in their safety and reliability, they have been included together in this analysis.

Based on the current asset demographics and failure projection, a replacement rate of 400-600 poles per year is recommended to maintain the current failure rates until 2016. Beyond 2016, replacement rates will need to be increased to roughly 1,400 poles annually. If proactive management of this asset class is not maintained it is projected that the labour resource requirements to maintain Hydro Ottawa's wood pole assets will exceed a sustainable level. If adequate replacement levels are not achieved this asset group will pose an increased risk to safety and reliability, as a result of the increased potential for cascading pole failures, and/or simultaneous pole failures during severe weather.

6.1.1 Demographics

Hydro Ottawa owns 47,815 wood poles and 537 non-wood poles and operate on an additional 11,635 wood and 126 non-wood poles which are owned by third parties. The proportions of these poles by material are shown graphically in Figure 6.1. Currently, Hydro Ottawa has installation date information for approximately 25% of its poles (41% of those operated on). Those poles for which installation information is not available, install data has been estimated using manufacture date, estimated from the adjacent property legal records, or assumed to be equivalent to the average age of the known poles in that region (roughly 41% of asset group).

The overall age demographics of poles in the distribution system are shown in Figure 6.2. It can be seen that the majority of the distribution poles were installed between 1960 and 1990 (roughly 70%). More than 35% of the poles in the system have been in operation for more than 50 years.

FIGURE 6.1 - DISTRIBUTION POLES BY MATERIAL (OWNED AND OPERATE ON)

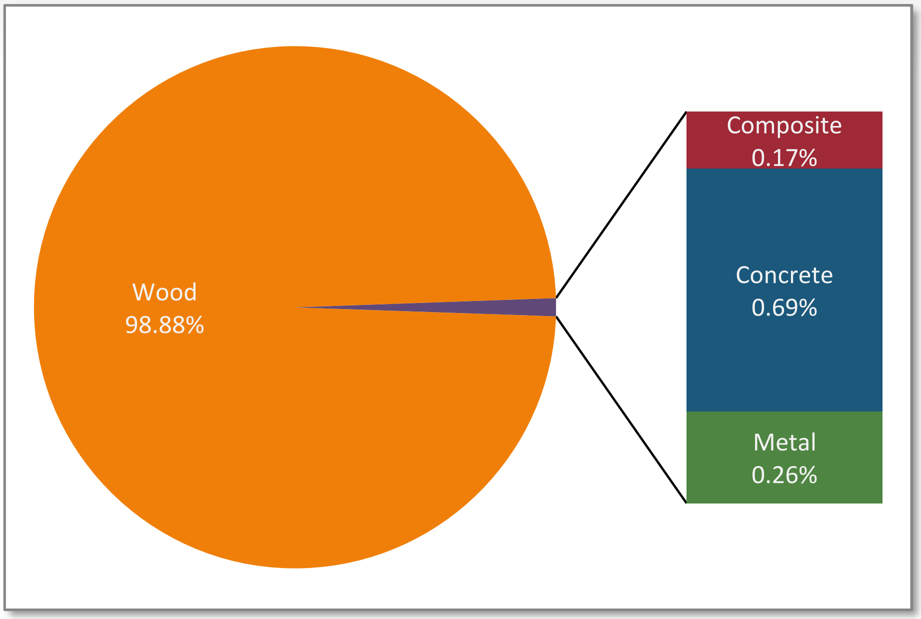
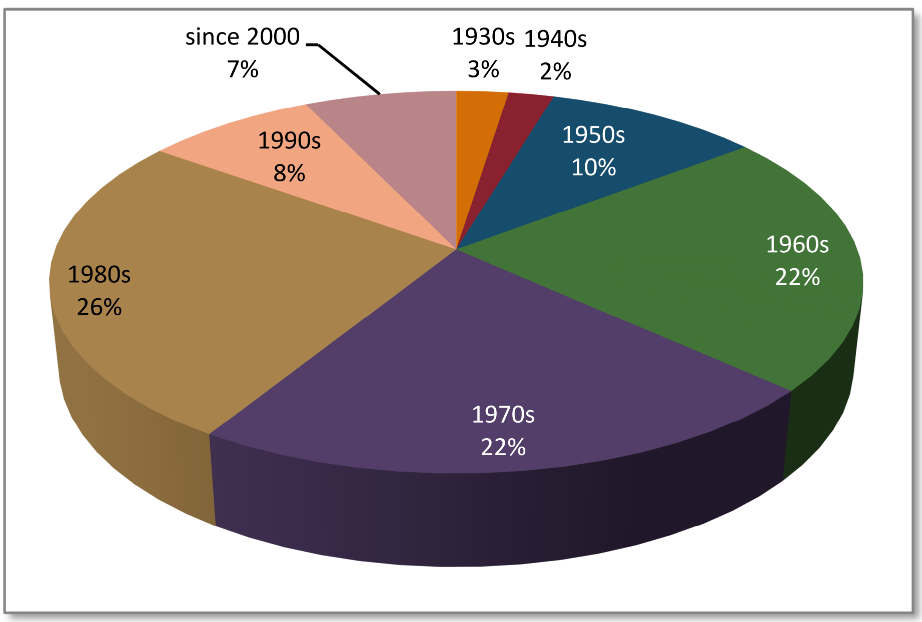


FIGURE 6.2 - PROPORTION OF WOOD POLES BY INSTALLATION DECADE (KNOWN AND ESTIMATED)



6.1.2 Assessment

The assessment of the asset class is focused on the management of wood poles as these represent 99% of the distribution poles in the system. The need for active management of non-wood poles is currently limited due to the limited number in service and their relatively young population.

6.1.2.1 Inspection program

Hydro Ottawa initiated a combined program of visual inspection and non-destructive testing in 2010. This program utilizes Resistograph drills for the detection and measurement of internal decay and measurement of the remaining shell thickness with minimal damage to the pole. Visual inspection is conducted on all poles in a section of overhead line, and approximately 20% of the poles in each pole line are tested using the Resistograph drill, the results of which can be extrapolated to all poles within the section, or poles of similar vintage. The management of distribution poles is driven by the results of this ongoing inspection program.

6.1.2.2 Health Index

Wood pole health is assessed relative to the ability to perform its designed function: support overhead plant under anticipated maximum climatic stress. In general, this can be assessed as a function of a pole's remaining strength at the ground line (which is the area of maximum stress on a pole). As per Canadian Electrical Code - CSA 22.3, poles should be replaced once they fall below 60% of the required strength. In the future, to better optimize the replacement program there may be value in further refining the pole assessment model to estimate the required pole strength as poles are typically oversized in new construction.

FIGURE 6.3 - IML RESISTOGRAPH DRILL

While remaining strength is a primary driver for pole replacement there are other factors which must be considered in evaluating the overall condition of poles and the prioritization of replacement projects.

Shell Condition – Weathering and external rot on the pole surface may not significantly impact the strength of the pole. However, it does impact the aesthetics and may present a safety hazard or impede HOL work if it is in a location where climbing the pole is required.

Pole Top – Weathering and rot at the pole top will not significantly impact the strength of the pole. It will however increase the risk of pole hardware coming loose (due to bolts pulling through the wood). It is also unsightly and may present a perceived issue/concern to the public.

Woodpecker Damage – Smaller holes are repairable and present predominantly aesthetic issues. Large woodpecker holes, depending on their location along the length of the pole, can significantly impact the strength of a pole. Woodpecker holes left un-repaired can potentially reduce the life of a pole, as the untreated pole heart-wood is exposed to elements which can lead to decay and insect attack.

6.1.2.3 Failure Consequence

A single pole failure will typically have low consequence. In general, pole failures will result in an outage affecting customers connected to that pole. While outages as a result of pole failures are typically limited in customers impacted and duration, as the density of poor quality poles increases the chances of cascading failures (see Figure 6.4) and simultaneous failures during severe weather increases. Such events can have a significant impact on overall system reliability.

When poles fail they also pose a safety risk to the public, employees and property as the result of downed wires and poles. In addition, when a pole supports oil filled transformers there is the chance of environmental impact due to the release of oil.

6.1.2.4 Failure Correlation

Correlation of pole failure to condition is difficult as poles can be at end-of-life and yet, not result in a failure. Required design strengths are based on the expected maximum climatic forces which the installation must endure. Even when a pole has reached end of life and/or that it has degraded to 60% or less of the required design strength, the actual failure of the pole is contingent on it being stressed by external forces approaching or equal to these maximal design conditions. Once a pole reaches end-of-life, it may remain standing and in service for many years before external forces result in a failure.

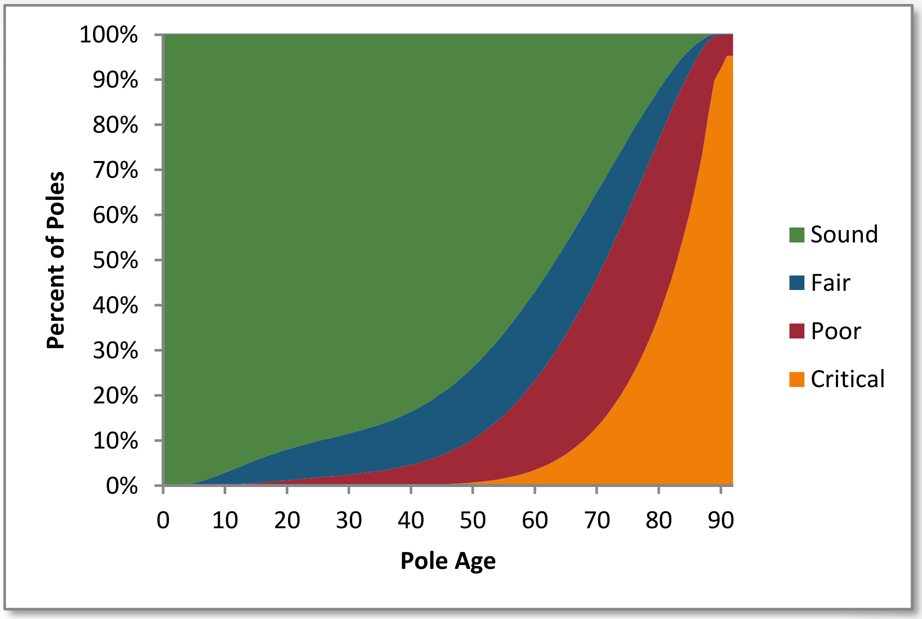
In the past, analysis has correlated the pole to failures to develop a hazard curve and estimate the probability of failure at any given age. With the increased availability of inspection data for the distribution poles, current analysis has been carried out to correlate the remaining strength to pole age. The remaining strength to pole age correlation will become more accurate as more inspection data is collected every year. Based on this analysis, poles have been grouped into 4 categories as shown in Table 6.1. The resulting pole distribution based on this model can be seen in Figure 6.5.

TABLE 6.1 - POLE CONDITION GROUPS

Group	Remaining Strength
Critical	Less than 25%
Poor	25 – 60%
Fair	60-75%
Sound	75-100%

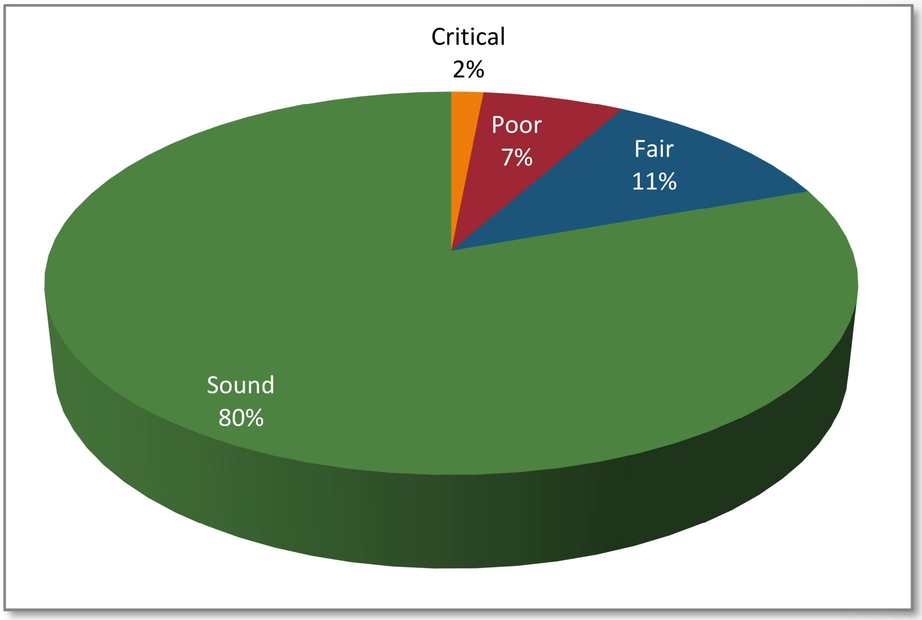
FIGURE 6.4 - 2013 POLE FAILURE ON SHEA ROAD

Figure 6.5 - Proportion of wood Pole Condition by Age



By extrapolating this model to the entire asset class it is estimated that 9% (4,945) of the wood poles which Hydro Ottawa owns or operates on are currently below 60% remaining strength and require replacement.

Figure 6.6 - Estimated condition of Wood Pole Assets



Poles in poor or critical condition have technically failed as they no longer have the required strength to perform the function for which they are designed. They will not necessarily be identified and may not fail unless subjected to external forces approaching the design forces (i.e. severe wind storm). Based on average pole failures it is estimated that only 1 in 10 critical poles and 1 in 150 poor quality poles will fail annually. If this trend continues it will result in an annually increasing organizational risk due to the increasing number of poles which will not be able to weather severe storms.

6.1.3 Outlook

Using the degradation model developed for wood poles, the impact of several replacement policies were analyzed. For all policies, it was assumed that the number of poles replaced annually will be maintained at 400 on average until the end of 2016, at which point the number of replacements will be increased to the indicated quantity.

Based on this analysis, it can be seen that an increase of replacements to 1,250 poles annually would be required to manage failures while bringing the number of poles in critical and poor condition to an acceptable level. The impact of different replacement policies is shown in Figure 6.7. The number of failed poles indicated in the first graph represents the number of poles that have reached end of life and/or degraded to 60% or less of the required design strength. The actual failure of the pole is contingent on it being stressed by external forces approaching or equal to these maximal design conditions.

The 1,250 replacement level is based on an assumed 100% program efficiency, that is to say only the oldest and poorest condition poles are replaced first. This level of program efficiency does not occur in practice, rather as areas are targeted for replacement all poles within 5-10 years of end-of-life are replaced. This approach allows for financial efficiencies, and reduced customer inconvenience, over the piece-meal approach of only replacing poles currently at end-of-life. It is estimated that the replacement program is typically around 50% efficient, that is, 50% of the poles that are projected to fail annually are able to be replaced in a planned fashion. If the annual planned replacements exceed this value the remaining planned replacement are assumed to be the oldest poles in the system. In order to achieve the results as the 100% efficiency 1250 pole replacement program, 1300 poles annually would be required at 50% efficiency and 1558 poles at 25% efficiency. Based on this analysis it is recommended that roughly 1400 poles annually be targeted for replacement in order to achieve the desired results.

If increases in pole replacements are deferred it will result in a potential increase in pole failures, but also increased replacement requirements in the future to achieve the same results. For example, if increase in pole replacements is deferred until 2020 the number of annual pole replacements required to achieve the same result as increasing the number of pole replacements to 1,250 in 2016, would be 1,317. This new program would only provide the same failure levels as the 2016 program in 2055; higher replacement levels would be required upon initiation in order to bring the two programs inline earlier. A summary of the impact of different deferrals on forecasted pole failures can be seen in Figure 6.8.

FIGURE 6.7 - POLE FORECASTS UNDER DIFFERENT REPLACEMENT POLICIES

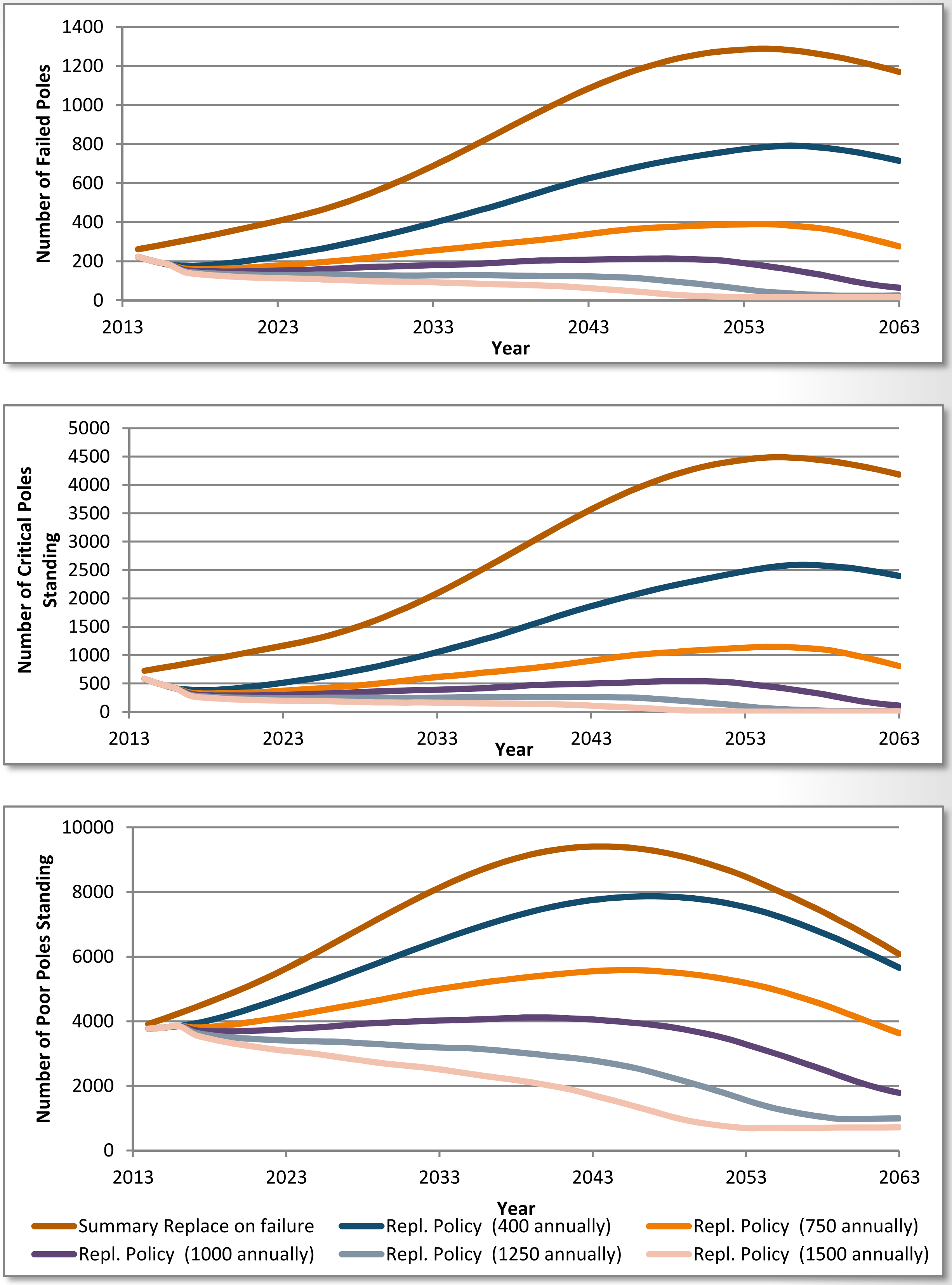
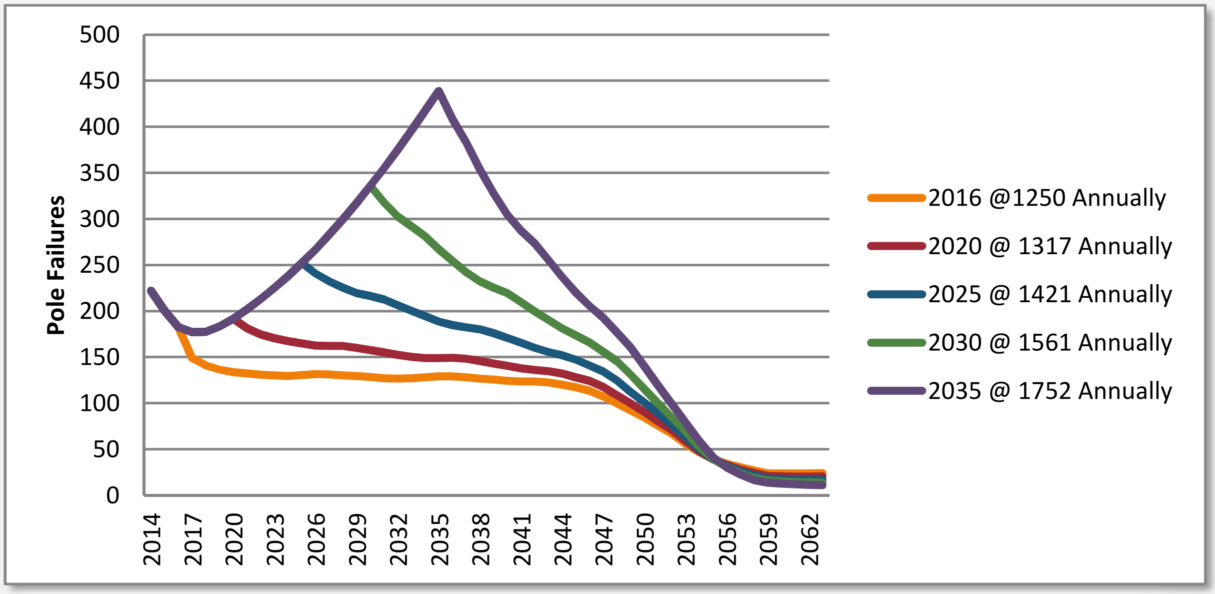


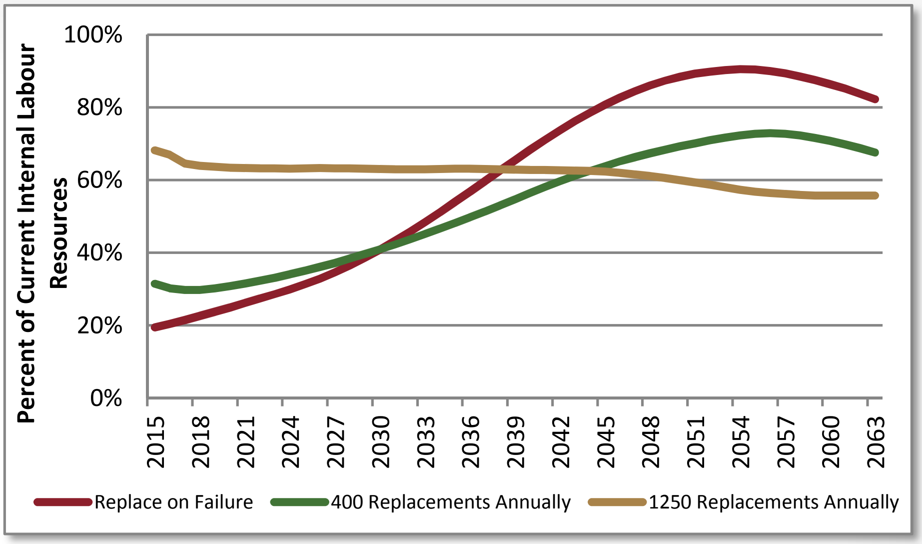
Figure 6.8 - Impact of Deferral



6.1.3.1 Labour Requirements

Replacement of 1250-1500 poles annually will be challenging from a resource perspective. The alternative will not only introduce organizational risk due to the potential for pole failures but it will also stress the available resources. Estimated labour requirements for planned and unplanned pole replacement work are shown in Figure 6.9. With the proposed planned program, by 2063 unplanned pole replacements are anticipated to be reduced to approximately 2% of the available labour. Conversely, with a 400 annual replacement policy unplanned replacements account for 50% of the available labour. A planned labour approach allows for the program to be scaled from year to year and contractor resources to be brought in to assist in the replacement program. With the replace at failure approach the majority of replacements would require the use of internal resources. In addition, the unplanned work would not be divided evenly between years as shown. Plant failure trends show that while the average annual number of pole failures annually since 2005 is 42, the maximum occurred in 2013 with 76 failures – almost 200% of the average. If this trend holds true under a 400 poles annual replacement program the unplanned replacement labour requirement would be anticipated to fluctuate between 20% and 65% of current internal staffing levels.

FIGURE 6.9 – LABOUR REQUIREMENTS



6.1.4 Use of Composite Poles

Composite poles have been Hydro Ottawa's Standard for use in wood-pecker prone areas, as well as in areas where treated wood-poles cannot be used due to standing water. Due to the composite pole material cost, the total installed cost is estimated to be roughly 1 to 11% higher than a wood pole. The main drawback to the use of composite poles is that they cannot be climbed. Potential benefits include:

1. **Longer life** – Hydro Ottawa's data indicates that wood poles have a life span between 40 and in rare cases 92 years, and where external attack is prevalent shorter service life has been seen. Composite poles by contrast will not rot, splinter or decay, nor are they susceptible to insect or woodpecker damage. Composite poles will degrade due to exposure to UV light. Hydro Ottawa has trialed composite poles from RS Technologies. Their poles have been engineered for a minimum service life of 65 years in high UV environments such as Florida. In the less demanding climate it is anticipated that pole life could be expected to last 125 years.
2. **Lower Liability** – Composite poles are more likely to bend in severe winds compared to other materials decreasing the likelihood of a break. In addition, the composite material used cannot sustain fire.
3. **Safety** – Composite poles weigh significantly less than wood poles, reducing potential for strain injuries when poles are installed. They are also hydrophobic and non-conductive, reducing potential for second point of contact injuries, and help prevent arcing caused by lightning and switching.
4. **Logistics** – Due to the lower weight and modular design of composite poles, transportation and warehousing costs can be reduced.
5. **Environmental** – Wood poles require deforestation (each pole is a tree), and requires chemical treatment in order achieve appropriate service life. By contrast, composite poles are manufactured from inert materials, preserving trees, and eliminating any leaching of preserving chemicals. They also result in lower emissions due to reduced transportation requirements.

With these benefits and potential savings and only moderate increase in direct capital costs, it is recommended that Hydro Ottawa considers the possibility of increasing the proportion of composite pole installations. While this will increase the capital costs in the short term, it will reduce overall program costs in the long term, while decreasing Hydro Ottawa's environmental footprint. With the increased minimum life of composite poles the life cycle capital costs for composite poles are expected to be on par or lower for composite poles (assumed minimum life wood-40 years, composite-70 years).

6.2 Pole Fixtures (Insulators, Arresters)

Insulators and arresters serve important functions in the support and operation of Hydro Ottawa's distribution system. While they are typically run to failure and/or replaced in concert with the replacement of the pole (or other equipment) to which they are affixed, they do from time to time require proactive replacement in response to known design or manufacture defects.

Issues have been encountered due to the failure of several styles of porcelain insulators. As these styles of insulators pose health, safety and reliability issues, proactive replacement has and continues to be deployed.

6.2.1 Demographics

There are currently no centralized records for Hydro Ottawa's insulator or arrester assets and is not required as these assets are essentially tracked along with pole inspections.

6.2.2 Assessment

Insulators

Two basic dielectrics are used in the construction of distribution class insulators: ceramics and polymers.

Insulators reach the end of their useful life either when they fail mechanically or when surface deterioration reaches the point where the number of flashover incidents on a line becomes unacceptable or the desired safety factors no longer exist.

While age may play a part in the eventual failure of these assets, other factors predominate. Mechanical failure modes such as cracking and separation may be due to defective design, manufacture or application and may not show up for many years after the devices have been installed. Electrical failure modes include tracking and flashover and are most often due to contamination on the surface due to contaminates such as salt spray, combated by programs such as insulator washing.

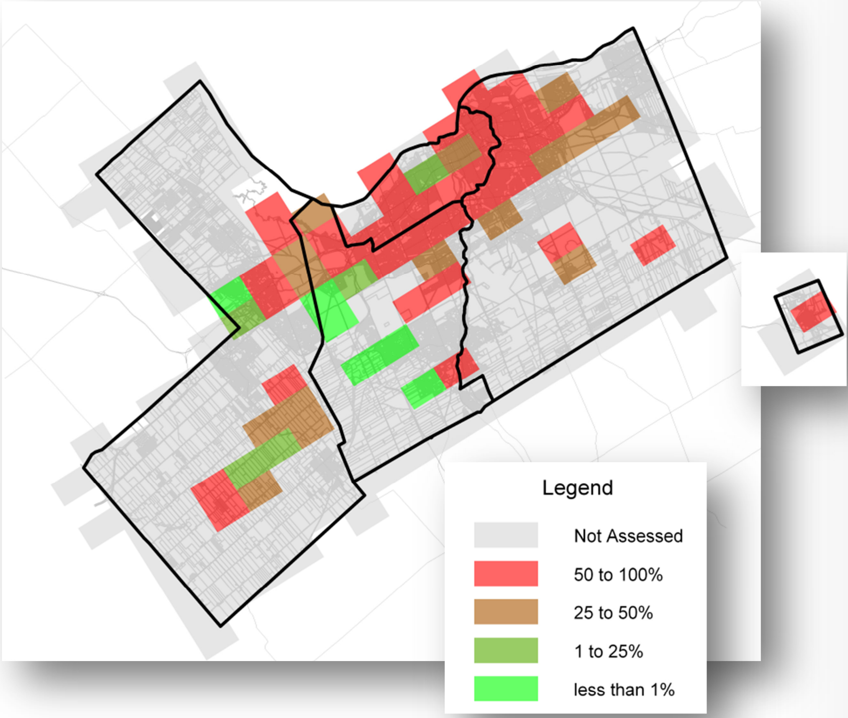
In the absence of specifically identified problems, Hydro Ottawa follows standard industry practice of running insulators to failure (maintaining only the porcelain insulators through a washing program during their life), recognizing that other external drivers will usually result in their replacement before failure. No specific inspection or testing program is generally required; however, the asset is inspected inherently as part of the periodic pole inspections as well as through IR scanning.

At the present time there are four specifically identified problems with primary insulators, - none with secondary type insulators:

- "WART" type porcelain post insulators
- Canadian Porcelain pin type 28/46kV insulators
- Horizontally installed porcelain pin type insulators
- Ohio Brass porcelain insulators on standoff brackets

Limited information is available on the locations of these insulators. At this time, funding for planned and ad hoc replacement should be maintained. In addition, information regarding location and quantity of the problem insulator types is beginning to be collected as part of the pole inspection program. Figure 6.10 below shows a map of the areas that have undergone pole inspection and the associated percentage of poles inspected that contain problem type insulators.

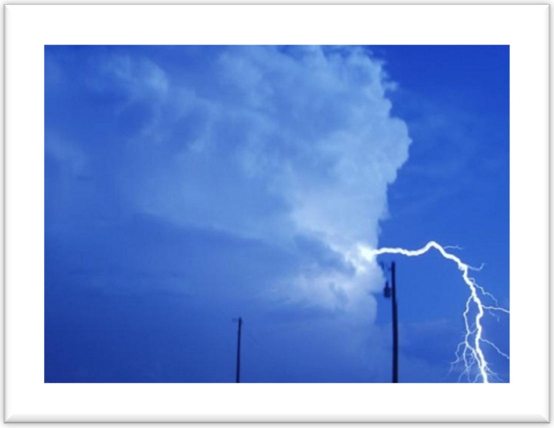
FIGURE 6.10 -PERCENTAGES OF INSPECTED POLES WITH PROBLEM TYPE INSULATORS



Arresters

Distribution surge arresters are designed to suppress voltage surges on an overhead circuit and protect overhead equipment such as transformers, switches and cable connections. A majority of the voltage surges occur through induction due to a lightning strike in the vicinity of the overhead circuit, although a direct lightning strike is also possible. Surge arresters reach end-of-life based on the amount of energy absorbed, and once this limit is reached they no longer operate (i.e. suppress surges) and require replacement.

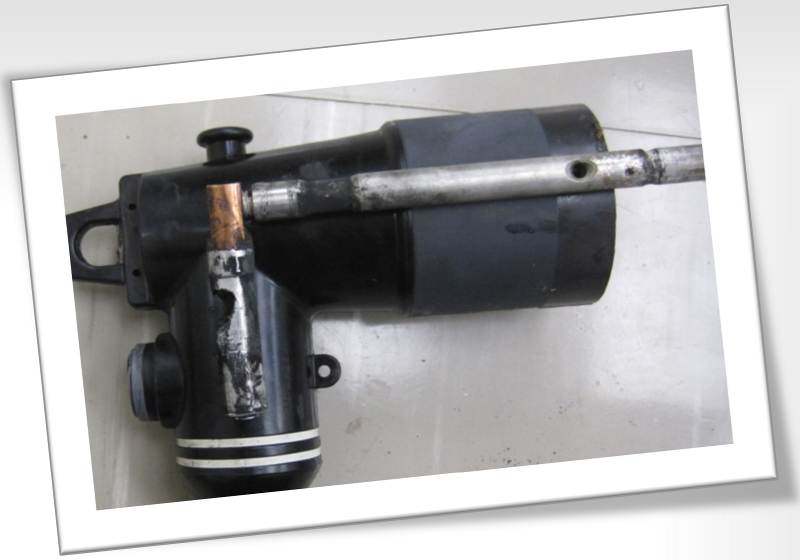
Hydro Ottawa practice is to run surge arresters to failure, recognizing that other external drivers (replacement recommended in conjunction with changing of poles, transformers, overhead switches and cable risers) will usually result in their replacement before failure.



6.2.3 Outlook

Information regarding health and integrity of these assets will continue to be gathered through regular visual inspection programs in order to determine required replacements.

6.3 Elbows and Inserts

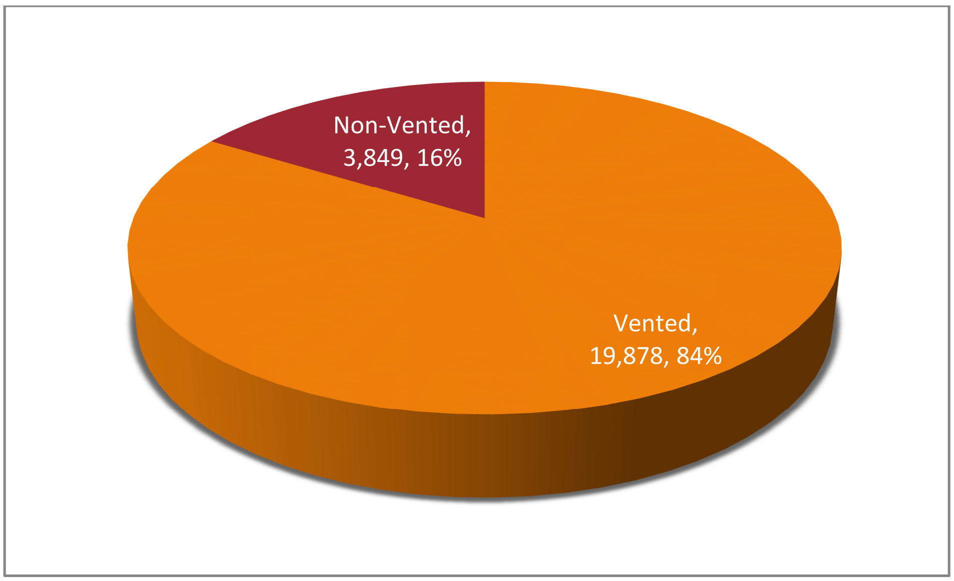


Padmount transformers and switchgear units have conical bushings, called an insert, which accept an elbow, a form of a plug that is connected to the incoming and outgoing cables.

6.3.1 Demographics

There are two categories of elbows: vented and non-vented, which equates to having the ability for full switching capabilities or restricted switching, strictly on the 27.6kV system. On the 27.6kV system, the non-vented elbow design has led to flashes, due to the creation of a vacuum at below freezing temperatures as the field crew separates the elbow from the bushing under load (live). Due to this, the elbows and inserts that cannot be separated while the circuit is energized must be identified as non-vented. The flash is a safety risk to employees and will typically cause a local outage. Figure 6.11 shows the proportion of non-vented elbows remaining on the 27.6 kV system, this data is taken from HOL's Geographical Information system (GIS).

Figure 6.11 - 27.6 kV Elbow Demographics



6.3.2 Assessment

The elbow and insert replacement program evolved from selective to bulk replacement. It was revealed during the program implementation that efficiencies were made in the organizational processes by replacing bulk elbows and inserts as well as allowing for proactive replacement of potentially problematic elbows and inserts from the system.

6.3.3 Outlook

Elbow and inserts are also proactively replaced with a transformer, cable replacement and cable injection program.

6.4 Polemount Transformers

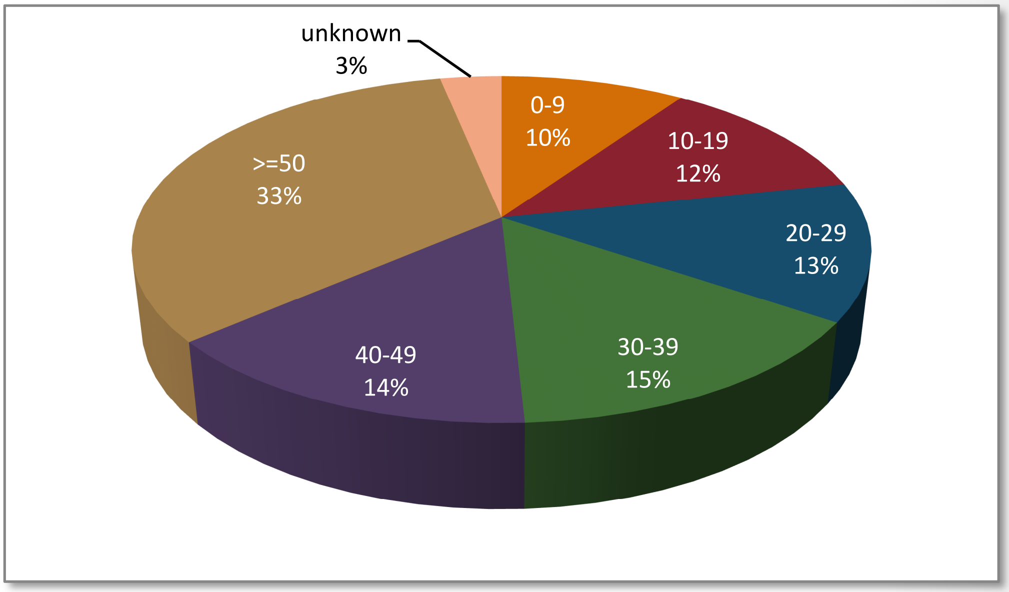
The polemount transformer asset class includes roughly 16,000 service transformers which convert electrical power from its primary distribution voltage to service level voltage, nineteen (19) step transformers which convert from one primary distribution voltage to another and six (6) voltage regulators. As there are only a few step-down transformers and voltage regulators in the Hydro Ottawa system, the focus of the asset management program is on polemount service transformers.

6.4.1 Demographics

Overhead Service Transformers

Demographic information for polemount transformer assets such as purchase date, manufacture date, ratings and manufacturer are stored in Hydro Ottawa's Geographical Information system (GIS). Hydro Ottawa owns and operates roughly 16,000 polemount transformers. Currently, the installation and manufacture date are not consistently available. As such, where install year is not available it has been approximated based on the purchase year, or estimated install year, based on legal documentation of the surrounding properties. This demographic information is presented in Figure 6.12, and utilized in the remainder of this report.

FIGURE 6.12 - PROPORTION OF OVERHEAD TRANSFORMERS BY AGE GROUP

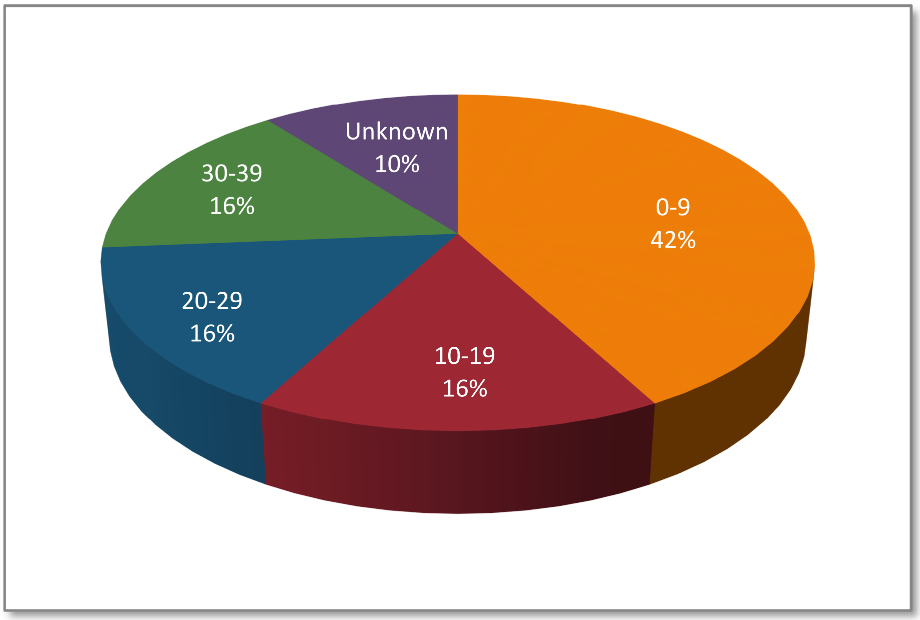


Voltage Regulators and Step Transformers

Currently, there are 6 polemount voltage regulators within Hydro Ottawa's Distribution system for which there is no manufacture or purchase date available. Based on visual review and inspection the units are approaching end-of-life. Further to this, all but one of the units has PCB concentrations greater than 10ppm and two of the units have sufficiently high levels to require replacement under PCB regulations. The replacement of these units will be completed in 2014.

Currently, there are 19 polemount step transformers in the Hydro Ottawa distribution system. Despite the low number of units, consistent reliable centralized data is not currently available. Combining information from the PCB transformer survey and GIS, the demographics of these transformers has been generated and can be found in Figure 6.13.

FIGURE 6.13 - PROPORTION OF STEP TRANSFORMERS BY AGE



6.4.2 Assessment

Federal Regulation SOR 2008-273 dictates that all polemount equipment with oil containing PCBs in concentrations of 50 mg/kg or greater must be removed from service by 2025. There are 150 known PCB containing Hydro Ottawa polemount transformers remaining in service, and 2 voltage regulators. As a result of the regulatory obligations, Hydro Ottawa has elected to take an accelerated approach to remove these remaining transformers from service. Aging infrastructure work will be superseded by the removal of the remaining PCB containing transformers, expected to be complete in 2016.

6.4.2.1 Health Index

Age can be related to the condition of distribution transformers however, it is not a linear relationship. The life of a transformer's internal insulation is related to temperature-rise and duration, therefore transformer life is affected by the electrical loading profiles and ambient temperature change. Other factors such as mechanical damage, exposure to corrosive salts, and voltage surges also have a strong effect on transformer life. Visual inspection and rotational IR scanning are able to provide considerable information on transformer asset condition. Leaks, cracked bushings, and rusting of tanks can all be established by visual observation and can be collected in the course of pole inspections.

At this time there is no centralized data available on the condition of these assets. The asset evaluation has therefore been based on the transformer purchase age alone.

6.4.2.2 Failure Consequence

The first step in assessing the consequence cost of failure is to summarize the expected effects of failure. In general, these will include some or all of the following:

- Customer outage effects. This will include "event" effects due to the outage (SAIFI), "duration" effects (SAIDI), and effects on critical customers;
- Health and safety consequences; and
- Environmental consequences.

6.4.2.3 Failure Correlation

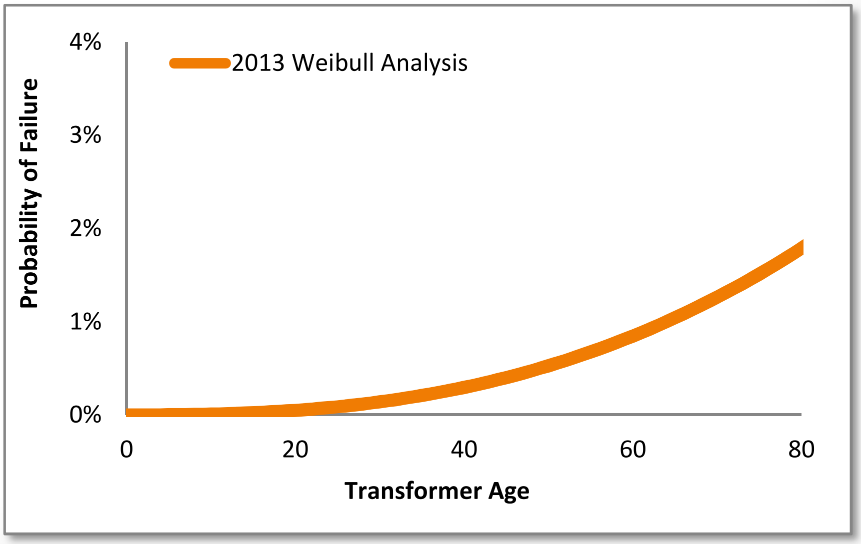
To correlate asset demographics to asset failure rates, statistical Weibull analysis has been undertaken as a two part study. Failure records, demographics from old Ottawa Hydro, current failure rates extracted from the interruption database and the current asset demographics stored in the GIS system were used for this analysis. The historic failure rates of overhead transformers are shown in Table 6.2.

The resulting failure rate developed through this analysis is shown in Figure 6.14. Based on the current analysis, the anticipated average life of a polemount transformer is in the range of 90 years. The low rise to the failure curve indicates that the polemount transformer failures may be more random and operating condition driven than age dependant. Given the high variability in the failure data, further refinement to these failure curves is necessary moving forward. These improvements will only be possible through more granular tracking of transformer failure data.

TABLE 6.2 - HISTORIC OVERHEAD TRANSFORMER FAILURES

Year	O/H XFMR Failures
2004	24
2005	120
2006	175
2007	81
2008	41
2009	49
2010	52
2011	70
2012	84
2013	61

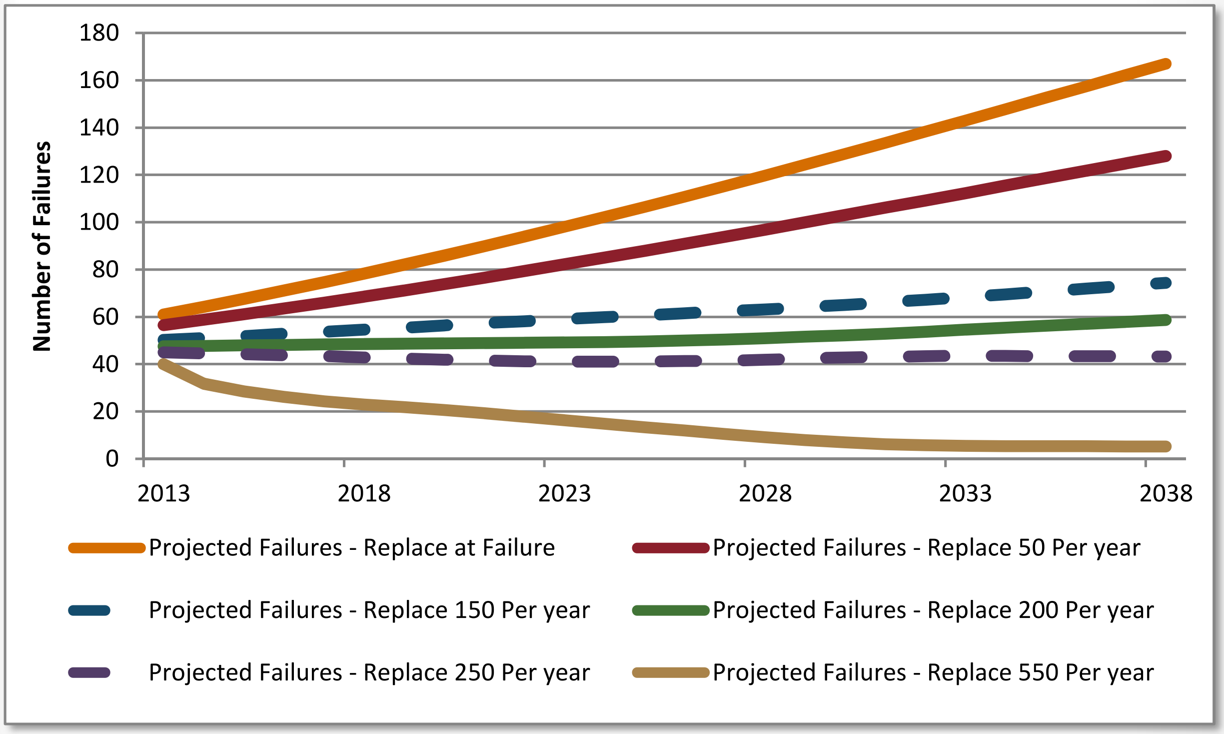
FIGURE 6.14 – POLEMOUNT TRANSFORMER FAILURE RATES



6.4.3 Outlook

Asset failures have been forecasted under different replacement policies. Based on this analysis, replacement of roughly 250 units annually is required to reduce annual failures from the 61 seen in 2013 to a more averaged number of failures around 40. This analysis is shown in Figure 6.15. Given the low correlation between risk of failure and age, and the renewal impact of polemount PCB replacements at this time, proactive replacement of this asset is not recommended.

FIGURE 6.15 - POLEMOUNT TRANSFORMER RECOMMENDED REPLACEMENT RATES



In the short term, planned replacement of PCB transformers will be the only proactive replacement undertaken in this asset class. In addition, replacement opportunities such as in coordination with pole replacement should be explored where-ever practical.

Hydro Ottawa's voltage regulators are at end-of-life and require replacement. As there are only 6 of these units in the HOL system, three will be removed and the remaining three will be replaced as part of the 2014 Woodroffe Voltage Conversion project.

6.5 Underground Transformers

Hydro Ottawa's underground transformer asset class includes a variety of transformers which are used in the delivery of power to customers. These transformers include submersible, padmount, kiosk and vault transformers. While primarily oil filled, there is also a subset of solid dielectric transformers owned and operated by Hydro Ottawa.

6.5.1 Demographics

Due to the differences in construction and operating environments, individual analysis for each transformer type has been done with the exception of Padmount and Kiosk transformers which were included in the same group. The proportion of underground transformers by type is shown in Figure 6.16.

Figure 6.16 - Proportion of Underground Transformers by Type

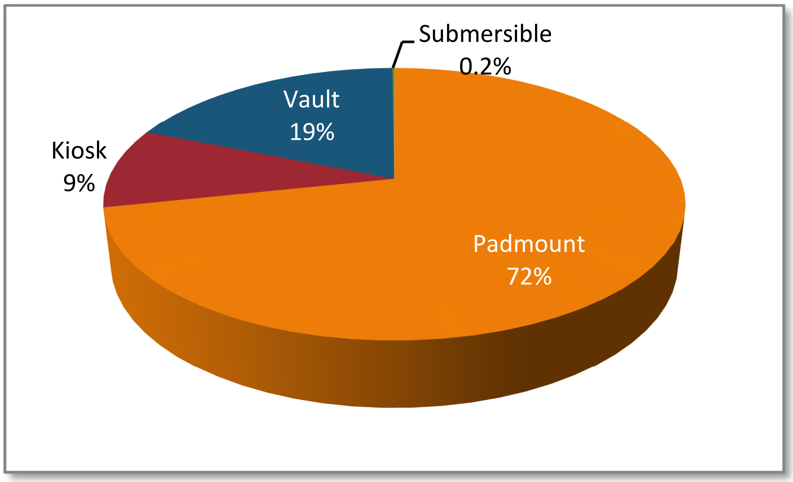
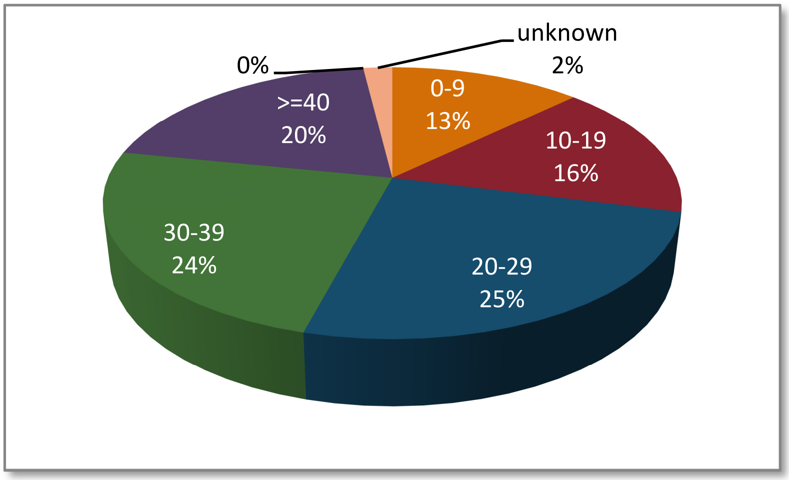


Figure 6.17 - Proportion of Padmount and Kiosk Transformers by Age Group



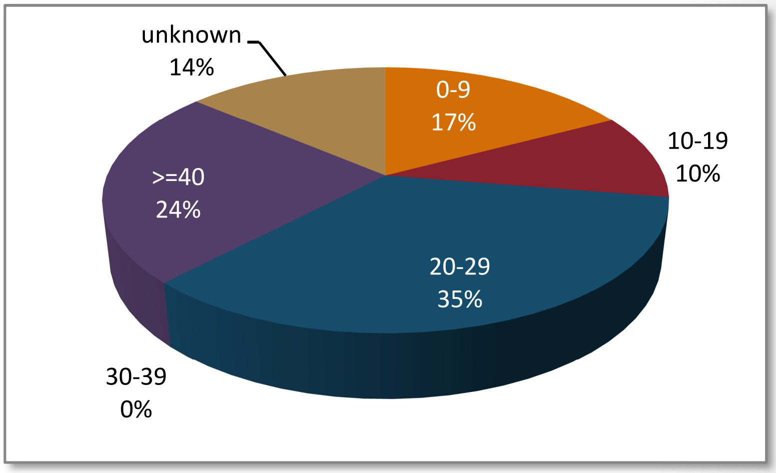
6.5.1.1 Padmount and Kiosk Transformer Demographics

Padmount and Kiosk transformers are located in the road right-of-way and convert electrical power to service voltage for one or more customers. Hydro Ottawa owns roughly 1,800 kiosk transformers and 14,000 padmount transformers. Padmount and kiosk distribution transformers have a well distributed age population and as a result a low proportion of the 15,800 units are approaching end-of-life. Kiosk style transformers have been in use for longer than padmount transformers and as a result there are a higher proportion of these transformers that are nearing end-of-life. Age demographics for these assets are shown in Figure 6.17.

6.5.1.2 Submersible Transformers Demographics

Hydro Ottawa's submersible transformer asset class includes transformers located in sidewalk vaults and in smaller underground structures. The primary driver for replacements is the reduction in risk of oil leaks and the associated environmental hazards that these transformers represent. Since the year 2000 this has resulted in replacement of oil filled transformers with solid dielectric models. As of 2010, HOL's approach was changed moving to replacement with stainless steel, oil filled transformers, to mitigate the environmental hazards. As shown in Figure 6.18 more than 50% of the in service units are 20 years old or greater. The 10 submersible transformers that have been installed since 2002 are solid dielectric transformers. The remaining 19 in-service submersible transformers are oil filled.

FIGURE 6.18 - PROPORTION OF SUBMERSIBLE TRANSFORMERS BY AGE GROUP

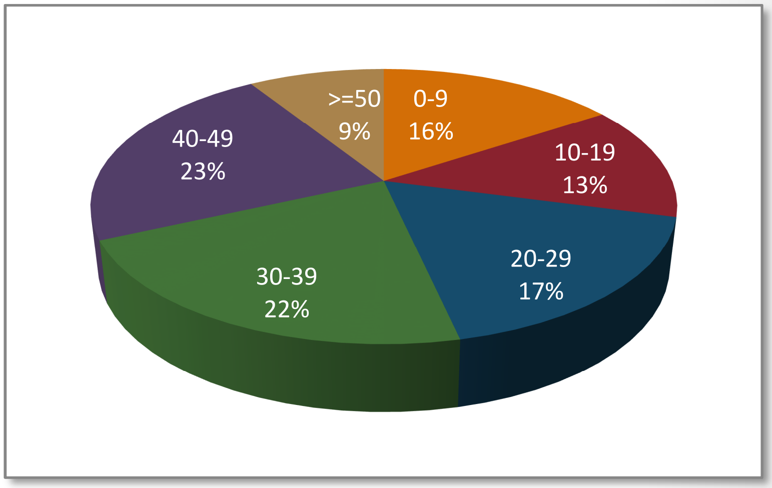


6.5.1.3 Vault Transformer Demographics

Hydro Ottawa's vault transformers are located in building vaults and typically service a single large customer. Currently, Hydro Ottawa owns approximately 3,500 vault transformers.

The population demographics are shown in Figure 6.19. Currently, more than half of the Hydro Ottawa owned vault transformers are over 30 years of age and a quarter are greater than 40 years old.

FIGURE 6.19 - PROPORTION OF VAULT TRANSFORMERS BY AGE GROUP



6.5.2 Assessment

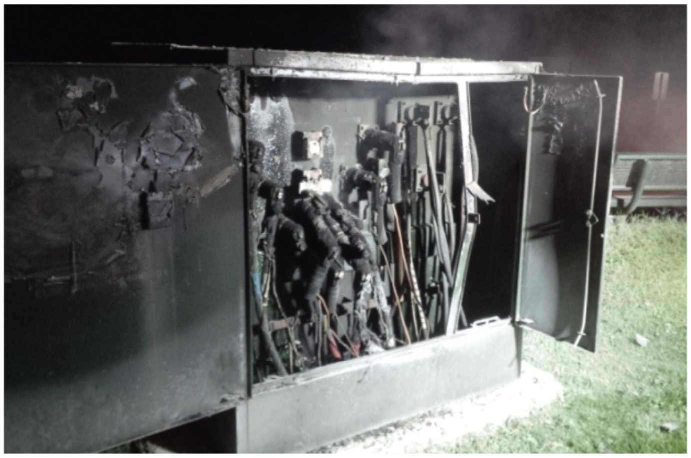
6.5.2.1 Health Index

Age can be related to the condition of distribution transformers, yet it is not a linear relationship. The life of a transformer's internal insulation is related to temperature-rise and duration, therefore transformer life is affected by electrical loading profiles and ambient temperature changes. Other factors such as mechanical damage, exposure to corrosive salts, and voltage surges also have a strong effect. In the future, the impacts of transformer service condition should be integrated into Hydro Ottawa's asset planning criteria.

The current asset evaluation has been based upon transformer age demographics alone. The exception to this is Hydro Ottawa's submersible transformer population. The primary mode of failure for these units is corrosion leading to leaking of oil. The submersible asset base is sufficiently small that the program moving forward will be inspection driven to identify those units which have reached end-of-life due to corrosion and pose a risk of oil release.

Federal Regulation SOR 2008-273 dictates that all underground equipment with oil containing PCBs in concentrations of 50 mg/kg or greater must be removed from service by 2009 or 2025 dependant on the equipment location and concentration. As of the beginning of 2014, there is one vault transformer remaining to be replaced under the regulation by 2025.

FIGURE 6.20 – 2013 TRANSFORMER FAILURE ON JEANNE D'ARC BOULEVARD



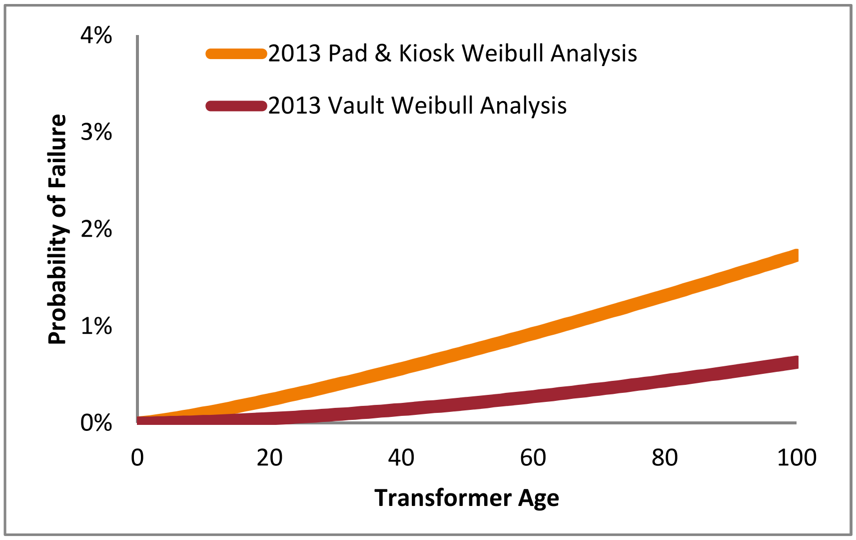
6.5.2.2 Failure Consequence

The first step in assessing the consequence cost of failure is to summarize the expected effects of failure. In general, these will include customer outage effects, health and safety consequences and environmental consequences.

6.5.2.3 Failure Correlation

In 2013, Hydro Ottawa had 96 kiosk and pad mounted transformers fail as well as 4 failed vault transformers. The asset failure curves have been estimated through Weibull analysis, the results are shown in Figure 6.21. These curves have been estimated using hazard fitting data; utilizing current asset demographics and failure data. In addition, the old Ottawa Hydro transformer age at failure records from 1990-1999 have been used as a point of comparison and to inform the statistical fitting. As there have been only two recorded submersible transformer failures in the data range, it has not been possible to perform this analysis on these assets. Records indicate a similar hazard rate for both kiosk and padmount transformers and as such, they have been considered concurrently in this analysis.

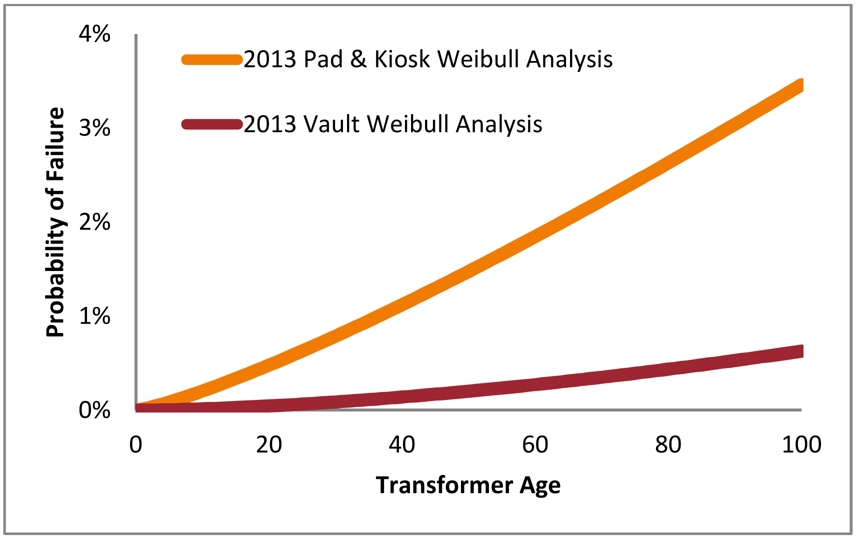
FIGURE 6.21 - UNDERGROUND TRANSFORMER FAILURE RATES



The gradual rise on the failure curve indicates a potentially low correlation to asset age and a larger component of asset failure predicated on operating conditions. Future data should be collected to clarify the contributing aspects. In the meantime, these curves provide a sufficient initial baseline for directing replacement activities although the programs should be tempered based on this uncertainty.

In the previous analysis, only plant failure data that caused an unplanned sustained interruption was considered. Leaking transformer failure data was not included since they generally do not cause an unplanned interruption. Due to the increase in the number of leaking transformers found in the field in the last three years, another asset failure curve has been estimated including the number of leaking transformers. The difference between the failure curves is shown in Figure 6.22. As observed the hazard fitting curves for both analyses do not differ significantly. However, the environmental impact and costs associated to clean-up the spilled oil are rising and need to be monitored.

FIGURE 6.22 - FAILURE CURVES INCLUDING LEAKER TRANSFORMERS



6.5.3 Outlook

6.5.3.1 Padmount and Kiosk transformers

Asset failures have been forecasted under different replacement policies. Based on this analysis, replacement of roughly 300 units annually is required to maintain failures in the current range of roughly 30 units per year. This analysis is shown in Figure 6.23. With the leaker units included in the analysis the replacement rate recommended will be the same, however the annual failure rate increases to 96 units. This is shown in Figure 6.24. Currently, padmount and kiosk transformers are not specifically targeted and are replaced as a result of failure, leaking oil, during voltage conversion, in conjunction with cable replacement projects or due to noticeable deterioration during IR scanning. Once the replacement of PCB containing transformers is finalized, the replacement rate of padmount and kiosk transformers should be increased to the recommended rate of 300-400 units per year. Construction efficiencies exist for replacing transformers in conjunction with cable replacement. These are determined based on financial lifecycle and inspection results for a project-by-project basis.

FIGURE 6.23 - PADMOUNT AND KIOSK TRANSFORMERS RECOMMENDED REPLACEMENT RATE

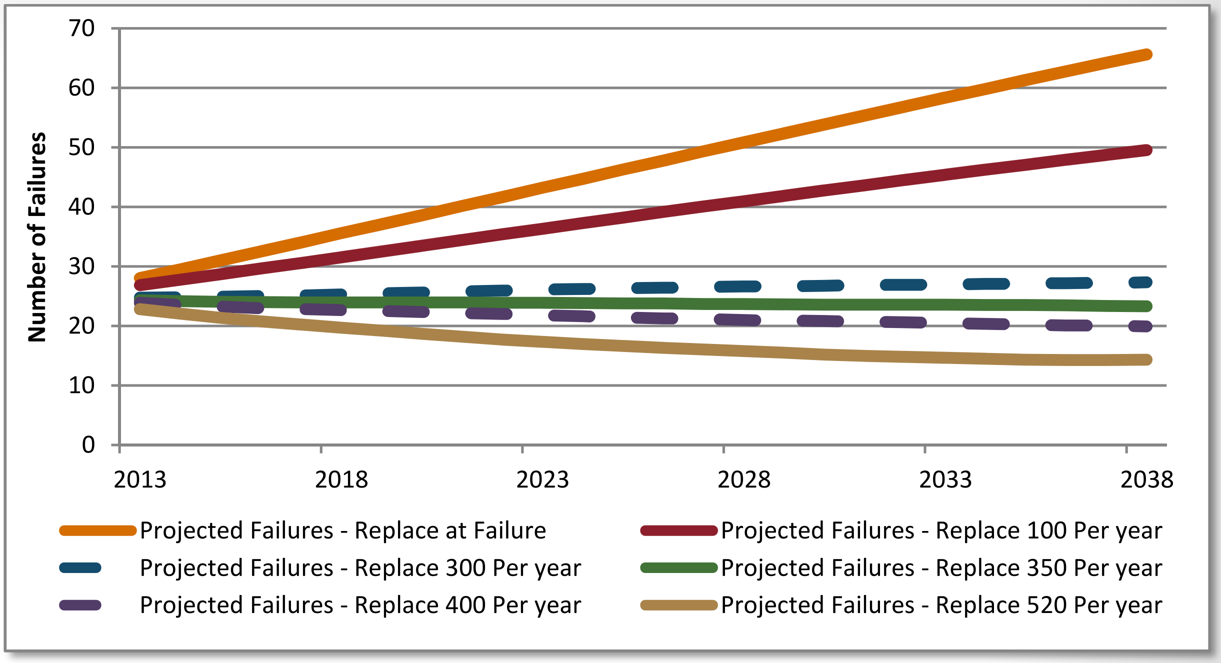
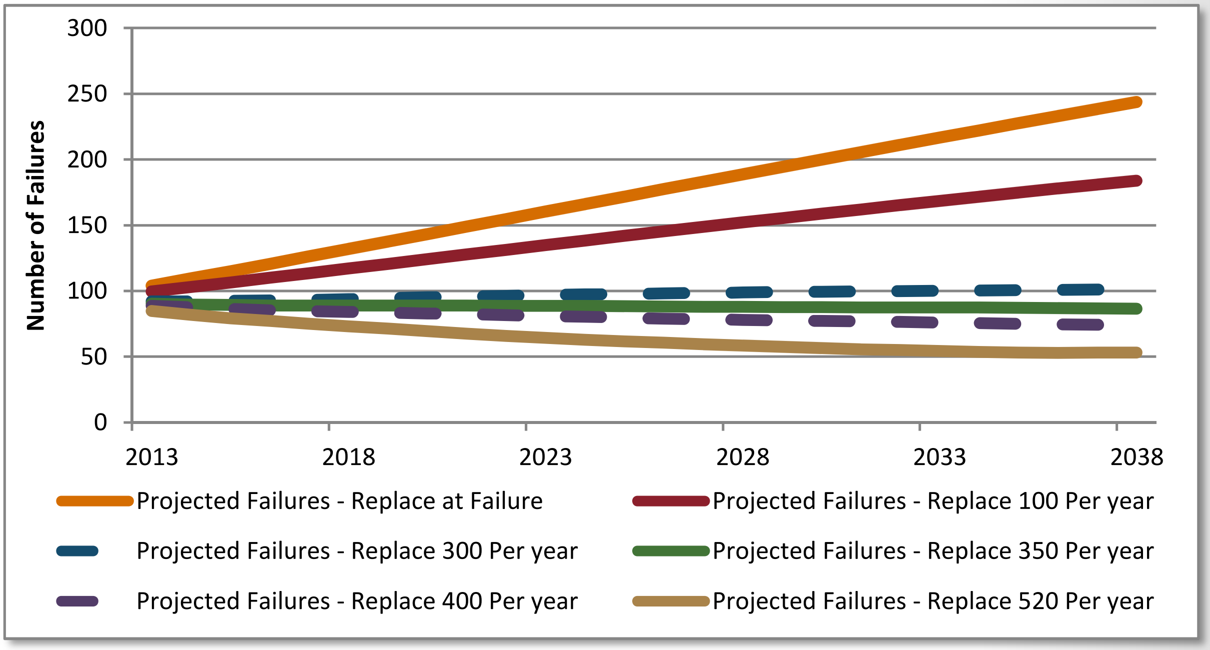


FIGURE 6.24 - PADMOUNT AND KIOSK TRANSFORMERS RECOMMENDED REPLACEMENT RATE INCLUDING LEAKER UNITS



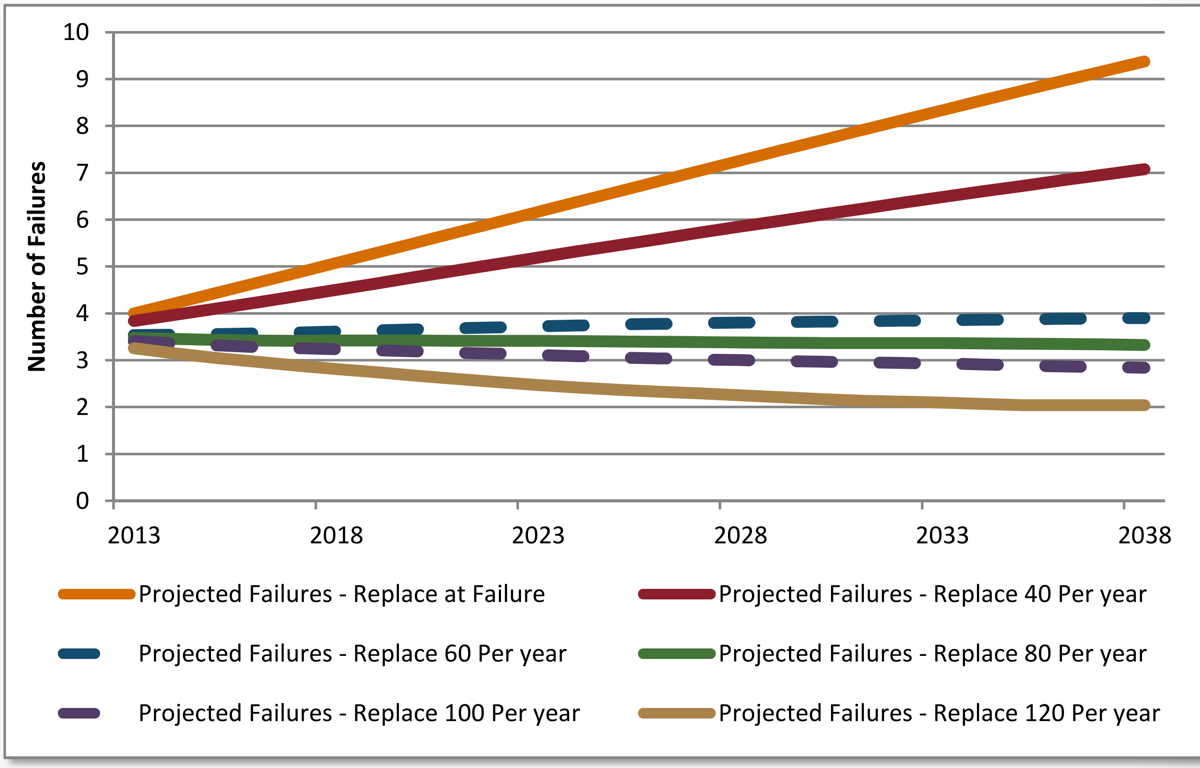
6.5.3.2 Submersible transformers

Although two units have failed in the last two years, there is currently insufficient information from which to project submersible transformer failures. While detailed condition data is not currently available for these transformers, reports from the field indicate that a significant portion of these units are beginning to corrode. As a result, active replacement of all remaining submersible transformers are expected to take place in 2016.

6.5.3.3 Vault transformers

Based on current projection, a replacement rate of 40 to 80 transformers per year is expected to maintain the failure rate in the current range of roughly 4 per year. This analysis is shown in Figure 6.25. The current replacement will meet this target, yet it will be driven by regulatory obligation to retire PCB containing equipment from the Hydro Ottawa system, rather than transformer condition or age.

FIGURE 6.25 - VAULT TRANSFORMER PROJECTED REPLACEMENT RATES



While PCB driven replacements will not target the worst condition or oldest units, the program will reduce the overall risk of this asset class through a large renewal of the asset base. Of the 163 PCB containing vault transformers, 162 were replaced at the end of 2013 and the remaining transformer is to be replaced in 2014.

6.6 Underground Civil Structures

Hydro Ottawa's Underground Civil Structure asset class consists of underground duct banks, hand holes and various types of underground chambers forming a network through which cables may be installed. Distribution underground civil structures are used in areas where underground wiring is required for aesthetics or clearances, to improve reliability, to reduce the time to access and correct faulty wiring, to permit access in congested areas and to allow re-entry or expansion in areas where further excavation would be costly.

For the purposes of developing the asset management plan for underground civil structures, the asset class has been divided into two primary groups; Duct Structures and Underground Chambers. While duct structures are run to the unlikely event that they fail, underground chambers are maintained through a replacement and rehabilitation program based on regular condition assessment. Based on the currently available inspection data it is recommended that the program target a minimum of 10 underground chambers per year. Underground chambers are a low complexity project with a cost ranging from $20,000 for the repair/replacement of a structure roof to $60,000 for a complete rebuild.

6.6.1 Demographics

Reliable centralized demographic information is not currently available for this asset class. Demographic information for these structures has been collected from various sources and is shown in Table 6.3. Around 1970, standards for underground cable chambers became more stringent and precast structures were favoured for applications outside the travelled road surface. Precast cable chambers are superior to cast-in-place as they are built in a controlled environment to the required specifications. Equipment pads have been included as they encompass both padmount equipment chambers and cast-in-place slab foundations in a variety of geometries.

TABLE 6.3 - CIVIL STRUCTURES BY TYPE

Civil Structure Type	Pre 1970	Post 1970	Unknown	Total
Cable Chambers	343	2,097	734	3,174
Handholes	8	238	82	328
Sidewalk Vaults	-	34	-	34
Equipment Pad	-	3,698	17,115	20,813

6.6.2 Assessment

6.6.2.1 Health Index

Deterioration of aging concrete structures is generally manifested by concrete spalling, leading to exposure and corrosion of the reinforcing steel. Water entering cracks in the masonry may freeze in the winter causing the surface layers of the concrete to pop off and further expose the reinforcing steel.

Currently and for many years, Hydro Ottawa maintains a regular inspection program of its underground chambers, which is administered by both HOL crews and external contractors. Inspection of underground civil structures involves a condition assessment and rating from 0 to 5 for the roof, collar, walls and floor in accordance with Table 6.4.

TABLE 6.4 - RATINGS FOR UNDERGROUND CIVIL STRUCTURE

Condition	0	1	2	3	4	5
Description	**Very Good**	**Good**	**Fair**	**Poor**	**Very Poor**	**Critical**
Criteria	No significant deterioration.	Minor hairline cracks or minor spalling.	Large cracks and some spalling.	Very large cracks and significant spalling.	Major spalling & cracks reaching the steel rebar, concrete falling, some rusting.	Concrete has deteriorated, large amounts of steel showing & strength of rebar is questionable.

6.6.2.2 Failure Consequence

Hydro Ottawa practice is to maintain its underground chambers proactively. This asset is not a significant risk item due to its extremely low probability of failure (essentially zero) and the ease of addressing issues prior to failure. It is important to highlight that this course of action is the result of the high consequence cost that would result from a collapse or other failure mechanisms. As most underground chambers are located in roadways and sidewalks, in the case of a collapse there is a strong possibility of injury to the public and potentially significant damage to Hydro Ottawa's corporate image.

6.6.2.3 Failure Correlation

There have been no recorded chamber failures from which to perform failure analysis. Moving forward, detailed review and tracking of the degradation of Hydro Ottawa's underground chamber assets is necessary to assess and project medium and long term asset performance.

6.6.3 Outlook

Currently, the civil structure rehabilitation rate is determined by historical spending. Increased inspection information will allow for a more effective rehabilitation program and will be used to support the need for future projects.

It is recommended that the civil structure rehabilitation program continue to be driven by the manhole inspection program and maintain the current spending rate of approximately $200 - 300 per manhole inspected. This budgetary figure is a historical representation of the rehabilitation/replacement of underground chambers. Typical cost of rehabilitation and replacement are $20,000 and $60,000 respectively and depending on the magnitude of the work will determine the number of civil structures being rehabilitated.

6.7 Distribution Cable

Hydro Ottawa's underground cable asset class includes sections of underground cable running from distribution stations to overhead lines and from overhead lines to transformers and switches. Distribution underground cables are used mainly in urban and newer residential areas where it is either impossible or extremely difficult to build overhead lines due to aesthetic, legal, environmental or safety reasons.

The consequence of a cable failure depends if it is used as trunk or distribution: a failure on trunk cable can result in an outage to thousands of customers while a failure on distribution cable will result in an interruption to only a few hundred customers.

6.7.1 Demographics

There is approximately 4,484 km of underground cable installed in the Hydro Ottawa service territory. The breakdown between type of cable is: 92% cross-linked polyethylene (XLPE), 8% paper insulated lead covered (PILC), and <1% Butyl rubber (14 km installed in the Nepean area). The age distribution is illustrated in Figure 6.26 and Figure 6.27. The breakdown between the various voltage classes is shown in Table 6.5.

TABLE 6.5 - CABLE LENGTH PER VOLTAGE CLASS

Voltage Class	Polymer (km) (XLPE, EPR, Butyl)	PILC (km)
44kV	19	-
27.6kV	1,770	-
13.2kV	1,104	308
12.43kV	73	-
8.32kV	756	-
4.16kV	406	48
Total	**4,128**	**356**

Demographic information for the underground cables has been collected from the GIS. Where installation date is not available, an estimated install date has been used. This is an estimated installation date for the cable based on the adjacent property legal records – i.e. date a subdivision was built.

Demographic information for the underground cables has been collected from various historical records and sources. Lead cable has been installed as far back as the 1930s; however, only information from 1966 to present is known.

FIGURE 6.27 - PROPORTION OF PILC BY AGE GROUP

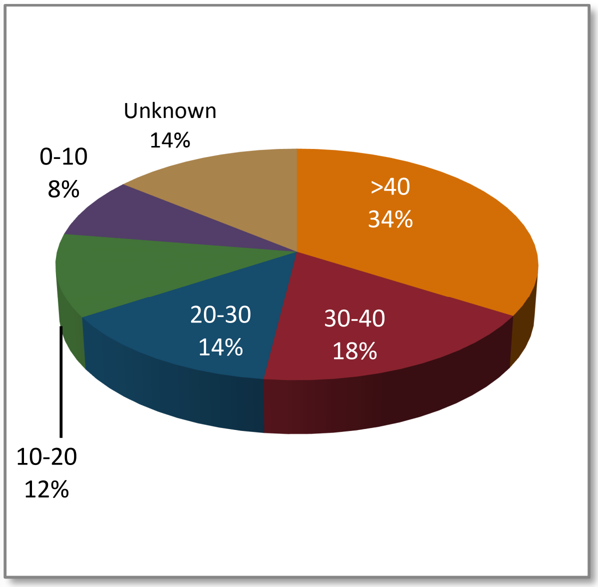
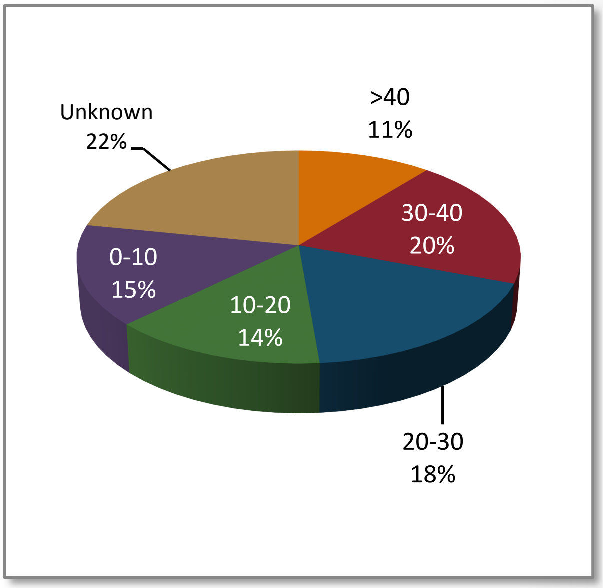


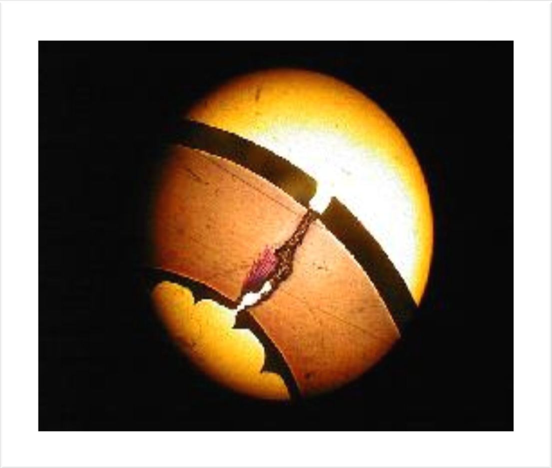
FIGURE 6.26 - PROPORTION OF XLPE BY AGE GROUP



6.7.2 Assessment

Currently, planned replacement is focused on the management of the polymer cable. Due to the limited population and relatively long life of PILC cable, this asset is currently being managed in a run to failure manner. Increasing failure rates of PILC cable will continue to be monitored to determine if the run to failure practice will continue or if planned replacement is required.

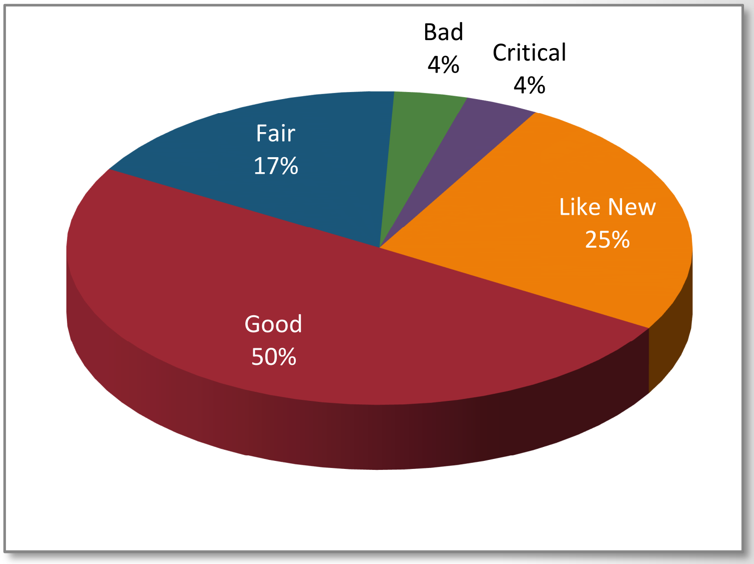
6.7.2.1 Health Index



Cable age is not the main factor in determining the insulation condition of in-service cable. Other factors such as soil condition, amount of moisture in the ground, presence of a cable jacket, and operating condition play an important role in determining the rate of decay. Historically, cable replacements have been prioritized based on the number of faults, or the number of customer interruptions due to cable faults. While these reliability figures provide indication of cable health, they are a lagging indicator. Replacement based on fault data may result in cable in good health being replaced prematurely when the cable faults were the result of localized defects or damage, and the remaining cable is in good health.

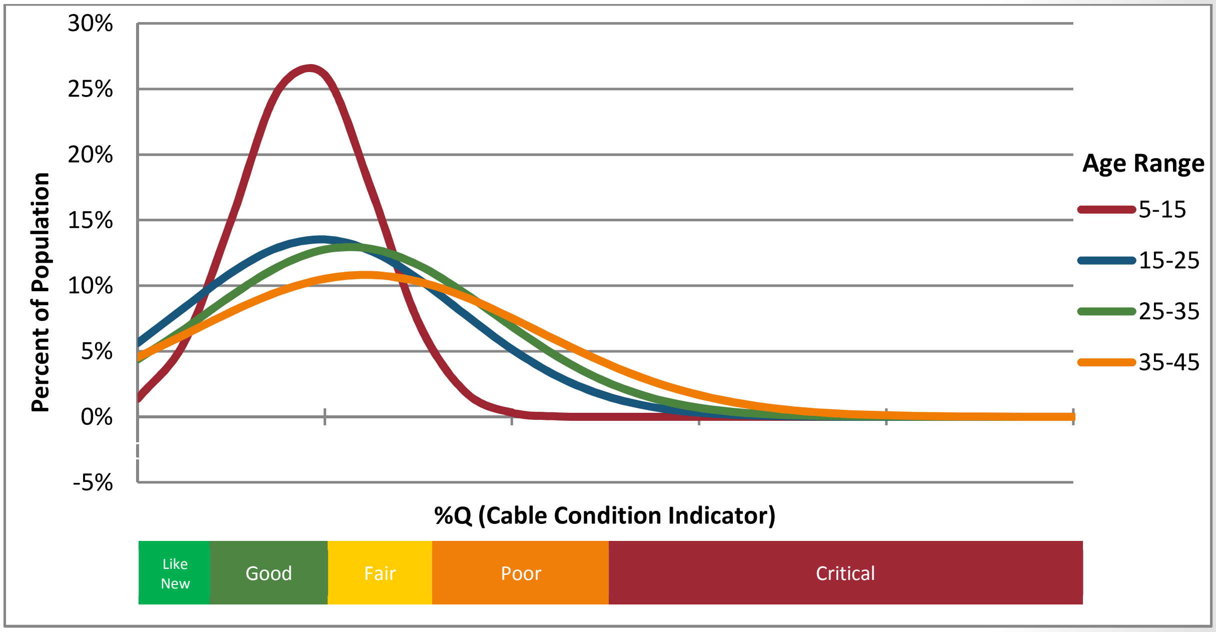
An underground cable testing program was initiated in the winter of 2011 with National Research Council Canada (NRC). The testing method used by NRC determines the general condition of a polymer cable segment. Cable sites targeted for testing include ones scheduled for replacement in the next 2 to 5 years, high fault areas, and areas with known aged cable. In the 3 years of testing, 1.7% of the total polymer distribution cable has been tested.

Figure 6.28 – Proportion of Tested Cable by Condition (by length)



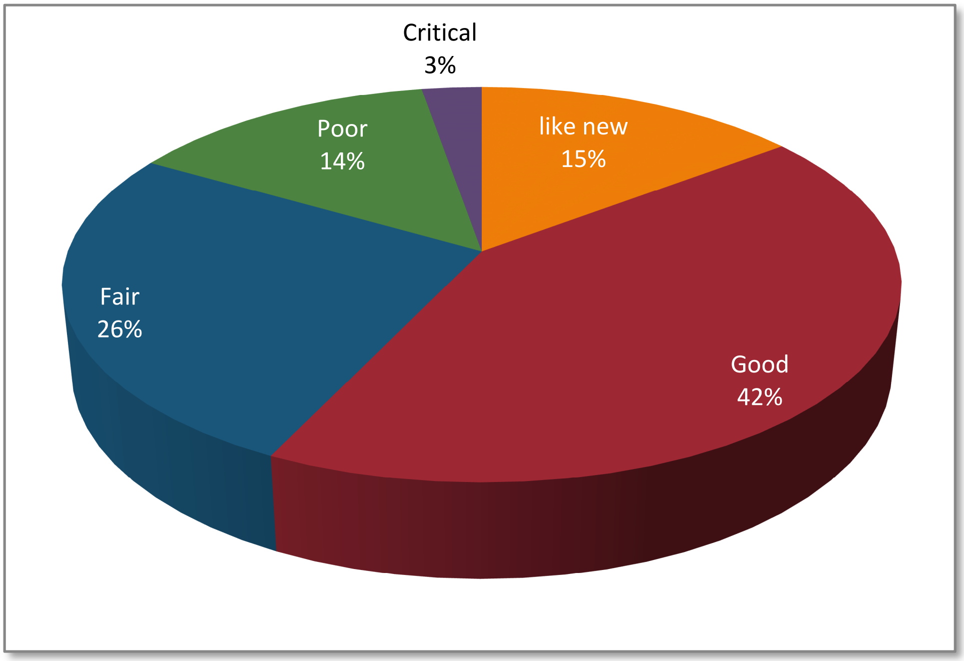
The NRC testing method assesses the progression of water-treeing in plastic cable to determine the relative condition of the entire segment. Water trees develop in the polymeric insulation due to the ingress of moisture and impurities from the soil which are driven into the dielectric by the electric field. Water trees cause the reduction of the insulation strength making the cable more prone to failure. While the testing procedure captures the general condition of the cable insulation it does not capture issues such as neutral corrosion, accessory issues or local defects that also impact cable life. These other issues must be qualitatively assessed when reviewing and prioritizing potential cable replacement projects. The cable condition of segments tested to date is shown in Figure 6.28. While cable age is not the main factor in determining cable condition, it is currently the most reliable data source captured for the entire asset class. The cable tested was grouped into age ranges and fitted to normal distribution. The estimated distribution of cable age ranges, cable quality and percentage of the systems cable can be seen in Figure 6.29. These results were created by sorting the tested cable into age ranges and using their testing results, extrapolating it city wide based on the system's cable age.

Figure 6.29 - Cable Degradation Model



Using the cable inspections and in service cable demographics, an overall HOL cable condition representation was created (see Figure 6.30). Further cable inspection will improve the accuracy of the estimated cable condition. The graph indicates that 3% of the cable is in critical condition and 14% in poor condition. Areas with high percentages of this cable condition are the focus for cable injection and cable replacement projects.

FIGURE 6.30 - ESTIMATED CONDITION OF IN-SERVICE POLYMER CABLE



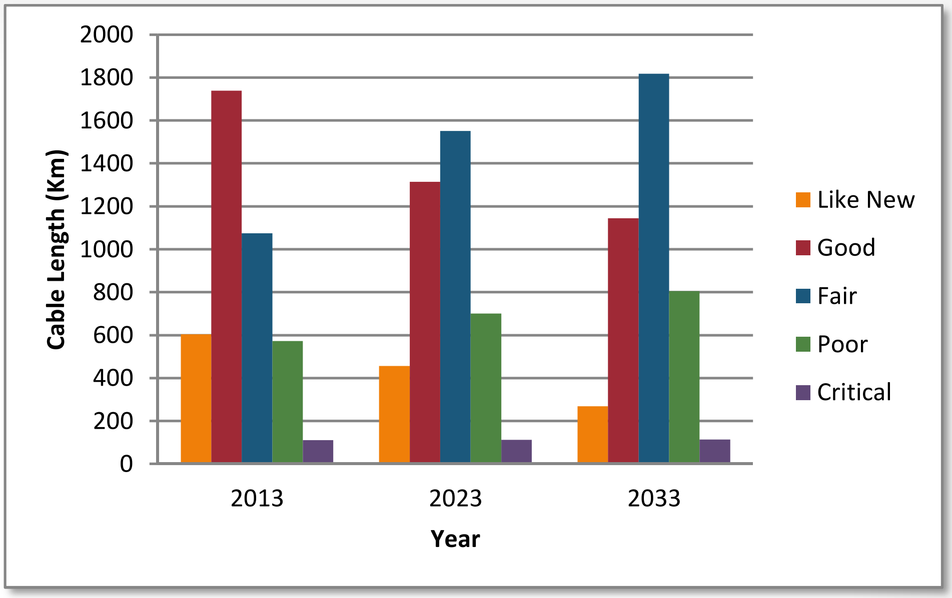
6.7.2.2 *Failure Consequence*

The main impact of cable failures is on system reliability. Each cable fault will result in an outage to the customers fed by that circuit. Cable outages can have significant duration due to the time required to locate, isolate and repair the failed section.

6.7.2.3 *Failure Correlation*

Cable replacement requirements have been forecasted based on the main consequence of cable failure – reliability impact. Using the current age demographics for the cable the cable condition distribution has been forecasted forward (neglecting the impact of new installations), this is shown in Figure 6.31.

FIGURE 6.31 - FORECAST POLYMER CABLE CONDITION



The average annual number of faults was calculated for the circuits which have had cable segments tested (see Table 6.6). As there have been several segments of cable tested on circuits, the result of the worst section was utilized to forecast overall condition. As cable segments selected for testing was based on the number of historic faults there was a bias towards cables representing poorer reliability than the system as a whole, which may have resulted in a higher fault rate than actual being forecasted.

TABLE 6.6 - FAULT RATE BY CABLE CONDITION

	Fault Rate (faults/100km/year)
Condition	**Average**
Like New	0.004
Good	0.012
Fair	0.018
Poor	0.021
Critical	0.039

6.7.3 Outlook

Reliability impact of different replacement rates has been modeled assuming annual replacement levels over 10 year periods. The results of this modeling can be seen in Table 6.7. Based on the levels of replacement over the last 5 years, Hydro Ottawa has averaged an investment of $2.7M annually for cable replacement. At this current replacement rate, the average number of cable faults annually is expected to increase from 43 to 46 in 2033. In order to reduce the number of annual cable faults, it is recommended that annual spending be increased to $5 million annually.

TABLE 6.7 – POLYMER CABLE REPLACEMENT POLICY IMPACTS

Scenario		2013	2023	2033
Allow Faults to increase at a rate of 0.2 Annually	Annual Cost	$ 2,074,764	$ 2,061,170	$ 2,059,588
	Cable lengths replaced (m)	59,279	58,891	58,845
Maintain Current Fault Level	Annual Cost	$ 3,461,776	$ 3,448,182	$ 3,446,600
	Cable lengths replaced (m)	98,908	98,519	98,474
Reduce faults at a rate of 0.2 Annually	Annual Cost	$ 4,848,789	$ 4,835,194	$ 4,833,612
	Cable lengths replaced (m)	138,537	138,148	138,103
Reduce faults at a rate of 0.5 Annually	Annual Cost	$ 11,149,405	$ 8,795,303	$ 8,011,702
	Cable lengths replaced (m)	318,554	251,294	228,906
Reduce faults at a rate of 1 Annually	Annual Cost	$ 19,460,771	$ 17,106,670	$ 16,323,069
	Cable lengths replaced (m)	556,022	488,762	466,373

In order to improve the costs of cable replacement, the 2013 cable injection trial will be evaluated in 2014. Cable injection fills water trees with a dielectric compound, rejuvenating the cable to like new condition. Cable injection is an alternative to replacement for direct buried cables and can offer considerable savings (between 1/5 and 1/10 of replacement costs). While injection has been found to be effective, it is not appropriate for all cable. Cable where neutral corrosion is a concern (un-jacketed), or which has a large number of existing splices are not appropriate for injection. Referring to the percentage of poor condition cable (see Figure 6.30) and using 14% as a representation of the Hydro Ottawa's cable being a candidate for injection, this would result in a reduction in annual costs of 15% when compared to the cost of replacement.

Hydro Ottawa is currently evaluating the viability of cable injection for cable life extension. Cable rejuvenation is typically a less expensive alternative to cable replacement and requires far less material and construction costs. Hydro Ottawa completed cable injection trials in 2004 and completed two more trials in 2013. The cable that was injected in 2013 will be retested to evaluate the impact on life extension and potential measurable improvements in the cable condition.

6.8 Underground Switchgear

Hydro Ottawa's distribution switchgear asset class consists of pad-mounted, vault installed and submersible types. There are only two submersible switches left in the system and will not be included in this study as they represent a small fraction of the underground switchgear asset group. Each of the other distribution switch categories has many sub-types with different insulating media (e.g. oil, air, SF_6) and various interrupting styles and media. Wall-mounted, stick-operated switches, although not strictly "switchgear", are included in this asset class as well. There are many different configurations of switchgear in service due to the amalgamation of the former utilities and their varying policies for servicing customers. Hydro Ottawa is developing policies and procedures for incorporating these different practices in a consistent manner.

6.8.1 Demographics

Detailed records do not exist for this asset class and as such the demographics have been estimated using available records. While these estimates provide an initial baseline for analysis, collection and consistent representation of switchgear information in a centralized repository is essential to enable accurate asset assessment in the future. The type and age of the 439 padmount switchgears and 191 vault switchgears that are currently owned by Hydro Ottawa are shown in the following figures.

FIGURE 6.32 – PADMOUNT SWITCHGEAR POPULATION BY TYPE

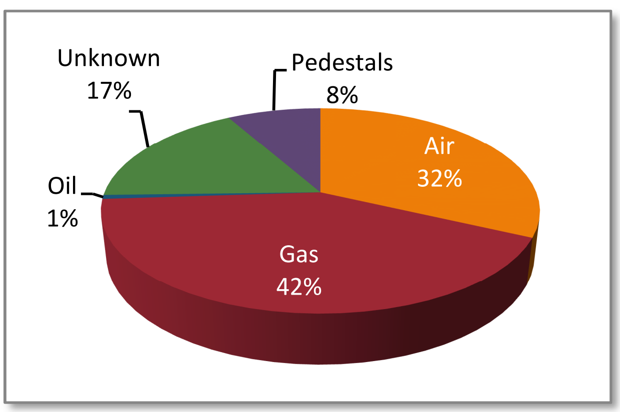


FIGURE 6.31 – VAULT SWITCHGEAR POPULATION BY TYPE

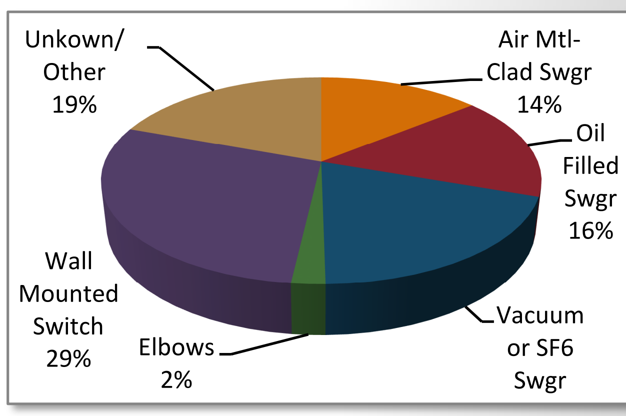
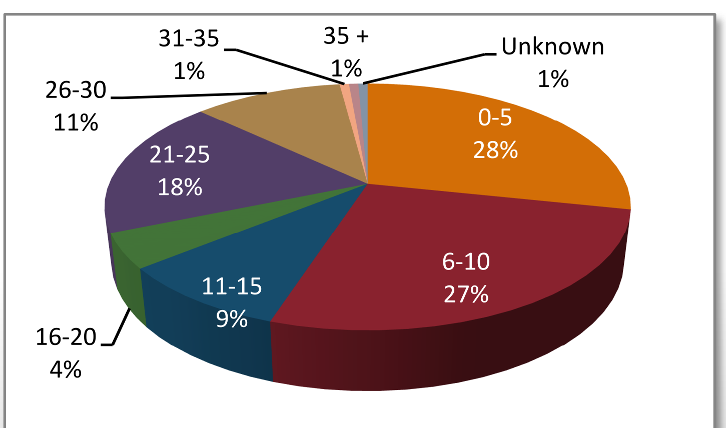


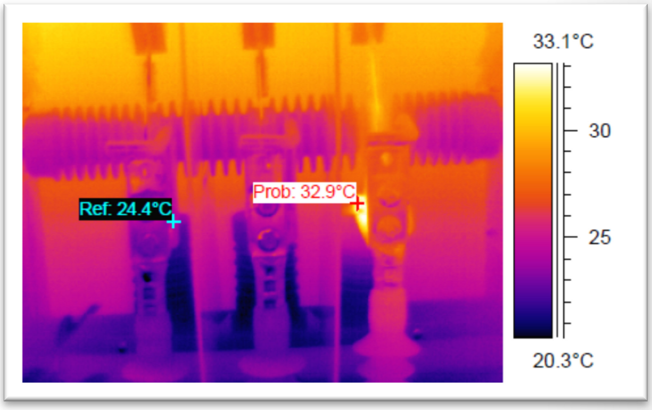
FIGURE 6.33 – PADMOUNT SWITCHGEAR POPULATION BY AGE GROUP



6.8.2 Assessment

6.8.2.1 Health Index

A large proportion of the padmount switchgear currently in use are air-insulated, gang-operated, load-break switches. The life expectancy of padmount switchgear is impacted by a number of factors that include frequency of switching operations, load dropped, and presence of a corrosive environment or dampness at the installation site. On average, padmount switchgear, when maintained regularly, can be expected to provide a service life of 25 to 35 years.



For below grade vault applications, switchgear comes in submersible designs and is commonly either oil insulated or SF_6 insulated. For above grade vault applications, metal clad, air insulated switchgear has been used in the past, although a majority of the current and future installations will employ SF_6 insulated switchgear; as these designs have sealed enclosures which are better protected against dirt or moisture and are expected to provide longer life.

Hydro Ottawa follows standard industry practice of running distribution switchgear to end of life, just short of failure. To extend the life of these assets, a number of intervention strategies are employed on a regular basis such as inspection with thermographic cameras and cleaning with CO_2 for air insulated padmount switchgear and inspection and cleaning for vault switchgear. If problems or defects are identified during inspection, often the affected component can be replaced or repaired without a total replacement of the switchgear.

6.8.2.2 Failure Consequence

While it is Hydro Ottawa's current practice to run switchgear to end of life, the 3 year rotational inspection program has improved identifying switchgear requiring maintenance and in worse case replacement before failure occurs. Switchgear is identified to require replacement from the consequence scoring which is based on the number of customers that will be affected by the interruption, the duration of the interruption, the environmental risk and the health and safety risk.

6.8.2.3 Failure Correlation

Currently, there is insufficient demographic data to correlate and/or utilize failure data to project future failure rates. However, through the review of switchgear failures which have led to sustained interruption it has been determined that air-insulated live front switchgear presents the highest failure rate. As live-front switchgear can be repaired following "failure" events, there are switches in the systems that have been identified for replacement which are known to pose reliability issues due to environmental and/or operational factors.

6.8.3 Outlook

Currently, there is one switchgear in service which has been identified to be at end-of-life and several more approaching end-of-life in the Hydro Ottawa system. These include 20 primary pedestals in both the South and West ends of the city. End of life padmount switchgear have been prioritized and scheduled over the next 3 years. Based on historical experience, 3 to 4 pieces of live front switchgear are identified to be at end-of-life annually. Sufficient funds to carry on these planned replacements are required beyond 2014 to maintain reliability of the distribution system.

6.9 Overhead Distribution Switches and Reclosers

Hydro Ottawa's distribution overhead switch and recloser asset class consists of all pole mounted load break switches, reclosers, fuse cut-outs and inline switches, with a primary voltage rating up to 44 kV. The primary purpose for this asset class is to provide a means to isolate or re-route a section of overhead line due to a fault condition or planned work.

The overhead switch and recloser program is typically a run-to-failure asset class unless a technical or health and safety issue have been identified.

6.9.1 Demographics

Accurate population data exists for reclosers, load break switches and inline switches in the GIS database. To estimate the number of fuse cut-out switches on the system, the total number of pole mounted transformer connections and the number of fused switches from the GIS was used. Table 6.8 outlines the number of in service switches by type.

TABLE 6.8 - OVERHEAD SWITCH & RECLOSER DEMOGRAPHICS

Switch Type	4.16 kV	8.32 kV	12.43 kV	13.2 kV	27.6 kV	44 kV	Total
Non-Load Break	1,610	2,293	39	1,342	1,467	483	7,234
Load Break	51	137	0	159	446	309	1,102
Cut-Outs	8,333	6,139	41	2,770	3,977	9	21,323
Reclosers	0	19	2	1	35	0	57

6.9.2 Assessment

Information on overhead switch and recloser failures has been collected to allow for predictive spending levels. Failure rates for this asset group have been minimal and do not require predictive analysis or active replacement programs.

Three switch types have been identified for replacement due to health and safety concerns. These include the 4kV rated porcelain box switches, two varieties of inline switch and the S&C 28kV SMD-20 Porcelain and Polymer fused cut-outs.

Porcelain box switches have been identified for removal due to issues of mechanical fracturing. There are 4 substations with a total of 28 sets of switches remaining that require porcelain box switch replacement which are expected to be completed in 2015.

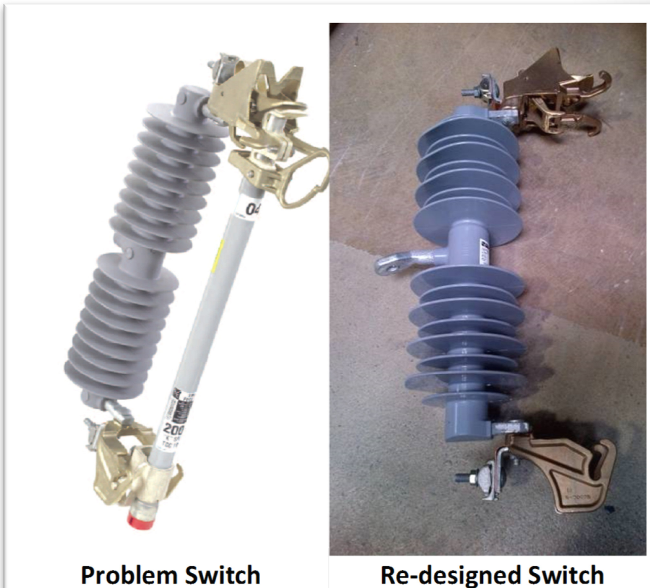
In 2011, S&C Electric Canada informed Hydro Ottawa that there have been a number of failures reported by various utilities across Canada of polymer 28kV SMD-20 switches manufactured between 2004 and 2011. S&C's investigation has determined that the 28kV SMD-20 switch failures occurred when the switches were operated using a load break tool. An example of a failed switch can be seen in Figure 6.34. Hydro Ottawa has approximately 2,800 of both the S&C polymer and old porcelain 28kV SMD-20 switches deployed in the system.

FIGURE 6.34 - FAILED S& C SMD-20 SWITCH

6.9.3 Outlook

In response to the design flaw identified with the S&C Polymer 28kV switches, a refurbishment has been initiated. In this program S&C will refurbish any of the affected switches at no cost; they will not however cover any of the labour costs associated with the replacement or removal of these switches. A multi-year replacement program was initiated in 2013 targeting the defective polymer switches first, followed by the remaining porcelain switches. This three year program was limited by resources in year one and 80 switches were replaced. The budgeted amounts for this program in 2014 and in 2015 have been increased in order to achieve the three year replacement target.

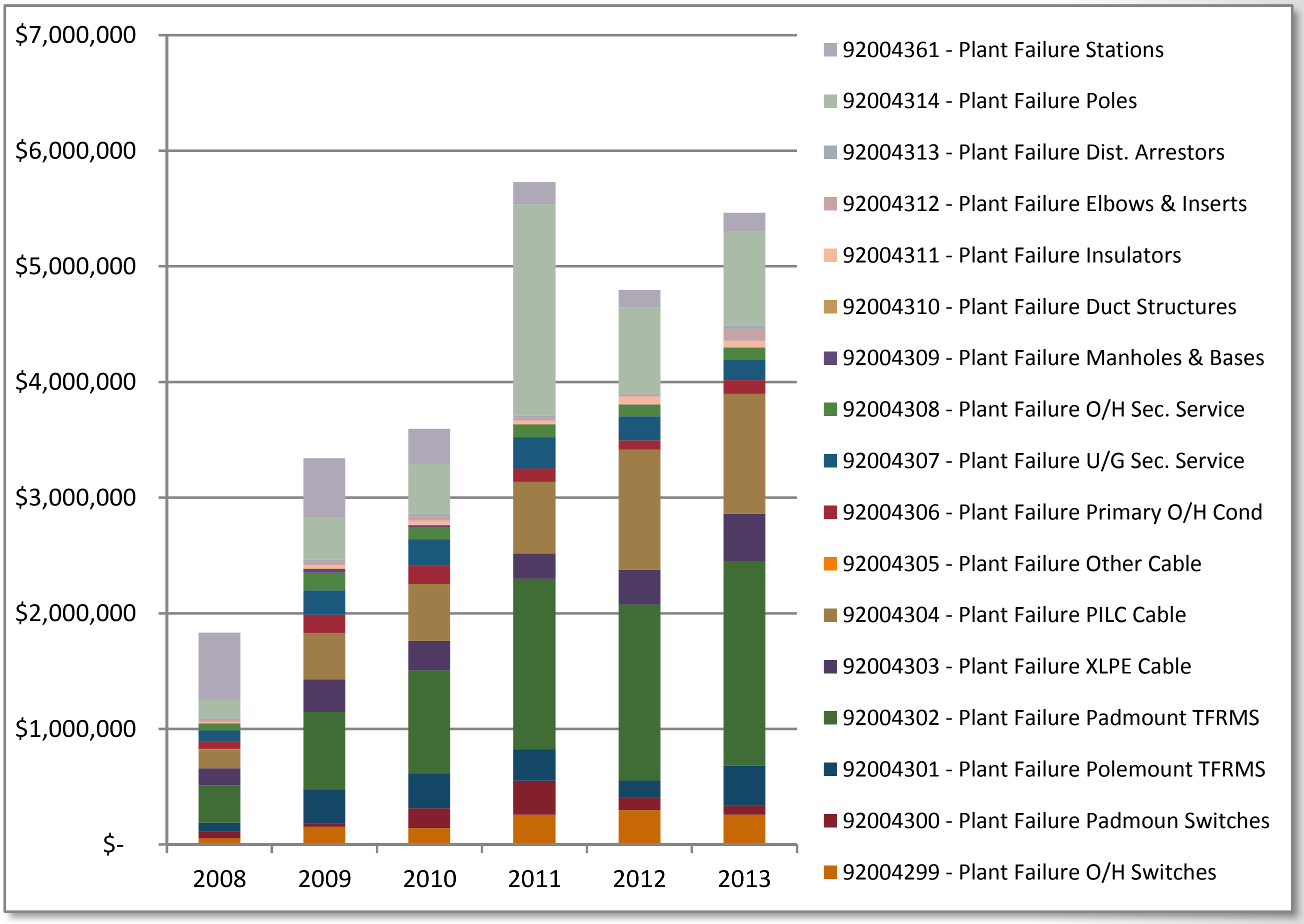
FIGURE 6.35 - PROBLEM & RE-DESIGNED SMD-20



6.10 Distribution Plant Failure

The 2013 plant failure expenditures are shown in Figure 6.36. While short term spending must be maintained at similar levels, asset life-cycle management and planning strives to reduce the required capital investment in this category through planned project investments.

FIGURE 6.36 - 2013 PLANT FAILURE EXPENDITURES



Spending in plant failure has been steadily increasing since 2008 due primarily to an increase in the failure of poles, padmounted transformers and PILC cable which points directly to the ageing of these asset groups.

7 Substation Asset Lifecycle Management

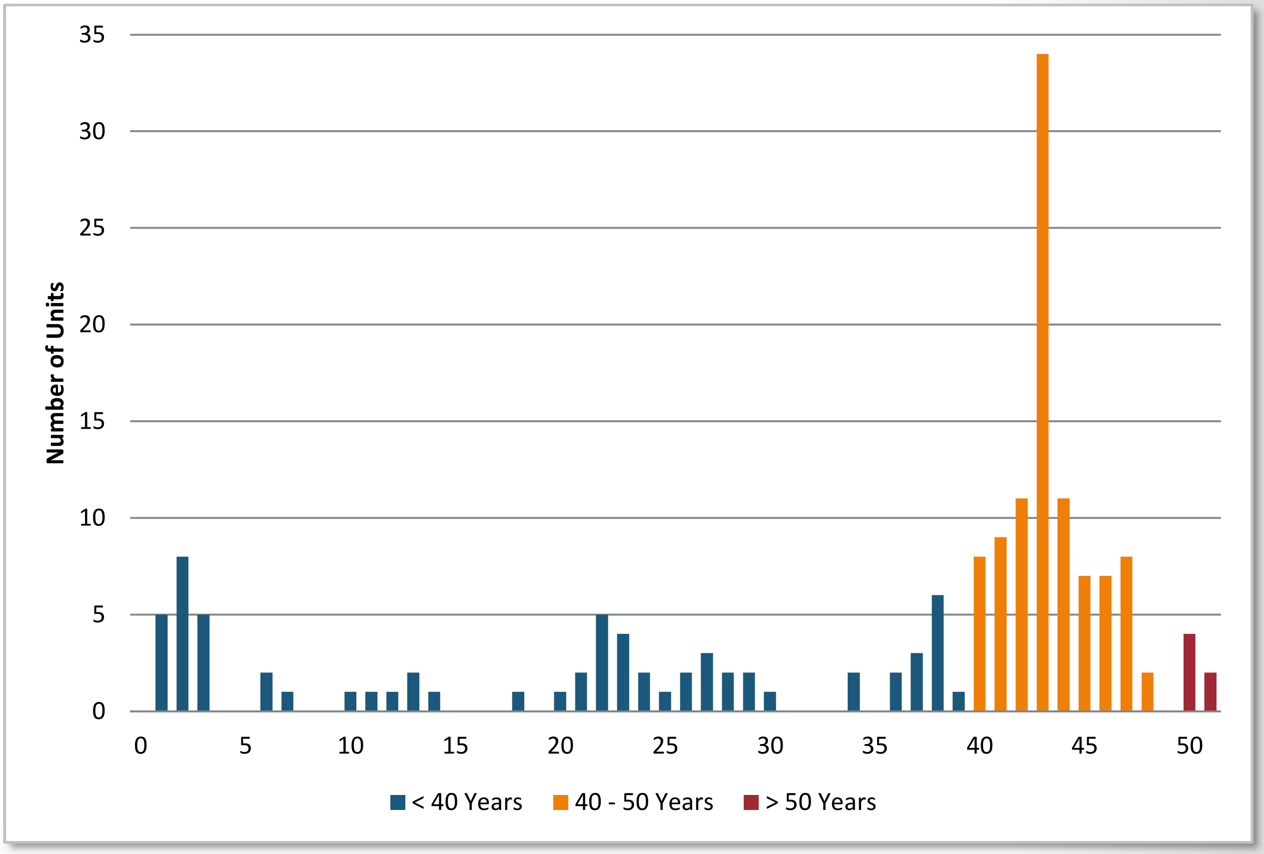
7.1 Station Transformers

Station transformers are a critical asset among Hydro Ottawa Limited's groups of assets. They provide voltage transformation from transmission line to a lower voltage to distribute throughout the city. Station Transformers have a few particularities that make them unique: replacement costs range from $300,000 to $2,500,000; a failure will have medium to major consequence, and a replacement is a six to twenty-four months project cycle. In addition, station transformer replacements may require additional upgrades such as oil containment, ground grid upgrades, cable replacement, and protection & control upgrades. In some cases a full substation upgrade (switchgear and transformers) may be triggered by a transformer replacement.

7.1.1 Demographics

Hydro Ottawa has 170 station transformers distributed over primary voltages: 103 at 13.2kV, 39 at 44kV, 22 at 115kV and 6 at 230kV. The age distribution of this asset class is illustrated in Figure 7.1 and displays that greater than 60% of the population (103 units) are over 40 years of age where the life expectancy is 50 years. This can be attributed to a large growth period in our history. A large majority of these transformers have primary voltages of 13.2kV or 44kV.

FIGURE 7.1 - STATION TRANSFORMER DEMOGRAPHICS



7.1.2 Assessment

The health of a transformer can be broken down into three main components: thermal, electrical, and mechanical stresses. Thermal stresses occur due to internal heating or local overheating due to short-time overload. Thermal stresses can be measured using dissolved gas analysis, paper deterioration, and infra-red scanning. Dielectric stresses occur due to system overvoltages, transient impulse conditions or internal resonances within the windings. They can be measured through oil analysis, partial discharge, and power factor tests. Mechanical stresses can occur between conductors, windings, or leads due to short-term overcurrents, faults, and inrush currents. They can be measured through frequency response analysis, capacitance and inductance measurements.

7.1.2.1 Health Index

Hydro Ottawa currently tracks the health index through results from dissolved gas analysis. The transformer health index is based on the dissolved gas condition, the generation rate of these dissolved gases and the oil or fluid condition, given by the following equation.

$$Health\,Index = \left(\frac{Gas\,Score + Rate\,Score + Fluid\,Score}{3}\right) \times 5$$

Figure 7.2 gives an indication of the condition of the station transformer population calculated using the above equation. Based on the Health Index, transformers can be grouped into three categories: Good – Health Index =0, Fair – 0 > Health Index <= 1, and Requires Attention – Health Index > 1

As of the end of 2013, there were four transformers that require attention based on their health index score: Leitrim 249T1, Borden Farms 130T1, Rideau Heights 180T1, and Bridlewood BRDT1. Nine other transformers are in fair condition and should be monitored.

FIGURE 7.2 – STATION TRANSFORMER HEALTH

7.1.2.2 Failure Consequence

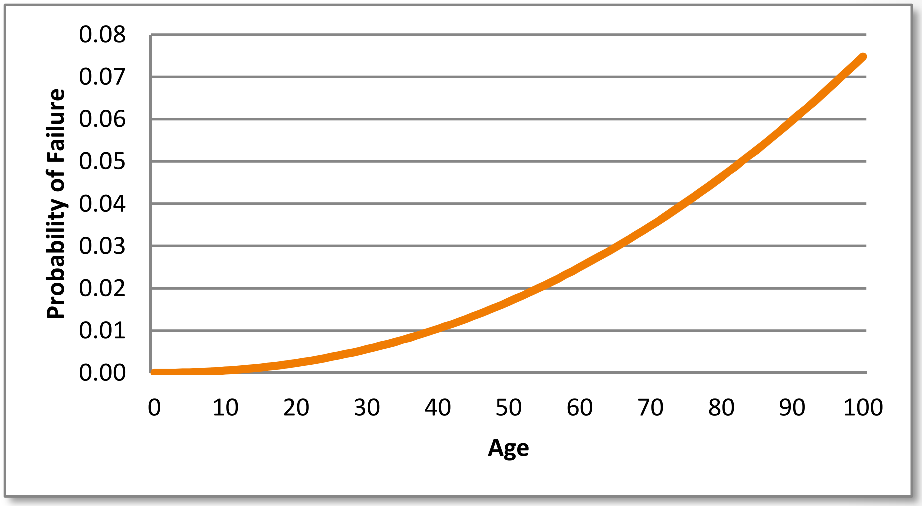
Station transformers have a large consequence of failure as they are an integral component to the system. For the most part, substations are designed with contingencies in the event of a transformer failure. However with long lead times and projects with high complexities, identifying and prioritizing station transformers that are end-of-life before failure is critical. Capacity constraints are also a factor when a contingency unit is required to support the entire load of a station. Aging or overloaded transformers are at a higher risk of failure and can have high consequences if they fail.

Prioritization of station transformers to minimize the consequence of failure is based on environmental consequences, effects on reliability, and health & safety concerns.

7.1.2.3 Failure Correlation

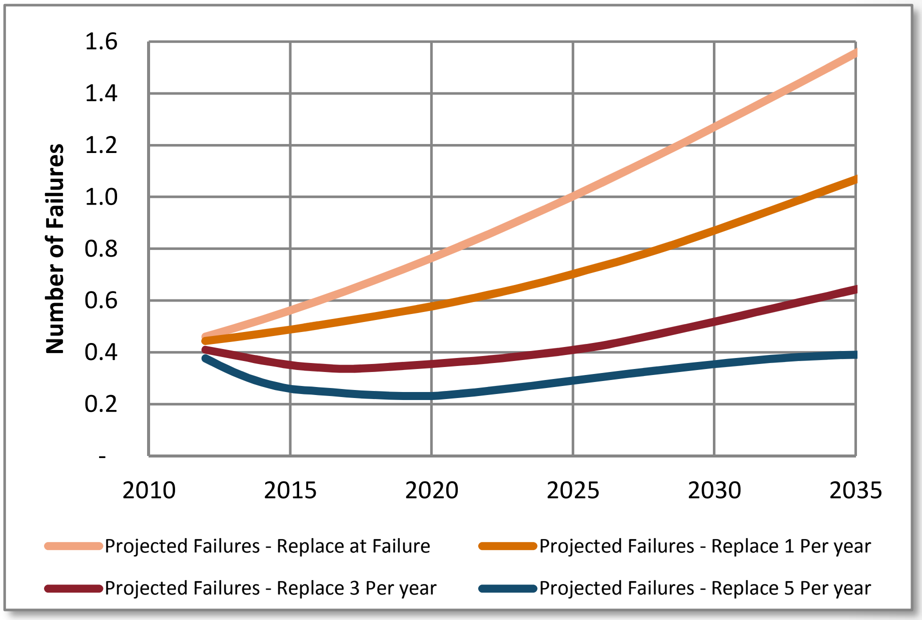
Minimum asset replacement rates are determined from the projected failure rate and are determined by evaluating historical failure data and the probability of failure at a particular age. Once a probability of failure is determined, a predictive analysis can be completed depicting the future failure rate of the asset. Active replacements can be incorporated into this analysis to show the effects of varying replacement rates on failures. This analysis is shown in Figure 7.3.

FIGURE 7.3 - STATION TRANSFORMER FAILURE PROBABILITY



The failure curve used in the analysis is a calculated Weibull probability based on the total age demographic and the age at failure. This allows a curve to be built not only on failure data but incorporates the surviving population. This translates into the failure probability curve shown in Figure 7.4. As inspection processes develop and failure data is recorded in more detail, the Weibull curve will be updated to more accurately represent long term projected failures.

FIGURE 7.4 - STATION TRANSFORMER RECOMMENDED REPLACEMENT RATE



7.1.3 Outlook

Hydro Ottawa has 170 station transformers with more than half in the age range of 40 years and older. To manage this aging asset group, an active inspection and maintenance program is required in order to maintain acceptable operating conditions and provide information to prioritize replacement projects.

"An active inspection and maintenance program is required in order to maintain acceptable operating conditions and provide information to prioritize replacement projects."

In order to maintain the current failure rate, it is recommended that 3-5 stations transformers be replaced per year in order to minimize failures and manage the risk of aging demographic.

In order to continuously monitor transformers, online monitoring systems will be installed on many transformers. These monitoring units will provide information on key gas generation, moisture, and oil temperature. Information will be communicated back through the SCADA network.

"It is recommended that 3 to 5 station transformers be replaced per year in order to minimize failures and manage the risk of aging demographic."

7.2 Station Switchgear

Hydro Ottawa's station switchgear asset class consists of breakers, switches, bus insulation, support structures, protection and control systems, arrestors, control wiring, ventilation and fuses. The base unit of this asset class is a switchgear assembly, which includes bus work, feeder breakers and appurtenances.

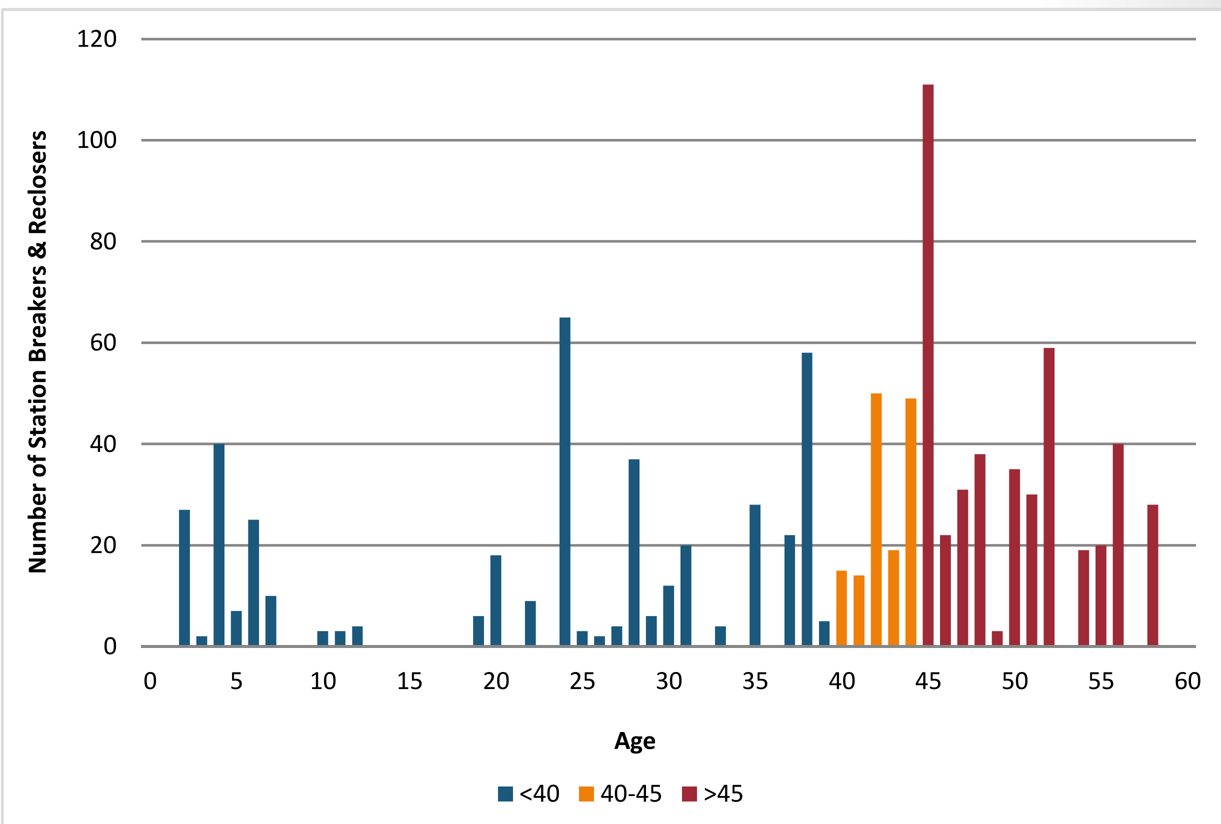
Hydro Ottawa currently manages switchgear assemblies in 83 substations containing a total of 936 breakers and 67 reclosers.

7.2.1 Demographics

Demographic information for the station switchgear has been collected from various sources included in Hydro Ottawa's existing condition assessment and maintenance programs.

Hydro Ottawa owns and maintains switchgear assemblies in 83 substations. Switchgear assembly age grouping is shown in Figure 7.5. Hydro Ottawa faces an aging population of its switchgear with more than half of the assemblies older than 40 years, the financial life expectancy.

FIGURE 7.5 – STATION BREAKER & RECLOSER DEMOGRAPHICS BY AGE



7.2.2 Assessment

7.2.2.1 Health Index

The health index of station switchgear is assessed through the insulation condition, breaker timing, arc protection and structure support. Currently, there is no reliable centralized information available to support the proposed health index, therefore age and qualitative information about the structural support condition is used to prioritize replacement projects. The structural support condition is evaluated and rated on a scale from 0 to 1 during regular maintenance inspections using the criteria laid out in Table 7.1.

TABLE 7.1 - STATION SWITCHGEAR CONDITION HEALTH INDEX

Health Index	Condition	Description	Requirements
0	Very Good	Some ageing or minor deterioration of a limited number of components	Normal maintenance
0.25	Good	Significant deterioration of some components	Normal maintenance
0.5	Fair	Widespread significant deterioration or serious deterioration of specific components	Increase diagnostic testing, possible remedial work or replacement needed depending on criticality
0.75	Poor	Widespread serious deterioration	Start planning process to replace or rebuild considering risk and consequences of failure
1	Very Poor	Extensive serious deterioration	At end-of-life, immediately assess risk; replace or rebuild based on assessment

7.2.2.2 Failure Consequence

Evaluating the consequence of failure allows for comparison within the asset class to determine the most crucial pieces of equipment. These consequence factors are based on corporate objectives and not the health of the equipment. A summary of the consequence scoring can be seen in Table 7.2.

TABLE 7.2 - SUBSTATION SWITCHGEAR FAILURE CONSEQUENCE SCORING

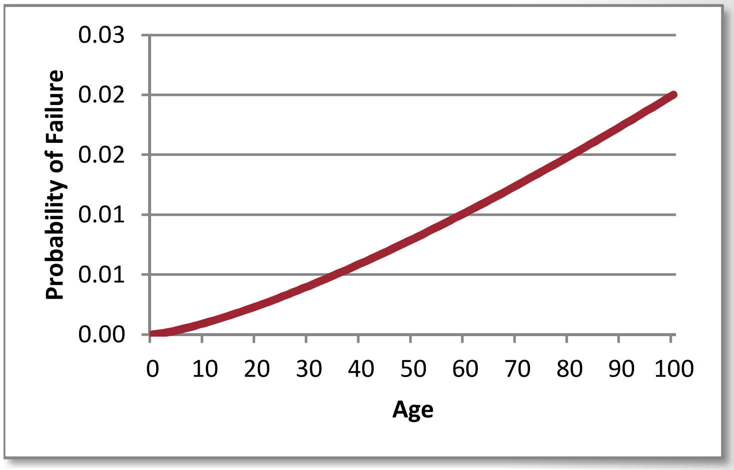
Consequence Score	Environmental	Safety	Reliability
0	Contains no contaminants	Full Arc-Proofing	$\frac{\#\ Customers}{Max\ Customers}$
0.25			$\frac{\#\ Customers}{Max\ Customers}$
0.5		Partial Arc-Proofing	$\frac{\#\ Customers}{Max\ Customers}$

0.75			$\frac{\text{\# Customers}}{\text{Max Customers}}$
1	Contains Oil or SF6	No Arc-Proofing	Max Customer Count

7.2.2.3 Failure Correlation

Failure correlation is used to determine the expected failure rate of an asset group. This can be used to determine the appropriate replacement age before it fails.

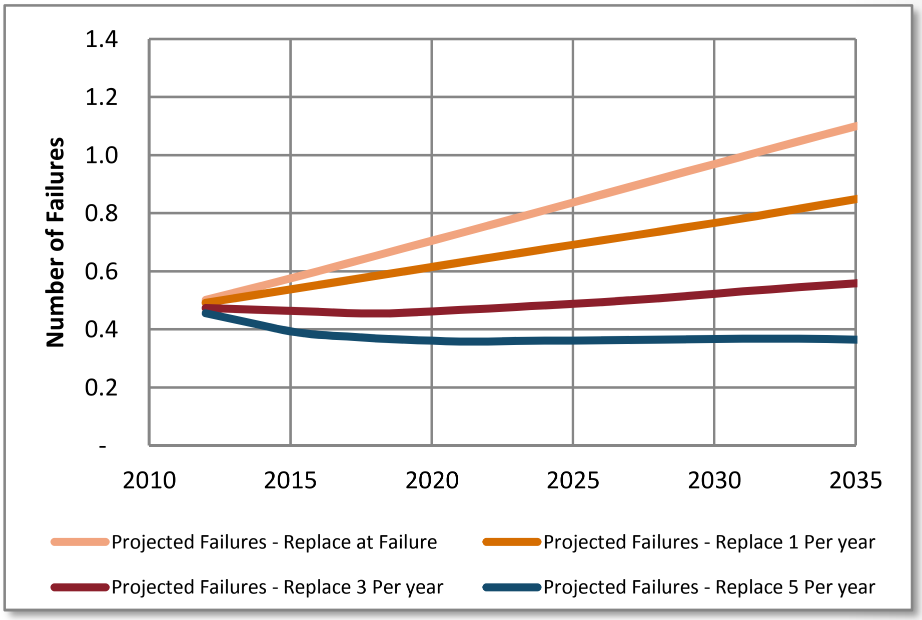
FIGURE 7.6 - STATION SWITCHGEAR FAILURE PROBABILITY



The curve used in the analysis is a calculated Weibull probability based on the total age demographic and the age at failure. This allows a curve to be built not only on failure data but incorporates the surviving population. This translates into the failure probability curve shown in Figure 7.6. More information is needed to have an accurate picture of failure probability.

Using population demographics and an estimated mean life of 55 years, a levelized replacement rate can be calculated to avoid large replacement peaks. This analysis is shown in Figure 7.7. The levelized replacement rate was calculated to be 3-5 units per year.

FIGURE 7.7 - STATION SWITCHGEAR RECOMMENDED REPLACEMENT RATE



7.2.3 Outlook

The station switchgear has over half of the breakers and reclosers with an age of 40 years or older. To manage this aging asset group, an active inspection and maintenance program is required in order to maintain acceptable operating conditions and provide information to prioritize replacement projects.

"An active inspection and maintenance program is required in order to maintain acceptable operating conditions and provide information to prioritize replacement projects."

It is recommended that 3-5 stations switchgear assemblies be replaced per year in order to minimize failures and manage the aging demographic. Efficiencies can be found by doing some of this work in conjunction with station transformer replacements.

Through an evaluation of the health condition of all station switchgear, 7 assemblies in 4 stations have been deemed end-of-life:

- Woodroffe UW is at end-of-life and will be retired by converting customers supplied by this station to Woodroffe TW 13kV substation. This project is to be completed in 2016.
- Overbrooke SO will be considered for replacement if there is no justification for voltage conversion.
- Merivale will require a study into the possible relocation, rearrangement, or voltage conversion of the station due to access issues.
- Overbrooke TO has seen multiple issues and refurbishment or replacement should be considered.

"It is recommended that 3 to 5 station switchgear assemblies be replaced per year in order to minimize failures and manage the aging demographic."

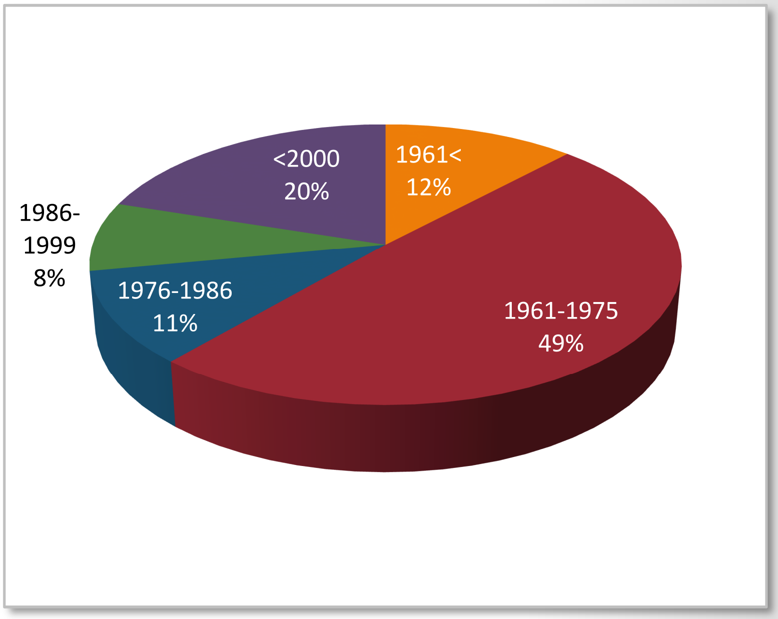
7.3 Station Ground Grids

Station ground grids are an essential element of a substation, impacting personnel safety and the protection of equipment. Hydro Ottawa Limited has deployed a multi-year program to survey the condition of existing ground grids in order to prioritize replacements and upgrades. The condition of older ground grids is unknown as they tend to deteriorate with time and the standards to which they were built have been updated over the years.

7.3.1 Demographics

HOL owns 75 substations and their associated ground grids. For the purpose of analysis it has been assumed that the ground grids were installed at the time of station construction unless there are records of upgrades. The following graph summarizes the ground grid population by year of construction or upgrade.

FIGURE 7.8 - SUBSTATION GROUND GRID AGE DEMOGRAPHICS



7.3.2 Assessment

Evaluation of existing ground grid systems is required to determine if corrections are required to maintain compliance with the most recent codes and standards. Maintaining the integrity of station ground grids is critical as the failure consequence is very high because it is based on the value of the equipment that it protects as well as the health and safety of individuals within the station area. Currently, ground grids are being assessed before major infrastructure work and integrated as part of the scope of work.

The design of ground grids must be done according to IEEE standard 80: *IEEE Guide for safety in AC Substation Grounding*. This standard has been revised four times, in 1961, 1976, 1986 and the most recent in 2000. HOL ground grids are categorized by age group according to the revision years of IEEE standard 80. A condition score of 1-5 (best to worst) is assigned to each ground grid based solely on the age of construction ranging from newest to oldest.

7.3.3 Outlook

The condition of station ground grids will continue to be accessed as part of major infrastructure projects and modification/retrofits incorporated into the scope of work where applicable.

To date, 32 substations have been surveyed and 9 retrofits or new builds have been completed.

7.4 Station Relays

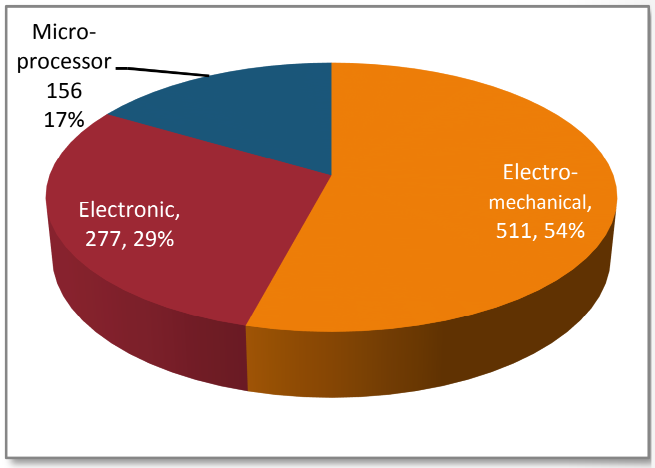
Hydro Ottawa's station relay asset class consists of a number of families of fault detection and control relays, generally classified as electromechanical, electronic, or microprocessor based. They measure abnormal conditions on the system and initiate the appropriate action such as tripping a breaker to protect the health of system equipment.

7.4.1 Demographics

Demographic information for the station relays has been collected from the ASPEN database which contains both station relay information and settings. Hydro Ottawa has approximately 1300 individual relay devices in its substations. There are currently 27 different types of relays used within the stations.

The station relays have been classified into 3 separate categories which are indicative of the evolutionary progression of the technology: electromechanical, electronic and microprocessor. The distribution of the population between the different categories is shown in Figure 7.9.

Figure 7.9 - Station Relay Population by Category



7.4.2 Assessment

Station relays are typically replaced in parallel with planned station switchgear and transformer replacement or upgrade projects. The station protection and controls equipment and philosophies are upgraded to follow the most current standards. There is currently no active replacement program in place.

The failure consequence of a station relay is based on the number of customers that could potential see an outage should the relay fail and whether or not a backup relay is in place. Based on this, priority would be given to transformer relays, followed by bus relays and finally feeder relays.

As well, the failure consequence of a relay not operating when the conditions call for it can result in safety risks to workers and the public as well as the potential to damage equipment.

7.4.3 Outlook

In the short term it is anticipated that relay replacements will continue to be driven by other station work.

The majority of future planned projects will include the addition of differential protection to station transformers in stations that will have the primary fuse protection replaced by circuit switchers. These are reactive projects to correct deficiencies discovered during the investigation of the Beaconhill station fire.

Future relay replacements will also be driven by obsolescence and the need for increased information to help assess the condition of other stations assets, i.e. breakers, transformers, etc. In addition, further replacements are anticipated to support the addition of distributed resources as required by the Green Energy Green Economy Act.

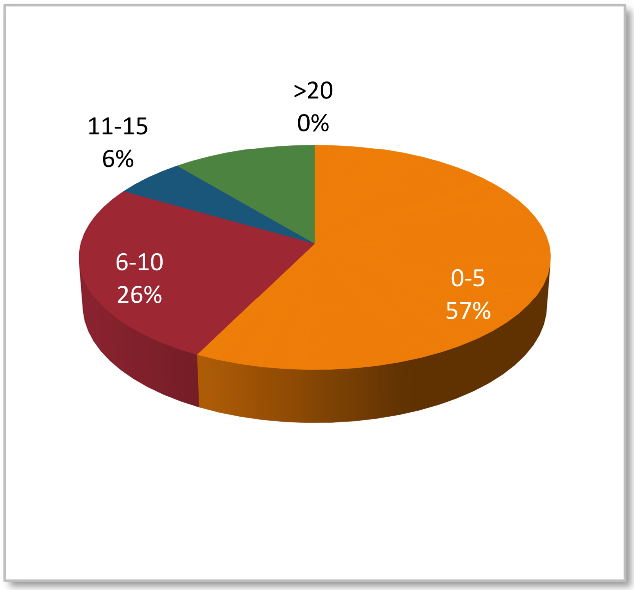
7.5 Station Batteries

Hydro Ottawa's station batteries and chargers asset class provide power for operating station breaker trip and closing coils, DC lights and relays, when station service power is lost. Batteries are typically lead acid type, but some NiCad units are also used. The present standard is to use sealed lead acid batteries.

7.5.1 Demographics

Hydro Ottawa has 53 station battery banks that supply 24V, 48V and most commonly 125V. The life expectancy of a station battery bank is in the range of 20 to 25 years. The current age demographics are shown in Figure 7.10.

FIGURE 7.10 - STATION BATTERY POPULATION BY AGE GROUP



7.5.2 Assessment

Hydro Ottawa evaluates the assets on short term and long term basis to establish which assets require specific maintenance or replacement. The short term evaluation for station batteries is based on condition. The long term evaluation is based on the number of assets per year of manufacturing, or age, which provides a minimum number for replacement in order to avoid the possibility of high failure rate due to the assets reaching end of life.

7.5.2.1 Health Index

Station batteries undergo regular maintenance and inspections; as such their health is closely related to their age.

7.5.2.2 Failure Consequence

The failure consequence for this asset can be significant as all the controls in a substation rely on the DC system to operate in case of power interruption. The consequences are offset by the regular inspection programs and the relative availability of replacement parts.

To avoid catastrophic failure, the station batteries and chargers are replaced before their expected end of life.

7.5.2.3 Failure Correlation

Station batteries are very reliable and Hydro Ottawa estimates a life in excess of 20 years. Based on current age demographics a replacement rate of 2-3 per year will allow for continued replacement before the units reach end of life.

In the unlikely event that a battery fails without notice, there are a number of mitigating measures that can be taken. As an interim measure, an inoperable cell can be removed from service and the terminals jumpered to provide continuity for the rest of the bank. Although functionality is restored, it is not a permanent solution to the failure.

7.5.3 Outlook

Station battery replacement is prioritized based on findings from the continuous inspections. If no major issues are seen, the replacement of 2-3 assets per year will be based on age, ensuring that replacement occurs when the asset approaches end-of-life, around 20 to 25 years.