ASSET CONDITION ASSESSMENT

1.0 INTRODUCTION

ACA is one of the tools used by Hydro One Transmission planners to develop investments that are part of this application. ACA is used to detect and quantify the extent of asset degradation of transmission system equipment and to provide a means of estimating remaining asset life based on its condition. The rate of change in asset condition over time helps to identify deterioration trends. The ACA information is one of several inputs used by planners to develop investments as described in Exhibit A, Tab 14, Schedule 4.

Hydro One Transmission has been using condition assessment practices for many years. These practices have been refined over the years through working with expert consultants such as Hatch International Inc., and benchmarking against industry practices. Hydro One Transmission has used various consultants over the past several years to conduct studies of the status and adequacy of the ACA process. A detailed Asset Condition Assessment was completed by consultants in August 2006 and submitted as part of Hydro One Transmission's last proceeding EB-2006-0501. For this application, Hydro One Transmission's ACA practices have been reviewed and validated by Hatch International Ltd, an international expert in ACA. Hatch's report, entitled "2008 Asset Condition Process Audit", is provided as Attachment A to this exhibit.

As part of the development of this application, Hydro One Transmission reviewed with the stakeholders the importance of its asset condition assessment practices and the role these assessments have in the process of developing investment plans. Stakeholders indicated support for Hydro One Transmission's ACA work as documented in Exhibit A, Tab 17, Schedule 1.

HATCH™

Hydro One Networks Inc.
Toronto, Ontario, Canada

2008 Asset Condition Assessment

Process Audit

H328712

Rev 1

September 16, 2008

Project Report

H328712
Rev. 1, Page 1

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Hydro One Networks Inc.
2008 Asset Condition Assessment

DISTRIBUTION

David Curtis - Hydro One Networks Inc.
Daryn Thompson – Hatch Ltd.
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Process Audit

Table of Contents

List of Tables and Figures

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Executive Summary

In general, it has been found that Hydro One Networks has undertaken a very careful and thoughtful evaluation of condition assessment needs, and has followed a steady and measured program of data collection to secure the information needed to assess the condition of its transmission assets. The data collection methods, tools and technologies are generally appropriate to the task of measuring asset condition, providing the right data at an appropriate cost. The methods used by Hydro One Networks have been found to be consistent with industry practices. The methods and procedures for data collection are well documented in head office procedure documents and specifications for data collection services.

Data collected for the use in the asset condition assessment processes is stored in centralized or distributed databases. Hydro One Networks is filtering and handling this data appropriately for Asset Condition Assessment purposes, having adopted condition criteria that form a rational basis for generation of Health Indices to assist in asset sustainment-based decision-making. Hydro One Networks has adopted methods of analysis that are consistent with industry practices in most cases, and are showing innovation relative to industry practices in several cases. In addition, Hydro One Networks continues to participate in and lead asset management discussions and presentations at various technical conferences. With composite Health Indices for critical class of assets Hydro One Networks has established a coherent and rational basis for evaluating the overall condition of each transmission asset owned by the company.

Asset Condition Assessment is an evolving technique that is dramatically affected by other processes such as the availability of data in centralized computer systems and ongoing developments in the field of power equipment testing and maintenance. It is the findings of the auditors that Hydro One Networks is succeeding in the development of Asset Condition Assessment tools and processes and taking advantage of opportunities to evolve and improve.

1. Introduction

Hydro One Networks Inc. (Networks) retained Hatch Ltd. to perform an audit of the Asset Condition Assessment (ACA) processes being used by Networks asset planners for inclusion in the application for rates for 2009 to the Ontario Energy Board.

The scope of the Asset Condition Assessment (ACA) project, as set out in the Terms of Reference issued by Networks, is as follows:

1. Provide expert advice relating to up-to-date utility/industry benchmarking/"best practices" on the process, strategy, condition criteria, and information requirements (including collection/analysis and supporting tools) for assessing asset condition and asset end-of-life. Reference material to include past "Practice" studies for Networks ACA projects and Hatch Energy involvement in the industry.
2. Verify whether the condition based "health indicators," their contribution weightings and overall "health index" formulas for assessing Transmission asset condition and asset end-of-life are still consistent with the 2006 Transmission ACA. Provide timely advice to Networks staff to address any information gaps identified.
3. Verify/confirm whether the Transmission ACA data reflect actual field condition by examining the asset planners' review of the quality of filed condition data. Note, field auditing of data is not in this scope.
4. Prepare a report documenting the results of the verifications and confirmations.
5. Explicitly identify all significant findings in this report (e.g. process, methodology, data or findings) and the impacts or benefits of these findings and report these findings in a timely manner to Networks to support Networks preparations for the transmission rate case.

This report documents the findings of the ACA process audit.

2. Asset Condition Assessment

The Asset Condition Assessment Process combines powerful algorithms for determining the condition of assets with the structured management of information related to those assets. The result is a comprehensive status report that provides information on each asset, on groups of assets (for example "Oil Circuit Breakers") and on the entire asset base. The standard reports offer these views but the underlying data is also available for other higher level Asset Management processes. The process is generally undertaken as needed to support the business planning process using the following process steps:

- Assets are divided into the categories by which they are normally managed. This leads to some 30 asset categories within typical utilities such as "Power Transformers", "Circuit Breakers", "Protective Relays", "Transmission Line Conductors", "Wood Poles" and so on.
- The asset categories are prioritized for impact. This results in prioritized asset category groups that will receive different degrees of attention and rigor. Assets defined as high value or critical will rise to the top.

- "Health Index" algorithms are then developed for each asset category (example "Power Transformers"). These algorithms identify the life determining parameters for the asset (example "dissolved gas"), apply weights according to their importance, provide internal quality control mechanisms, and do the required calculations. These algorithms are developed by "subject matter experts" and normalized to provide a Health Index score out of 100 for each asset having sufficient data for a meaningful calculation.

Condition Criteria	Weighting	Condition Ratings	Factors	Maximum Score
DGA	3	1,2,3 or 4	3,2,1,0	9
Standard Oil Tests	4	1,2,3 or 4	3,2,1,0	12
Furan	3	1,2,3 or 4	3,2,1,0	9
Doble	3	1,2,3 or 4	3,2,1,0	9
Tapchanger Condition	3	1,2,3 or 4	3,2,1,0	9
Bushing/Ancillary Condition	2	1,2,3 or 4	3,2,1,0	6
Transformer Condition	2	1,2,3 or 4	3,2,1,0	6

Table 2.1: Typical Health Index Formulation (Transformer)

- Translation Tables are then developed to translate the life determining parameters into condition criteria in terms that can be interpreted by maintenance staff for data collection.
- Demographic data on each asset category is collected to establish an inventory of the asset base that includes a unique asset identifier, year of installation and other information required to clearly define each asset.

		Age Group								
	Voltage Class	0-10yrs	11-20yrs	21-30yrs	31-40yrs	41-50yrs	>50yrs	# Unknown	Total	%
Autotransformers	115kV	0	0	0	0	1	1	0	2	
	230kV	4	11	15	25	14	14	1	84	
	345kV	0	0	2	2	0	0	0	4	
	500kV	5	12	4	20	0	0	0	41	
Sub-Total		9	23	21	47	15	15	1	131	18.0%
2-3 Winding Transformers	115kV	22	23	15	59	76	103	4	302	
	230kV	9	70	39	114	30	0	3	265	
Sub-Total		31	93	54	173	106	103	7	567	77.8%
Phase Shifters	230kV	2	0	0	0	1	0	0	3	
	regulator - 230kV	0	0	1	1	0	0	0	2	
Sub-Total		2	0	1	1	1	0	0	5	0.7%
Shunt Reactors	<50kV shunt	4	7	4	5	5	0	1	26	3.6%
Grand Total		46	123	80	226	127	118	9	729	100.0%
%		6.3%	16.9%	11.0%	31.0%	17.4%	16.2%	1.2%	100.0%	

Table 2.2: Typical Demographic Result for an Asset Category (Transformers 2006)

- Condition Parameter Data is collected on each asset in each asset category to the degree required by the priority previously assigned to that category. Typical data sources are "maintenance databases", "paper maintenance records". Other data may have to be collected in the field or otherwise. This data must be compatible with the input requirements of the algorithms and must be consistent.

- Data is "cleansed". This step uses algorithms and human intervention to identify data problems and to deal with them to the extent possible. For example an asset may be identified differently in asset databases and maintenance databases, or date formats could be inconsistent.
- The Health Index algorithms are "run" using all available data and tested for valid results. This is the process step that produces a Health Index for every asset with adequate and credible data.
- Finally condition and demographic reports are produced on an asset category basis. These reports are tailored to the specific asset management processes they support.

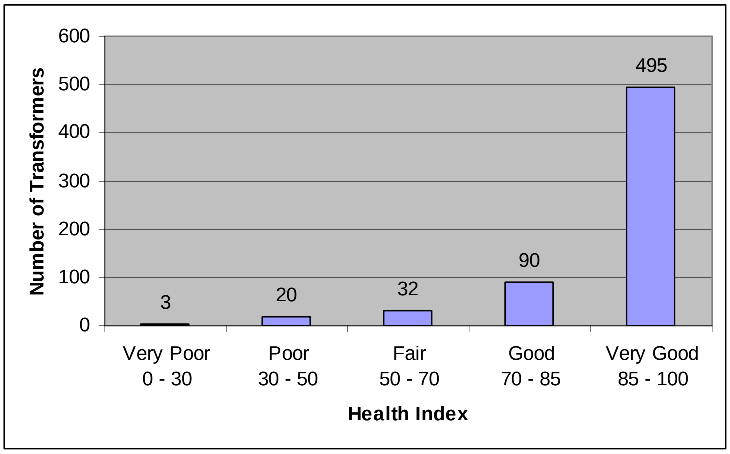


Table 2.3: Example Health Index Result for an Asset Category (Transformers 2006)

- To correlate the continuum of asset health scores into discrete meanings for asset health, five categories have been deemed appropriate for the purpose of helping program investment and maintenance activities as shown in the table below.

Condition	Description	Requirements
Very Good	Some aging or deterioration of a limited number of components	Normal inspection and maintenance
Good	Deterioration of some components	Normal inspection and maintenance
Fair	Noticeable deterioration or serious deterioration of specific dominant components	Increase diagnostic testing, component replacement or possible complete replacement needed before 5 years, depending on criticality
Poor *	Widespread serious deterioration or significant deterioration of a dominant component	Start planning process to replace, considering risk and consequences of failure. Expected failure within 1-5 years.
Very Poor *	Extensive serious deterioration or serious deterioration of a dominant component	At end-of-life now, immediately assess risk; replace based on assessment

3. ACA Process Audit

3.1 Methodology

The data collection phase of the audit took place at the Networks offices in January 2008. The audit took the form of interviews with key asset planners and a review of documentation and electronic spreadsheets provided.

The Auditors were looking to make the following assessments of Hydro One's 2008 ACA process.

1. Was a Health Index result created.
2. Is the documented Health Index Algorithm the same as in the 2006 report.
3. What are the data collection methods to ensure that the audit is based on data that accurately reflects the field condition.
4. What new information is available that should be incorporated in the Health Index Algorithm and what are the Audit findings relative to the production of the Health Index for that asset relative to Industry Best Practices (where applicable).

3.2 Findings

In general, it has been found that Networks has undertaken a very careful and thoughtful evaluation of condition assessment needs, and has followed a steady and measured program of data collection to secure the information needed to assess the condition of its Transmission assets. The data collection methods, tools and technologies are generally appropriate to the task of measuring asset condition, providing the right data at an appropriate cost. The methods used by Networks has been found to be consistent with industry practices. The methods and procedures for data collection are well documented in head office procedure documents and specifications for data collection services.

Where Health Index results were created, there was clear documentation as to the formulation and the supporting data. Where Health Index results were not created, appropriate asset experts were made available to discuss the process and reasons for the actions taken.

Data collected for use in the asset condition assessment processes is stored in centralized or distributed databases. Networks is using this data appropriately, having adopted condition criteria that form a rational basis for asset decision-making. Networks has adopted methods of analysis that are consistent with industry practices in most cases, and is at the leading edge of industry practices in several cases. In addition, Networks continues to participate in and lead asset management discussions and presentations at various technical conferences. With composite Health Indices for critical class of assets, Networks has established a coherent and rational basis for evaluating the overall condition of each transmission asset owned by the company.

For some asset categories, Health Index results were not produced. These cases are generally explained by either the absence of new data, or a declining need to have asset sustainment information as part of the decision process. For some assets, a Health Index has never been produced and the reasons for this have been discussed in previous reports.

There were some findings for improvement, which are generally minor in nature. The most significant concern is that for those asset categories where a Health Index was produced, it was based on data that was extracted in March 2007. Given that the previous report was issued based on 2006 data, only a small amount of movement in the condition can be observed. However the date of March 2007 was selected because this aligns with Networks business planning cycle. and since it is unlikely that major differences would have been reported with data longer data period, it is preferred to get the data extraction cycle consistent with the planning cycle.

In many cases electronic hand-held devices are used to collect and automatically upload data into the databases as part of the regular maintenance procedures. The use of forms on such devices greatly enhances the quality of the data collected. Where practical the use of such devices for data collection should be expanded across the entire list of asset categories.

Some assets do not have defined data collection cycles at this time. For many of those, there is no new data since the previous or original data collection to produce earlier reports. Generally the affected assets are low value or "run to failure" assets for which detailed data gathering may not add value. To the degree that the Health Index result is desired to support asset sustainment planning, maintenance/data collection cycles appropriate to the asset should be defined and implemented or possibly the Health Index process should recognize low value activities with less frequent update requirements.

Current Health Indices were not produced for some asset categories where updated data is available on the basis that due to slowly changing data, there would be limited changes in the results. This may be a reasonable approach, however care should be taken that Health Index results are published as needed to support asset sustainment initiatives. It may be possible to adopt a more practical reporting cycles for assets considered to be "slow moving".

3.3 Best Practice Assessment

As part of the process for the 2006 report, an extensive Best Practice survey was undertaken by EPRI Solutions USA and the conclusion reported was that "In general, these observations [of EPRI], remarks and commentary were consistent with practices and processes known or already in place at Networks".

For the purpose of this audit, this best practice review was not re-examined. Where Networks is continuing to apply sound data management techniques and the same Health Index algorithm, the process was deemed to be "consistent with previously evaluated best practices". Where differences were found, the audit presents a conclusion as to whether the differences represent an improvement to previous processes, or an area of potential concern.

The results of the assessment have generally concluded that Hydro One's activities with regards to Health Index presentation have remained true to the Best Practice Assessments. This includes the used of well documented and consistent Health Index Algorithms, relatively complete data and an automated and repeatable approach to the generation of Health Index results.

3.4 Summary of Differences Between Hatch and Hydro One Calculations

After the 2006 Asset Condition Assessment report was conducted jointly by Hatch and Hydro One, Hydro One, with the guidance of Hatch, undertook a project to automate the preparation of the Health Index results by importing the algorithms into in-house systems. At that time a few mechanical improvements were made and the resulting algorithms were accepted as the Practice tools and reflected the same Health Index algorithms as per the original intent.

When the published 2006 ACA results were compared to those created in an initial run with the new tools, they were found to be in close agreement for 12 out of 18 health indices. The improved tools resulted in slight deviations between the histograms for 4 health indices (Air Blast Circuit Breakers, Wood Poles, Metal Breaker and Metal Bus). and more substantial deviations for the remaining 2 histograms (HV switches and Capacitors). The resulting in-house tools were deemed to be a more accurate reflection the intent of the published Health Index Algorithms.

In this report, when Health Index results are compared with 2006 results, it is the in-house systems with the corrected results that are in comparison rather than those in the 2006 ACA publication. This will only make a noticeable difference for the HV Switch and Capacitors assets.

3.5 Conclusion

The auditors were given good access to the Hydro One Planners and those involved in the creation of the Health Index Results. The available information was presented clearly and well explained and it was clear that the planners had a sound understanding of the end of life factors that affect the assets in their areas.

There is pressure from the planners to continue to evolve the Health Index Algorithms to align with new information about Asset Sustainment which would further enhance the Practice status of the process.

The overall conclusion of the audit is that the process of generating the Health Index Results is meeting the target of compliance with the previously published algorithms, that the data is being collected in a consistent and effective manner and that the results are in keeping with the previously established Best Practices of the Industry.

3.6 Summary

Tables 3-1, 3-2 and 3-3 (following) summarize the findings of the ACA Process Audit. (note: Reported Data Collection Consistency is documented as reported in interviews. Complete maintenance reporting requirements are detailed in approved Hydro One Maintenance Procedures.

Table 3-1: Priority 1 Assets

REPORT SECTION	ASSET	2008 HEALTH INDEX (HI) RESULTS AVAILABLE	HEALTH INDEX FORMULATION STATUS	REPORTED DATA COLLECTION CONSISTENCY	AUDIT FINDINGS
4.1	**Transformers**	Yes	Formulation slightly changed Recommendation for further adjustments	Variable Maintenance Cycles by component-type, from 6 months to several years based on approved Hydro One procedures.	Adjustments to formulation are reasonable and will not adversely affect the ability to compare HI year over year. Recommended adjustments will result in an improved result
4.2	**Gas Insulated Switchgear Equipment**	Update not warranted due to long cycle data	Same formulation as 2006	**Visual Inspection:** Once/6mths **Functional** / **Diagnostic Testing:** 3,4 or 5 yr intervals depending on type	2008 HI result would not give a significantly different picture.
4.3	**Oil Circuit Breakers**	***Superseded by Overriding Strategy HI not an Investment Driver***			
4.4	**Air Blast Circuit Breakers**	Yes	Same formulation as 2006	Data used in the HI calculation is collected via a documented program of field inspections and testing	Consistent and in keeping with Best Practices

REPORT SECTION	ASSET	2008 HEALTH INDEX (HI) RESULTS AVAILABLE	HEALTH INDEX FORMULATION STATUS	REPORTED DATA COLLECTION CONSISTENCY	AUDIT FINDINGS
4.5	**HV/LV Switches**	Yes	Same formulation as 2006	**General Condition Assessment:** once/yr Collection of new data has been suspended since approx. 2004	Data can become "stale" if not renewed. Reasonable data collection plan should be established. Planned automated process for HI will be leading edge.
4.6	**Operating Spares**	***Dependent on actual asset.***			Consistent and in keeping with Best Practices
4.7	**Protection and Control**	Update not warranted due to long cycle data.	Same formulation as 2006	**Visual Inspection:** Data is constantly being collected; updated in master database once/yr	Consistent Industry leader in predictive failure rates.
4.8	**Phase Conductor**	Update not warranted due to long cycle data	Same formulation as 2006	Tests carried out on 20 samples since 2006	Current HI results are not an investment driver at this time. The Health Index formulation is to be reviewed.
4.9	**Wood Pole Structures**	Update not warranted.	Same formulation as 2006	Field inspections are conducted constantly; information updated via GPS devices	Current HI results are not an investment driver at this time and are to be reviewed. Pole replacement program is based on ongoing Condition Assessment programs.

REPORT SECTION	ASSET	2008 HEALTH INDEX (HI) RESULTS AVAILABLE	HEALTH INDEX FORMULATION STATUS	REPORTED DATA COLLECTION CONSISTENCY	AUDIT FINDINGS
4.10	**Underground Cables**	Yes	Same formulation as 2006	Constant field inspections conducted	Consistent and in keeping with Best Practices
4.11	**Transmission Rights-of-Way**	Update not warranted due to long cycle data.	Same formulation as 2006	**Visual Inspection** / **Maintenance:** 6-8 yr cycle	HI results are not an investment driver at this time. ROW maintenance program is based on the regular inspection program.

Table 3-2: Priority 2 Assets

REPORT SECTION	ASSET	2008 HEALTH INDEX (HI) RESULTS AVAILABLE	HEALTH INDEX FORMULATION STATUS	REPORTED DATA COLLECTION CONSISTENCY	AUDIT FINDINGS
5.1	**High Pressure Air Systems**	Yes	Same formulation as 2006	Data is collected via a documented program of field inspections and testing	Consistent and in keeping with Best Practices
5.2	**SF_6 Circuit Breakers**	Yes	Same formulation as 2006	Constant field inspections conducted	Consistent and in keeping with Best Practices
5.3	**Metalclad Switchgear**	Yes	Same formulation as 2006	Constant field inspections conducted	Consistent and in keeping with Best Practices
5.4	**Power Line Carrier**	Update not warranted overriding program	Same formulation as 2006	**Field Inspections:** Once/yr, along with defect reports after a unit has failed or generated a trouble alarm	Health Index results are not an investment driver at this time. PLC maintenance program is based on the regular inspection program.
5.5	**HV Instrument Transformers**	Yes	Same formulation as 2006	Data is collected via a documented program of field inspections and testing	Consistent and in keeping with Best Practices
5.6	**Revenue Metering**	***Revenue metering becoming Market Participant's responsibility***			
5.7	**Station Insulators**	Unchanged from 2006	Unchanged from 2006	Consistent visual examination takes place	Consistent and in keeping with Best Practices
5.8	**Station Cables and Potheads**	Unchanged from 2006	Unchanged from 2006	No data collected, typically assets are run to failure then replaced	Health Index results are not an investment driver at this time.

REPORT SECTION	ASSET	2008 HEALTH INDEX (HI) RESULTS AVAILABLE	HEALTH INDEX FORMULATION STATUS	REPORTED DATA COLLECTION CONSISTENCY	AUDIT FINDINGS
5.9	**Batteries and Chargers**	Yes	Formulation slightly changed	**Field Inspections:** Once/yr. Load tests every 5 yrs.	Improved Result
5.10	**Station Grounding Systems**	No 2006 results were inferred	Same formulation as 2006	Detailed grounding survey completed	Limited data for full HI. Survey acts as proxy for condition, with limited data.
5.11	**Capacitor Banks**	Yes	Same formulation as 2006	Data is collected via a documented program of field inspections and testing	Consistent and in keeping with Best Practices
5.12 5.13	**Station Building, Fences**	***Responsibility shifted to Real Estate Group***			
5.14	**Drainage and Geotechnical**	No No new Data Update not warranted?	Same formulation as 2006	No new data collected since 2006	Data collection to be aligned with planning cycle.
5.15	**Fire Systems**	Unchanged from 2006	Unchanged from 2006	Not enough available info to perform condition assessment	HI results are not an investment driver at this time. Consistent and in keeping with Best Practices
5.15	**Security Systems**	***Responsibility shifted to Real Estate Group***			

Table 3-3: Priority 3 Assets

REPORT SECTION	ASSET	MAINTENANCE PROCEDURES & END OF LIFE INDICATORS
6.1	**Protection System Monitoring**	Routine functionality checks and self-monitoring features
6.2	**Station Buses**	Routine visual inspection & thermal imaging
6.3	**Station Surge Protection**	Annual visual inspection / thermographic testing
6.4	**AC/DC Service Equipment**	Routine visual inspection & alarms
6.5	**HV/LV Station Structures**	Normally replaced during major substation refurbishment
6.6	**Heating, Ventilation and Air Condition**	Routine visual & electrical safety inspections
6.7	**Boilers and Pressure Vessels**	Defined maintenance schedules
6.8	**Oil Containment Systems**	Routine visual inspection
6.9	**Oil and Fuel Handling Systems**	Routine visual inspection
6.10	**Microwave Radio Systems**	Six month inspection schedule, annual functionality check
6.11	**Fibre Optics**	Routine visual inspection
6.12	**Metallic Cable**	Periodic insulation resistance tests and continuity checks
6.13	**Site Entrance Protection Systems**	Inspected and tested on a 1-3 year cycle
6.14	**Teleprotection Tone Equipment**	Repaired / replaced when failures occur
6.15	**Line Steel Structures**	Foot or helicopter annual inspection and corrosion inspections as required
6.16	**Line Shieldwire and Hardware**	Foot or helicopter annual inspection and shieldwire sampling and laboratory analysis
6.17	**Line Insulators and Hardware**	Generally replaced on failure

4. Priority 1 Assets

4.1 Power Transformers

Transformers are devices whose primary purpose is to either step-up or step-down voltage. Transformers change alternating current (AC) electric energy at one-voltage level to AC electric energy at another level through the action of a magnetic field. A transformer consists of two or more coils of wire wrapped around a common ferromagnetic core. One of the transformer windings is connected to the source of the AC electric power called the primary or input winding, and the second winding connected to the load is called the secondary or output winding. The main connection between the primary and secondary windings is the common magnetic flux present within the transformer's core. Some transformers contain "tap changers", motor driven switches that alter the transformer's voltage ratio. A shunt reactor is very similar to a transformer but has only one winding and is used to control voltage on the transmission system. Both transformer and shunt reactors are covered here.

4.1.1 Health Index (HI) Formulation

The HI formulation used by Networks in the 2006 condition assessment is included in Appendix I. The current HI formulation being used by Networks differs from that used in 2006, in that the tap changer Dissolved Gas Analysis (DGA) is now taken into consideration in the calculation. The condition rating assigned to the tap changer DGA result is compared against the condition rating assigned to the main tank oil DGA result and the worst value of the two is then used in the HI calculation. The weighting assigned to this test remains unchanged from 2006.

Oil analysis from tap changers has traditionally been viewed as less useful than oil analysis for transformers due to the generation of fault gases and general degradation of the oil during normal tap changer operation. However, recent developments have suggested that a more complete understanding of the parameters measured during oil testing can enable effective discrimination between normal tap changer operation and tap changer operation indicating the need for maintenance. Such processes have been successfully employed, particularly in North American utilities and are currently being employed by several European utilities.

4.1.2 Data Collection Methods

Data used in the HI calculation is collected via a documented program of field inspections and testing. Included in this documentation are definitions for the condition ratings that can be assigned against each inspection or test. Data collected during field investigations is recorded on an electronic handheld devices that shows all of the required inspections and tests as well as providing drop down menus for the selection of condition ratings. Information from the tablet computers is then uploaded into a centralized database where the asset planner can subsequently access the data. The use of handheld devices and drop down menus ensures consistency in the data collection process.

Detailed visual inspections are undertaken on a six month cycle following a well documented procedure for both the transformers and ancillary equipment.

Oil sampling and dissolved gas analysis is undertaken on an annual basis for autotransformers and every two years for other transformers.

Preventative maintenance, including functional tests on alarm and protection relays, is undertaken on a 2-year cycle.

Specific diagnostic tests, each with a well defined pass or fail criteria, are undertaken on a 6 or 7-year cycle along with Doble testing designed to detect dielectric degradation.

In addition, some further diagnostic procedures are applied following an automatic trip or an indication of a developing fault from DGA or other procedures. These may include Insulation Resistance Testing and Transformer Turns Ratio tests.

The maintenance activities for tap changers is type specific based on a maximum time interval or number of operations.

Data from the inspections and tests, with the exception of DGA test results, are stored in a centralized database. DGA test results are maintained in a separate database maintained by the asset planner.

4.1.3 2008 Health Index (HI) Results

The 2008 HI results presented by Networks for the Transformer Assets are shown in Figure 4.1.

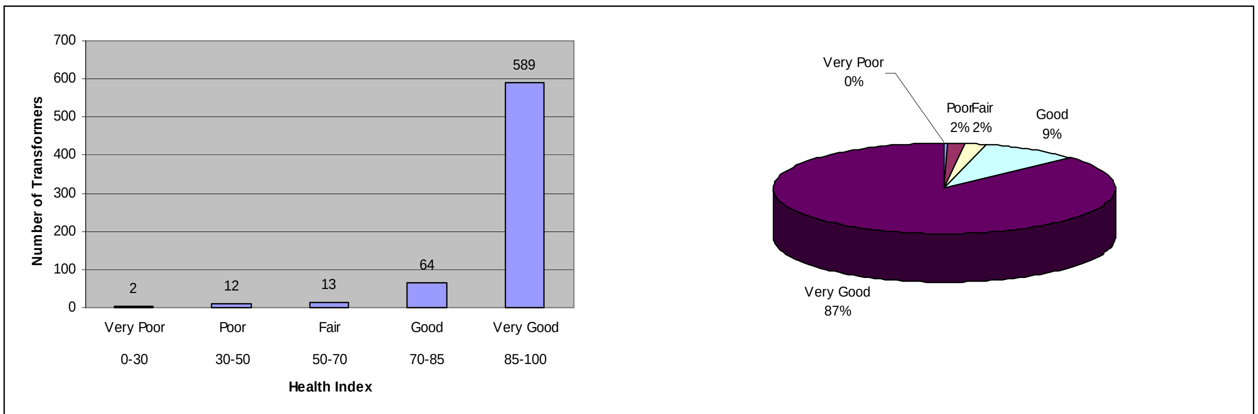


Figure 4.1: 2008 Health Index Results for Transformers

4.1.4 Audit Findings

Due to a change in Networks work practices, the DGA Tests and Standard Oil Tests have been combined into a single test called "General Oil Test". Now instead of separate condition ratings being returned for each of the DGA and Standard Oil Tests, a single condition rating will be returned for the General Oil Test. Consequently, the HI formulation will need to be modified to incorporate this change. Networks is still in the process of determining the appropriate weighting to apply to the General Oil Test.

As the data requirements of the maintenance/planning process evolve, the data requirements of the Health Index Algorithm should evolve as well. The combination of the gas tests will not substantially change the results of the assessment, if the weighting factors are properly selected. Therefore the proposed changes to the algorithm are not expected to invalidate the year over year comparison.

The responsible asset planner also advised that the formulation could be improved if it were expanded to include a few other known end of life indicators. The existing algorithm appears to not give weight to known measures such as noise and vibration, so in some cases transformers are scheduled for replacement that are rated as Fair to Good with the Health Index. Adjusting the algorithm to incorporate these two criteria would result in a small change in the results that could impact year over year comparisons, but updating the Health Index with all know end-of-life indicators would be considered consistent with the practice procedures.

4.2 Gas Insulated Switchgear Equipment

Gas Insulated Switchgear (GIS) is an assembly of switchgear in which all of the major components, except for the entrance bushings, are housed within a grounded metal enclosure containing pressurized sulphur hexafluoride (SF_6) gas. The GIS is compartmentalized in such a manner as to facilitate maintenance of individual components with minimum disruption to adjacent components and also to minimize gas losses in the event of an uncontrolled rupture of an enclosure. Many compartments are fitted with pressure relief devices. GIS is very compact compared to air insulated substations and is applied at all the voltage levels, LV, HV and EHV on Networks system. Gas insulated switchgear is an attractive alternative to an outdoor AIS, particularly where space constraints and protection from harsh environmental conditions are a consideration.

4.2.1 Health Index (HI) Formulation

The HI formulation used by Networks in the 2006 condition assessment is included in Appendix I. The current HI formulation being used by Networks remains unchanged from that used in 2006.

4.2.2 Data Collection Methods

Networks has detailed, fully documented maintenance activities for each type of GIS that include twice yearly visual inspections and a range of functional and diagnostic tests carried out at 3, 4 or 5-year intervals for different types. Selected intrusive maintenance is scheduled at intervals of between 10 and 20 years or when required by the manufacturer's specification. The inspection, testing and maintenance activities reflect the recommendations of the manufacturer and take into account the specific issues, which have been recognized, for the individual types of switchgear. Leak detection and management and mechanism and breaker operational checks are a dominant part of the maintenance activities.

For each inspection and test Networks has defined condition ratings (or test-pass/test-fail-TP/TF) to ensure effective remedial action, where necessary. This also provides the basis for collecting information on overall condition. The use of an algorithm for the evaluation of the health of each asset that allows an objective and repeatable measurement of the condition based health of that asset continues to be consistent with world-wide utility best practice.

4.2.3 2008 Health Index (HI) Results

A new 2008 HI profile was not produced by Networks for Gas Insulated Switchgear. The reason for not producing a 2008 HI is that there has been very little new data collected since the last time the HI was calculated.

4.2.4 Audit Findings

The responsible asset planner has indicated that there are no additional end-of-life factors that need to be incorporated into the HI formulation and therefore the practices and algorithms in place are deemed to be consistent with previously evaluated practice procedures.

Industry standard testing schedules for many assets have multi-year maintenance cycles, and new data is not collected between cycles. Even a proactive replacement program might only replace a few of the assets in a given year. GIS equipment would be such an asset. Since the input data has not been sufficiently changed, it is reasonable that an update of the 2006 HI was not produced.

4.3 Oil Circuit Breakers

Oil Circuit Breakers (OCBs) are installed on the power system to interrupt load and fault currents and to isolate power equipment to facilitate maintenance. An OCB consists of either one or three steel tanks filled with insulating oil in which operating contacts are immersed. These contacts are enclosed in an arc control "pot" which is designed to facilitate rapid extinction of the electrical arc during an interruption.

Since 2004 Networks has had a program to replace all of the OCBs on its system which is an overriding strategy driven by technical obsolescence, that does not involve the use of asset condition assessment or a health index calculation. In such cases it is in keeping with industry best practices to not conduct Asset Condition Assessments where asset sustainment is not considered to be an investment driver.

4.4 Air Blast Circuit Breakers

Air Blast Circuit Breakers (ABCBs) are installed on the power system to interrupt load and fault currents and to de-energize power carrying assets to facilitate maintenance. ABCBs employ compressed air as an interrupting and insulating medium. They are complicated in design and incorporate a large number of moving parts, valves and seals. They also require a high-pressure compressed air supply consisting of a centralized high pressure air compressor/dryer plant as well as an air storage facility.

4.4.1 Health Index (HI) Formulation

The HI formulation used by Networks in the 2006 condition assessment is included in Appendix I. The current HI formulation being used by Networks remains unchanged from that used in 2006.

4.4.2 Data Collection Methods

Data used in the HI calculation is collected via a documented program of field inspections and testing. Included in this documentation are definitions for the condition ratings that can be assigned against each inspection or test. Data collected during field investigations is recorded in an unstructured manner. The unstructured information is then entered into a centralized database where the asset planner can subsequently access the data. The use of freeform data entry can introduce a certain amount of error and inconsistency in the data.

4.4.3 2008 Health Index (HI) Results

The 2008 HI results presented by Networks for the Air Blast Circuit Breaker Assets are shown in Figure 4.2. Comparison of the 2008 HI results against those for 2006 shows that consistency is being maintained in the ACA process for the Air Blast Circuit Breaker asset.

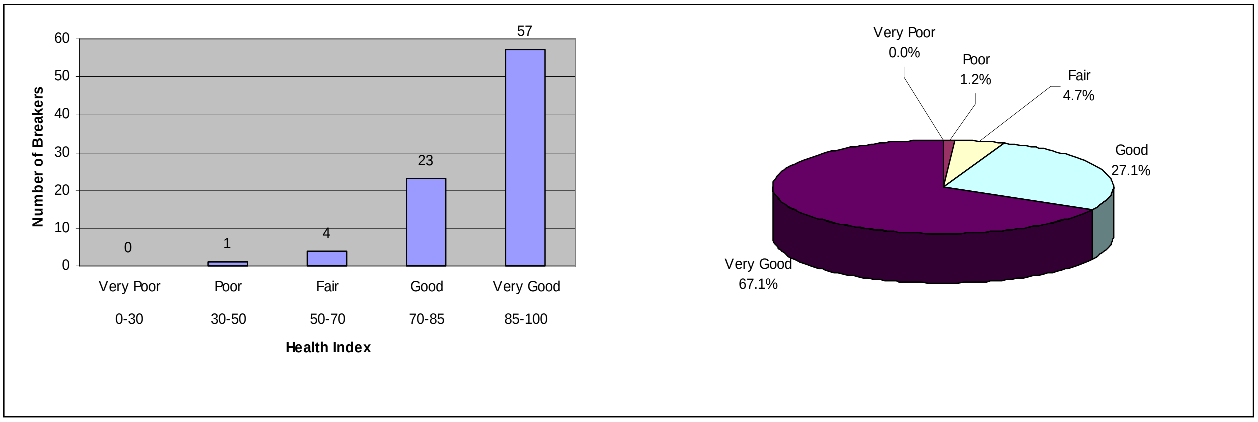


Figure 4.2: 2008 Health Index Results for Air Blast Circuit Breakers

4.4.4 Audit Findings

The responsible asset planner has indicated that there are no additional end-of-life factors that need to be incorporated into the HI formulation. Networks approach continues to align with previously evaluated best practices.

4.5 High Voltage/Low Voltage (HV/LV) Switches

This asset class consists of high voltage and low voltage disconnect switches used to physically and electrically isolate sections of the power transmission system for purposes of maintenance, safety, and other operational requirements. These switches are normally operated when there is no current through the switch, unless specifically designed to be capable of operating under load. Also included here are load interrupter switches which have load and limited fault interrupting capability and also grounding switches that are designed to apply a maintenance related safety ground connection.

4.5.1 Health Index (HI) Formulation

The HI formulation used by Networks in the 2006 condition assessment is included in Appendix I. The current HI formulation being used by Networks remains unchanged from that used in 2006.

4.5.2 Data Collection Methods

Data used in the HI calculation is collected via a documented program of field inspections and testing. Included in this documentation are definitions for the condition ratings that can be assigned against each inspection or test. Data collected during field investigations is recorded on an electronic handheld device that shows all of the required inspections and tests as well as providing drop down menus for the selection of condition ratings. Information from the tablet computers is then uploaded into a centralized database where the asset planner can subsequently access the data. The use of handheld devices and drop down menus ensures consistency in the data collection process.

Data collection is typically carried out on an annual basis for general condition assessment, however maintenance activities on HV/LV switches have currently been suspended for a 3 to 4-year period (except for 500kV switches), so new data is not becoming available.

4.5.3 2008 Health Index (HI) Results

The 2008 HI results presented by Networks for HV/LV switch assets are shown in Figure 4.3. Comparison of the 2008 HI results against those for 2006 shows that consistency is being maintained in the ACA process for the HV/LV switches asset group.

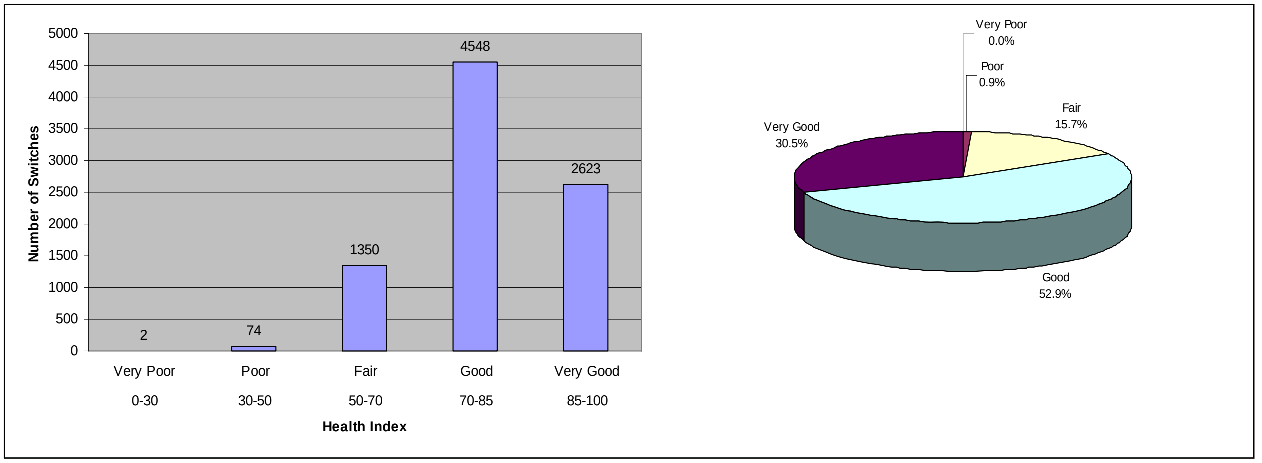


Figure 4.3: 2008 Health Index Results for HV/LV Switches

4.5.4 Audit Findings

The responsible asset planner has indicated that there are plans to change the HI formulation so that the tests and measures directly align with the preventative maintenance activities . The HI calculation will be performed with a computerized tool called Asset Data Mart (ADM). The information for ADM is gathered from a number of Networks centralized databases and refreshed on a weekly basis. All future HI calculations will be made on that basis.

The suspension of maintenance activities on the switches over the last 3 or 4 years has resulted in a freeze of input data. In that context the HI results will become increasingly invalid. In the short term, this will not have a drastic impact on the reporting of asset condition, as the condition of non-load break switches typically changes slowly over time. However, a definitive maintenance plan and schedule should be developed to ensure that the condition of this asset is not left unreported for any period of time.

In terms of assessment of condition and utilization of the condition information of individual switches in the decision making process with regard to end-of-life, Networks continues to follow practices in keeping with previously evaluated best practices and the ultimate move to automated tools would be considered leading edge.

4.6 Operating Spares

Operating Spares deals only with the condition of Networks existing fleet of operating spare equipment. It does not address the methods used for optimizing the number, type, strategy, or planning of specific spares required to provide the necessary transmission operating coverage. This asset class consists of strategic operating spares that Networks maintains and considers essential for the safe, reliable and efficient operation of its transmission system. This asset class includes items such as spare power transformers, regulators, shunt reactors, grounding and station service transformers, and spare circuit breakers. The transmission equipment in this asset class operates at voltages of 13.8 kV to 500 kV.

4.6.1 *Audit Findings*

The condition of operating spares equipment is monitored using the same general criteria as other assets of the same type. Details of the manner in which these assets are handled can be found in the respective sections of this report. However as an asset category is it impractical to produce a HI of any meaning. The management program for operating spares can continue to be described consistent with previously evaluated best practices.

4.7 Protection and Control

Protection and Control (P&C) consists of protective relays and their associated systems. These devices are connected throughout the transmission system for the purpose of sensing and eliminating abnormal conditions. They detect and isolate, in conjunction with circuit breakers, any abnormal conditions resulting from natural events, physical accidents, equipment failure or mis-operation due to human error. P&C systems are therefore indispensable for the safe and reliable operation of the transmission system. The maximum time allowed for power system protection to correctly sense and isolate faulted equipment is measured in fractions of a second. High-speed isolation is necessary to protect and mitigate damage to expensive system equipment, reduce the health and safety risks to public and personnel and to maintain power system security and reliability. Both failure to operate and incorrect operation can result in major power system disruption involving increased equipment damage, increased personnel hazards and extended interruption of service. These stringent requirements with high potential consequences make it imperative that protection systems be extremely reliable.

4.7.1 *Health Index (HI) Formulation*

The HI formulation used by Networks in the 2006 condition assessment is included in Appendix I. The current HI formulation being used by Networks remains unchanged from that used in 2006.

4.7.2 *Data Collection Methods*

In 2000, data was collected during a targeted program of field inspections on the condition of protection and control assets. Since that full scale data collection, data is continually being updated based on new visual inspection records that are retrieved from a centralized database, defect reports that are generated by Grid Operations following investigation of devices that have failed or generated trouble alarms, and from extracts taken from operator logs. The data is maintained in an electronic spreadsheet by the asset planners and is updated annually.

4.7.3 *2008 Health Index (HI) Results*

A 2008 HI result was not produced by Networks for Protection and Control Systems. Networks is currently in the process of merging its data sources used for the HI calculation so that it will have data available on a larger population of its assets. At the completion of this process a new HI calculation will be performed.

4.7.4 Audit Findings

The responsible asset planners have indicated that there are no additional end-of-life factors that need to be incorporated into the HI formulation. The asset planners feel that they have all of the necessary data to assess the condition of their assets and are now attempting to make the leap toward predicting the failure rates of equipment. In this asset group and particularly in the area of predictive failure rates, Networks has demonstrated that it is one of the leaders in industry in the management of protection and control assets.

Since the condition of the asset base of P&C equipment will change fairly slowly, and the input data has not been sufficiently changed, it is reasonable that an update of the 2006 HI was not produced. However this asset will ultimately need updated Health Index results to reflect the status of on-going maintenance activities over time.

4.8 Phase Conductors

Transmission line conductors carry electrical energy from generating stations to transformation stations where the transmission voltage is lowered and the energy is redistributed to customers through distribution line conductors, generally of smaller capacity than the transmission conductors. Normally three conductors (one for each phase) constitute a single circuit, with an operating voltage on the circuit that results in phase-to-phase voltages between the conductors.

4.8.1 Health Index (HI) Formulation

The HI formulation used by Networks in the 2006 condition assessment is included in Appendix I. The current HI formulation being used by Networks remains unchanged from that used in 2006.

4.8.2 Data Collection Methods

Data used in the HI calculation for Phase Conductors is collected from tests conducted on samples of conductors taken from in-service lines. In this process a small section of conductor is cut out of an existing line and then the line is spliced back together.

Since 2006, tests have been carried out on approximately 20 samples by an independent laboratory and the results are maintained by the Asset Management Group in a database.

4.8.3 2008 Health Index (HI) Results

A new 2008 HI profile was not produced by Networks for Phase Conductors. The reason is that there has been very little new data collected since the last time the HI was calculated. The relatively small amount of additional data was deemed insufficient to impact the existing 2006 HI profile. Consequently, an update of the 2006 HI is not warranted at this time.

4.8.4 Audit Findings

The asset planner pointed out a problem with the HI formulation for Phase Conductors in that the two of the main measures making up the HI formulation (Tension Test and Turns to Failure Test) are independent of each other and the combination of the two in the HI formulation does not always point to an accurate condition assessment nor to a likely course of remedial action. A phase conductor can return a poor condition rating from the Tension Test but score very high on the Turns to Failure Test and vice-versa. The resulting HI for this combination may indicate that the phase conductor is in good condition, when in fact a low condition rating on either of these tests can each be indicative of end-of-life. The current HI formulation is really only applicable to ACSR (Aluminium Conductor Steel Reinforced) conductor which makes up the majority of the phase conductors used by Networks. The HI formulation does not apply well to other types of phase conductors such as copper conductors.

For the HI to be applied to these types of conductors, a new HI formulation would need to be created possibly reinforcing the concept that a failure of either test could result in an assessment of Poor or Very Poor condition.

There continues to be a number of diverse approaches used by utilities worldwide, including in-situ detection of broken strands and in-situ detection of loss of galvanizing on the steel core. At Networks, the current process provides for a relevant, cost effective and practical means of identifying conductors at or close to end-of-life and the potential to reliably estimate remaining life.

The process in place continues to be consistent with previously evaluated best practices, however, an update to the Health Index algorithm would produce enhanced results.

4.9 Wood Pole Structures

Transmission lines are supported by a variety of structure types, and wood pole structures are a common form of support in Ontario.

4.9.1 Health Index (HI) Formulation

The HI formulation used by Networks in the 2006 condition assessment is included in Appendix I. The current HI formulation being used by Networks remains unchanged from that used in 2006.

4.9.2 Data Collection Methods

Networks is currently migrating foot patrol and helicopter field inspection data into a new database. New GPS correlated data used in the HI calculation is collected via a documented program of field inspections and testing. Included in this documentation are definitions for the condition ratings that can be assigned against each inspection or test. Information uploaded into a centralized database can be extracted by the asset planner. In this regard, the consistency of the ACA process for the Wood Pole Structures asset group is being maintained.

4.9.3 2008 Health Index (HI) Results

A 2008 HI result was not produced by Networks for Wood Poles. Networks is currently in the middle of an existing program for the replacement of wood poles based on the overall level indicated by previous HI profiles and have not seen any evidence to change the overall direction of this program and, as a result, no plans to recalculate the HI until the current program nears completion.

4.9.4 Audit Findings

The responsible asset planner has indicated that there are no additional end-of-life factors that need to be incorporated into the HI formulation.

In such cases, it is in keeping with industry best practices to not conduct Asset Condition Assessments where changes in the Health Index results would not be considered an investment driver. However, in the future, it is recommended that Health Index results be generated in such a manner as to facilitate specific investment decisions.

4.10 Underground Cables

Networks currently manages approximately 260 circuit-km of 115 kV and 230 kV high voltage cable systems. Transmission underground cables are typically extensions or links that connect portions of the transmission system. They are mainly used in urban areas where it is either impossible, or extremely difficult to build overhead transmission lines. Depending on the cable design the three phase conductors may be contained together within a steel pipe or each phase conductor may be self-contained in its own sheath and installed separately underground. Transmission underground cables are systems, similar to transmission lines, made up of numerous components, all of which need to integrate and function properly in order to deliver the electric power with the reliability that is demanded. Main components include the core conductors, insulation, the sheath, cable jacket, outer pipe, pipe coating, thermal backfill, cathodic protection and liquid pressurization systems.

4.10.1 Health Index (HI) Formulation

The HI formulation used by Networks in the 2006 condition assessment is included in Appendix I. The current HI formulation being used by Networks has produced a Health Index result for this asset using a HI formulation that remains unchanged from that used in 2006.

4.10.2 Data Collection Methods

Data used in the HI calculation is collected via a documented program of field inspections and testing. Included in this documentation are definitions for the condition ratings that can be assigned against each inspection or test. Data collected during field investigations is recorded by field staff on forms and spreadsheets against each cable section and stored on shared folders that can be viewed by asset planners for ongoing review and for annual update of the health index.

4.10.3 2008 Health Index (HI) Results

The 2008 HI results presented by Networks for Underground Cable Assets are shown in Figure 4.4. Comparison of the 2008 HI results against those for 2006 shows that consistency is being maintained in the ACA process for the Underground Cable asset group. Overall, Networks processes related to management and condition assessment of their underground cables continues to be more rigorous and complete than most other comparable utilities. These processes include a regular preventative maintenance program and the adoption of a positive approach to addressing long term issues of degradation and condition.

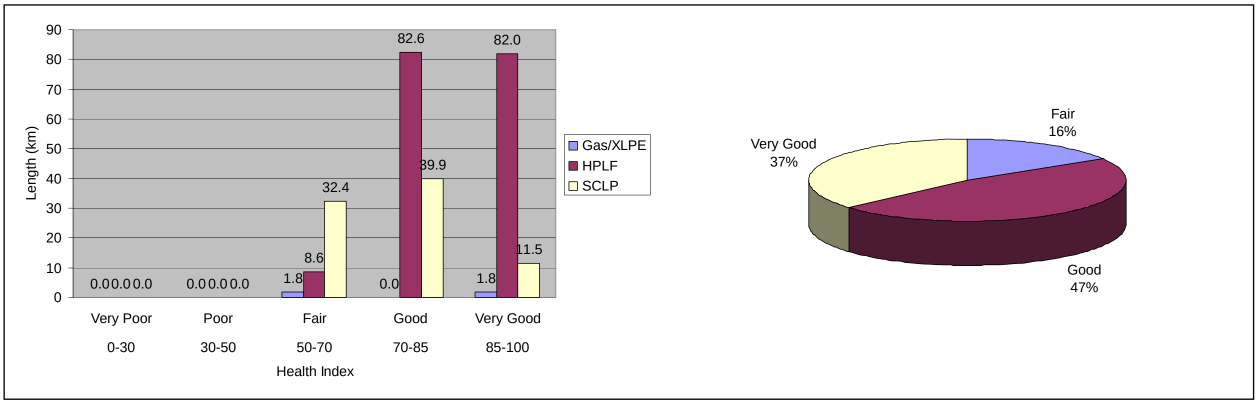


Figure 4.4: 2008 Health Index Result for Underground Cables

4.10.4 *Audit Findings*

The responsible asset planner has indicated that there are no additional end-of-life factors that need to be incorporated into the HI formulation.

4.11 Rights-of-Way

Networks maintains approximately 82,000 hectares of transmission Rights-of-Way. These are corridors of lands that have the vegetation on them controlled to varying widths of the right-of-way depending on the nature and operating voltage of the towers occupying the right-of-way. Vegetation is managed on a 6-year cycle in the south and on an 8-year cycle in the north.

4.11.1 *Health Index (HI) Formulation*

The HI formulation used by Networks in the 2006 condition assessment is included in Appendix I. The current HI formulation being used by Networks remains unchanged from that used in 2006. Networks is currently in the middle of an existing program for the maintenance of Rights-of-Way based on the level indicated by previous HI profiles and have not seen any evidence to change this program and, as a result, no plans to recalculate the HI until the current program nears completion.

4.11.2 *Data Collection Methods*

Data used in the HI calculation is collected via a program of visual inspections of the Rights-of-Way. Observations made during inspections are recorded manually on paper forms which are subsequently managed by the asset planner on an electronic spreadsheet. In this regard, the consistency of the ACA process for the Right-of-Way asset group is being maintained.

Each right-of-way is generally inspected and maintained on a 6 or 8-year cycle.

4.11.3 *2008 Health Index (HI) Results*

A 2008 HI result was not produced by Networks for Rights-of-Way. The Health Index is not generally used by the asset planner in making investment decisions. The growth of vegetation within the right-of-way is somewhat consistent year over year. Networks has a program in place with specific scheduling based on Condition Assessment programs, to perform maintenance on each right-of-way generally on a 6 or 8-year cycle.

4.11.4 Audit Findings

The responsible asset planner has indicated that there are no additional factors that need to be incorporated into the HI formulation. The planners have elected not to produce a HI result.

In such cases, it is in keeping with industry best practices to not conduct Asset Condition Assessments where changes in the Health Index results would not be considered a investment driver. However, if asset sustainment is expected to be an investment driver, it is recommended that HI results be generated in such a manner as to facilitate specific investment decisions.

5. Priority 2 Assets

5.1 High Pressure Air Systems

Centralized high-pressure air (HPA) systems are installed at all locations that have a population of ABCBs. These breakers employ compressed air as an interrupting and insulating medium. This requires a high-pressure compressed air supply consisting of a centralized HPA compressor/dryer plant as well as an air storage facility. The HPA systems are usually comprised of multi-stage compressors, chemical or heated dryers, numerous air storage receivers, extensive piping and valving arrangements and controls.

5.1.1 Health Index (HI) Formulation

The HI formulation used by Networks in the 2006 condition assessment is included in Appendix II. The current HI formulation being used by Networks remains unchanged from that used in 2006.

5.1.2 Data Collection Methods

Data used in the HI calculation is collected via a documented program of field inspections and testing. Included in this documentation are definitions for the condition ratings that can be assigned against each inspection or test. Data collected during field investigations is recorded on an electronic handheld device that shows all of the required inspections and tests as well as providing drop down menus for the selection of condition ratings. Information from the tablet computers is then uploaded into a centralized database where the asset planner can subsequently access the data. The use of electronic handheld devices and drop down menus ensures consistency in the data collection process.

5.1.3 2008 Health Index (HI) Results

The 2008 HI results presented by Networks for High Pressure Air System Assets are shown in Figure 5.1 and Figure 5.2. Comparison of the 2008 HI results against those for 2006 shows that consistency is being maintained in the ACA process for the High Pressure Air Systems asset. Networks continues to combine the knowledge of the condition of the HPA systems with its assessment and strategy for ABCBs in a manner that is consistent with best practice in other utilities.

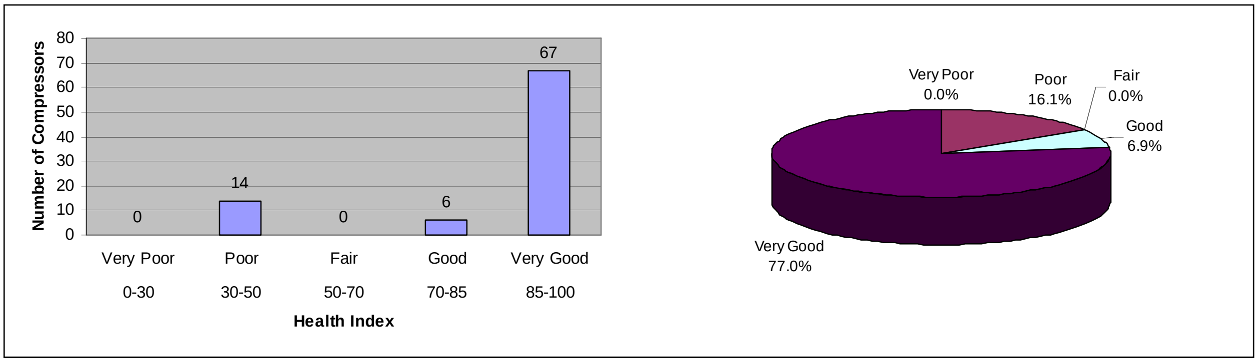


Figure 5.1: 2008 Health Index Results for High Pressure Air System Compressors

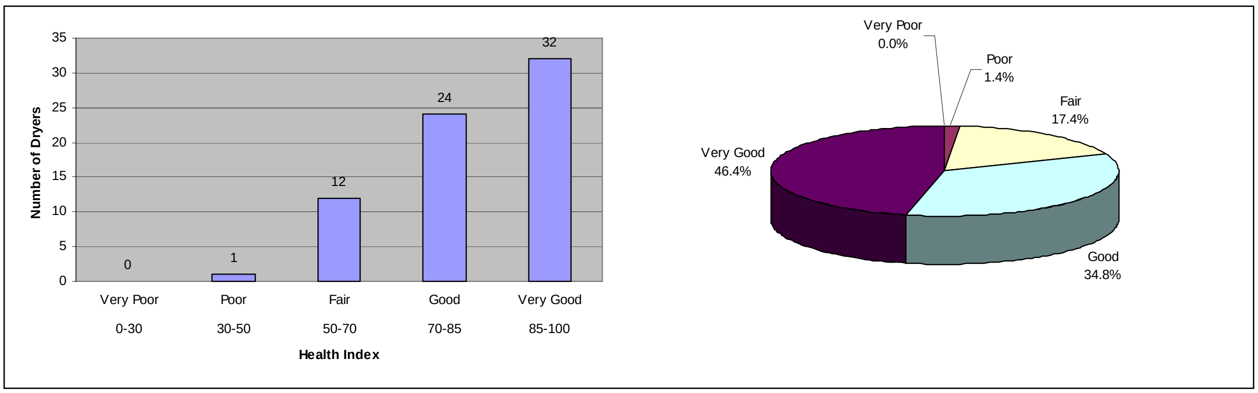


Figure 5.2: 2008 Health Index Result for High Pressure Air System Dryers

5.1.4 Audit Findings

The responsible asset planner has indicated that there are no additional end-of-life factors that need to be incorporated into the HI formulation. Networks approach continues to align with previously evaluated best practices.

5.2 SF_6 Circuit Breakers

A circuit breaker is a mechanical switching device that is capable of making, carrying and interrupting electrical currents under normal and abnormal circuit conditions. Abnormal conditions occur during a short circuit such as a lightning strike or conductor contact to ground; or during switching of equipment in or out of service. During these conditions, very high electrical currents are generated that greatly exceed normal operating levels. A circuit breaker is used to break the electrical circuit and interrupt the current to minimize its effect on the rest of the system.

SF_6 is a very stable compound with remarkable dielectric properties and is used to insulate the live parts with the device. Its use has enabled transmission equipment to become more compact, safer and have fewer maintenance requirements. Recent SF_6 designs have improved the technology substantially. Because of these improvements, SF_6 equipment has become popular and has replaced all other high voltage technologies and, over the last 30 years, single pressure SF_6 breakers have become the technology of choice for transmission class switchgear.

5.2.1 *Health Index (HI) Formulation*

The HI formulation used by Networks in the 2006 condition assessment is included in Appendix II. The current HI formulation being used by Networks remains unchanged from that used in 2006.

5.2.2 *Data Collection Methods*

Data used in the HI calculation is collected via a documented program of field inspections and testing. Included in this documentation are definitions for the condition ratings that can be assigned against each inspection or test. Data collected during field investigations is recorded on an electronic handheld device that shows all of the required inspections and tests as well as providing drop down menus for the selection of condition ratings. Information from the tablet computers is then uploaded into a centralized database where the asset planner can subsequently access the data. The use of handheld devices and drop down menus ensures consistency in the data collection process.

5.2.3 *2008 Health Index (HI) Results*

The 2008 HI results presented by Networks for SF_6 Circuit Breaker Assets are shown in Figure 5.3. Comparison of the 2008 HI results against those for 2006 shows that consistency is being maintained in the ACA process for the SF_6 Circuit Breakers asset group.

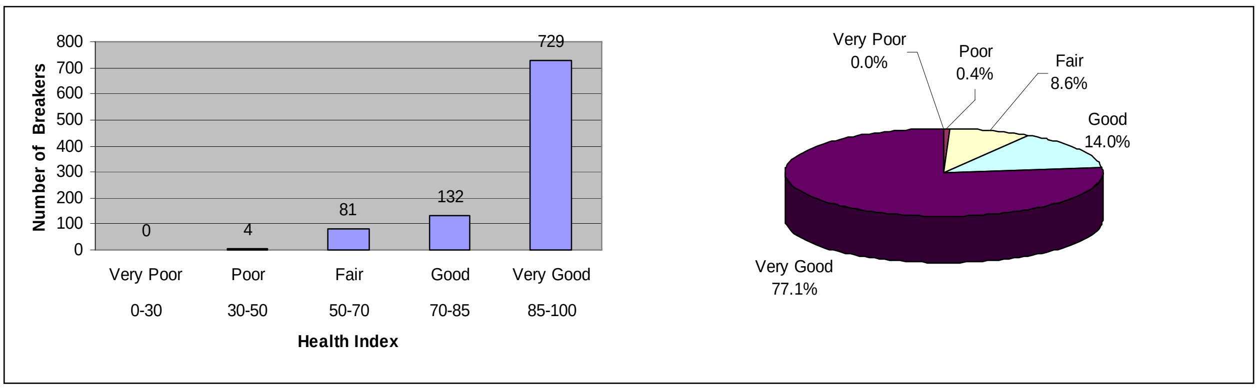


Figure 5.3: 2008 Health Index Results for SF_6 Circuit Breakers

5.2.4 *Audit Findings*

The responsible asset planner has indicated that there are no additional end-of-life factors that need to be incorporated into the HI formulation. Maintenance, inspections, and management processes applied by Networks to SF_6 circuit breakers are reported to continue to be the same as other leading utilities. Maintenance processes generally follow manufacturers' recommendations, particularly on minimally intrusive activities. Networks approach continues to align with previously evaluated best practices.

5.3 Metalclad Switchgear

In a typical low voltage switchyard the switchgear is assembled with sufficient clearance between live parts and ground so that the ambient air provides insulation between phase conductors. However, if the live parts can be coated with a suitable insulating material, the required clearances can be reduced, and the switchgear assembly can be made much more compact. Switchgear that is thus insulated and then has its major components enclosed in separate grounded metal compartments is called metalclad switchgear. Metalclad switchgear for indoor application is extensively used by Networks to supply power to local utilities in urban areas.

5.3.1 Health Index (HI) Formulation

The HI formulation used by Networks in the 2006 condition assessment is included in Appendix II. The current HI formulation being used by Networks remains unchanged from that used in 2006.

5.3.2 Data Collection Methods

Data used in the HI calculation is collected via a documented program of field inspections and testing. Included in this documentation are definitions for the condition ratings that can be assigned against each inspection or test. Data collected during field investigations is recorded on an electronic handheld device that shows all of the required inspections and tests as well as providing drop down menus for the selection of condition ratings. Information from the tablet computers is then uploaded into a centralized database where the asset planner can subsequently access the data. The use of handheld devices and drop down menus ensures consistency in the data collection process.

5.3.3 2008 Health Index (HI) Results

The 2008 HI results presented by Networks for Metalclad Switchgear Assets are shown in Figure 5.4, Figure 5.5, and Figure 5.6. Comparison of the 2008 HI results against those for 2006 shows that consistency is being maintained in the ACA process for the Metalclad Switchgear asset.

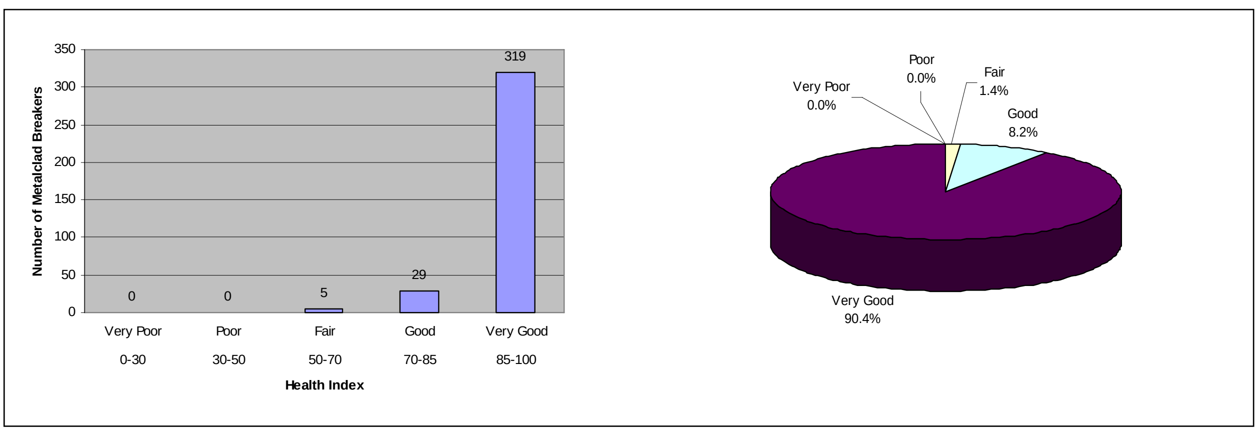


Figure 5.4: 2008 Health Index Result for Metalclad Breakers

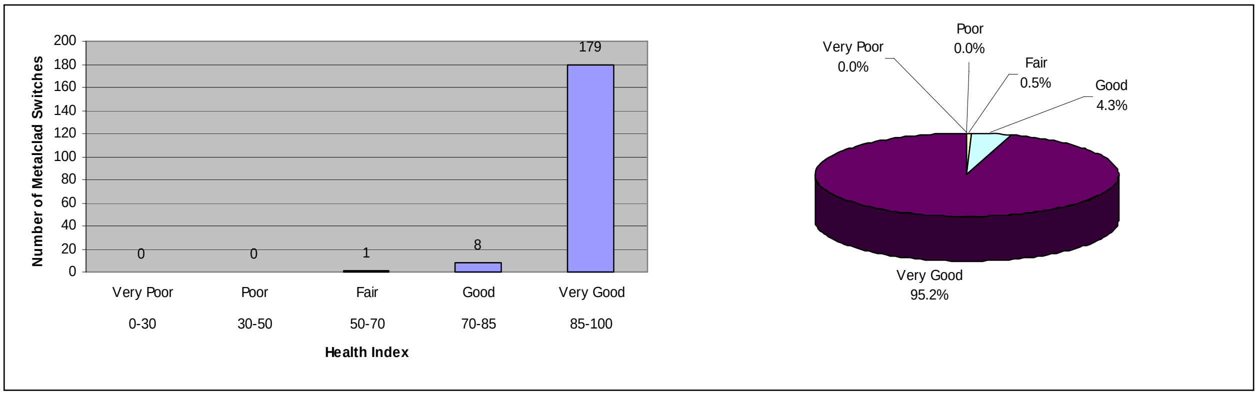


Figure 5.5: 2008 Health Index Result for Metalclad Switches

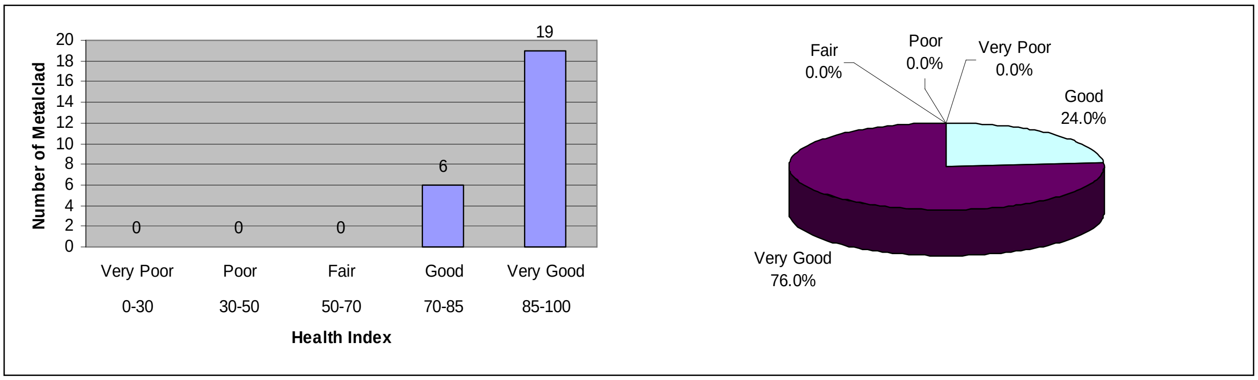


Figure 5.6: 2008 Health Index Results for Metalclad Bus

5.3.4 *Audit Findings*

Generally, replacement decisions being made to this asset are based on an over-riding strategy to replace 1-2% of the metalclad breaker population per year. As such, the responsible asset planner has indicated that there are no additional end-of-life factors that need to be incorporated into the HI formulation.

Networks maintenance practices continue to be based on the traditional time based activities used by most other leading utilities and, in common with other utilities, end-of-life has predominantly been defined by factors that are not related to condition.

5.4 Power Line Carrier

Power Line Carrier (PLC) communications is the practice of transmitting information using the electrical power line as the communication media. This information is transmitted in the form of modulated radio signals over 115 kV, 230 kV and 500 kV transmission lines. PLC has proven to be a highly reliable and robust communication system. While offering limited signal transmission capacity, PLC is a cost effective communication solution for remote areas where other communication media are not available or applications where greater bandwidth is not required. For these reasons, Networks continues to operate and maintain PLC facilities.

A PLC "system" consists of terminal equipment (transmitter, receiver, tone equipment and ancillary equipment) at each end of the power line that is being protected, and coupling equipment (line traps, couplers, co-axial cables and hybrid equipment) that connects the terminal units to the power line. Separation of the PLC signal from the electric power being transmitted is achieved by transmitting the PLC signal within a frequency range of 30 kHz to 300 kHz while electrical power is transmitted over the same line at 60 Hz.

5.4.1 Health Index (HI) Formulation

The HI formulation used by Networks in the 2006 condition assessment is included in Appendix II. The current HI formulation being used by Networks remains unchanged from that used in 2006.

5.4.2 Data Collection Methods

Data used in the HI calculation is collected via a documented program of field inspections and testing. Inspections are carried out on an annual basis. Additionally, the asset planner gathers information from defect reports that are generated by Grid Operations following investigation of devices that have failed or generated trouble alarms. Data collected during field investigations is recorded on an electronic handheld device that shows all of the required inspections and tests as well as providing drop down menus for the selection of condition ratings. Information from the tablet computers is then uploaded into the a centralized database where the asset planner can subsequently access the data. The use of handheld devices and drop down menus ensures consistency in the data collection process.

The relevant data for use in the HI calculation is extracted manually from the centralized database and from the defect reports and recorded in a spreadsheet by the asset planner. This same spreadsheet is also used to calculate the HI result. Consequently, consistency of the ACA process for Power Line Carrier asset group is being maintained.

5.4.3 2008 Health Index (HI) Results

A 2008 health index result was not produced by Networks for PLC. Networks currently has a program in place to replace trouble PLC systems at a level based on previous HI results. Currently there are approximately 70 PLC systems that remain in-service and are relatively new and considered to be in very good condition. Networks does not foresee any new programs being instituted to replace the remaining units in the near future.

5.4.4 Audit Findings

The responsible asset planner has indicated that there are no additional end-of-life factors that need to be incorporated into the HI formulation.

In such cases, it is in keeping with industry best practices to not conduct Asset Condition Assessments where changes in the HI results would not be considered an investment driver. However, in the future, HI results should be generated to assess the impact of or need for ongoing programs.

5.5 High Voltage Instrument Transformers

The application of control, protection (relaying) and metering functions to high voltage (HV) systems requires the use of sensitive measuring devices, which are typically incapable of withstanding the high currents and high voltages present on the Networks primary system. For this reason, the primary voltages and currents in typical HV systems must be accurately transformed to lower values that are acceptable to the measuring devices.

In HV systems special transformers called instrument transformers carry out this function. There are two basic types of instrument transformers: voltage (potential) transformers (PTs) and current transformers (CTs). Traditionally, these transformers have been oil insulated. Other types of current transformers are now being supplied that use SF_6 as the insulating medium.

5.5.1 Health Index (HI) Formulation

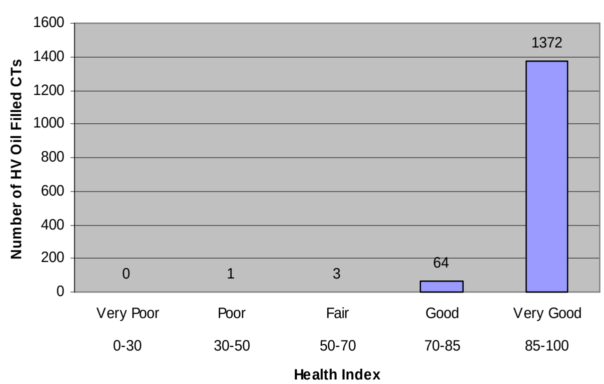
The HI formulation used by Networks in the 2006 condition assessment is included in Appendix II. The current HI formulation being used by Networks remains unchanged from that used in 2006.

5.5.2 Data Collection Methods

Data used in the HI calculation is collected via a documented program of field inspections and testing. Included in this documentation are definitions for the condition ratings that can be assigned against each inspection or test. Data collected during field investigations is recorded on an electronic handheld device that shows all of the required inspections and tests as well as providing drop down menus for the selection of condition ratings. Information from the tablet computers is then uploaded into a centralized database where the asset planner can subsequently access the data. The use of handheld devices and drop down menus ensures consistency in the data collection process

5.5.3 2008 Health Index (HI) Results

The 2008 HI results presented by Networks for High Voltage Instrument Transformer Assets are shown in Figure 5.7, Figure 5.8, Figure 5.9, and Figure 5.10. Comparison of the 2008 HI results against those for 2006 shows that consistency is being maintained in the ACA process for the High Voltage Instrument Transformers asset group.



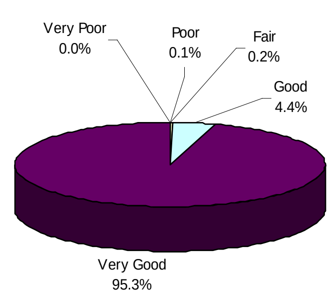


Figure 5.7: 2008 Health Index Result for Oil Filled Current Transformers

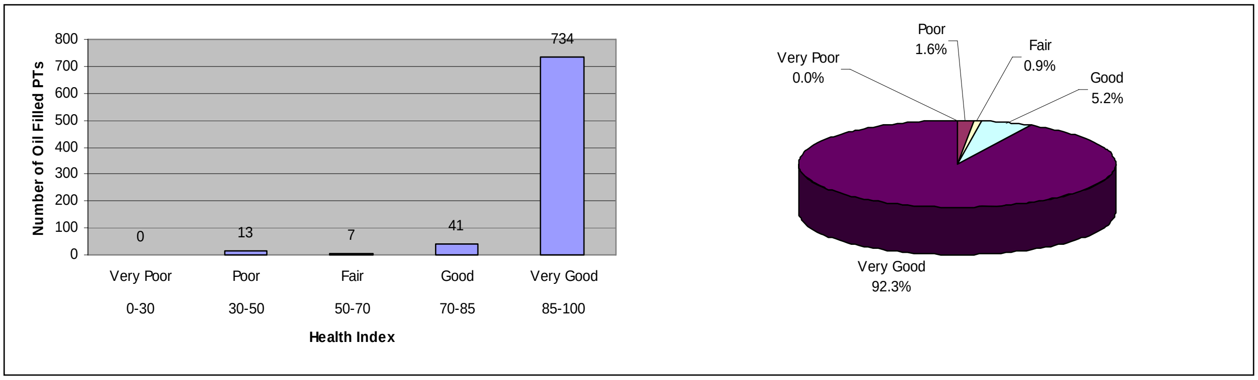


Figure 5.8: 2008 Health Index Result for Oil Filled Potential Transformers

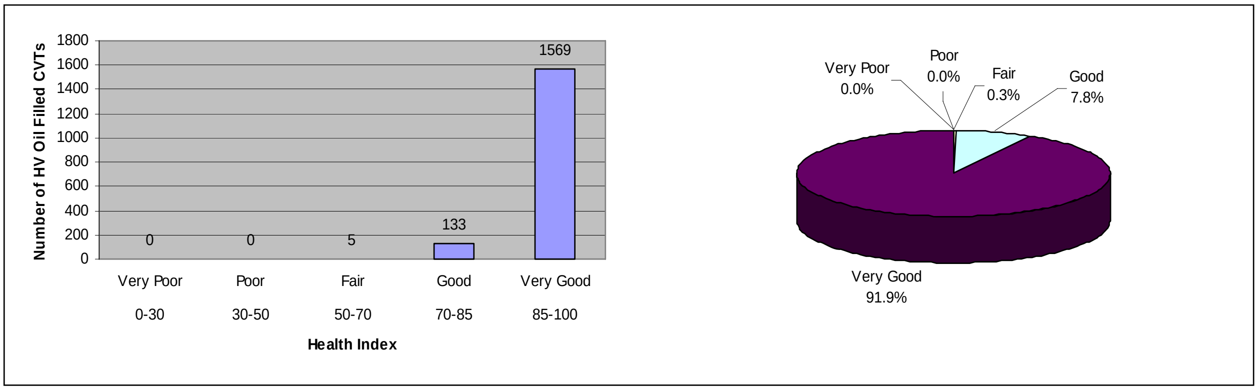


Figure 5.9: 2008 Health Index Result for Oil Filled Capacitive Voltage Transformers

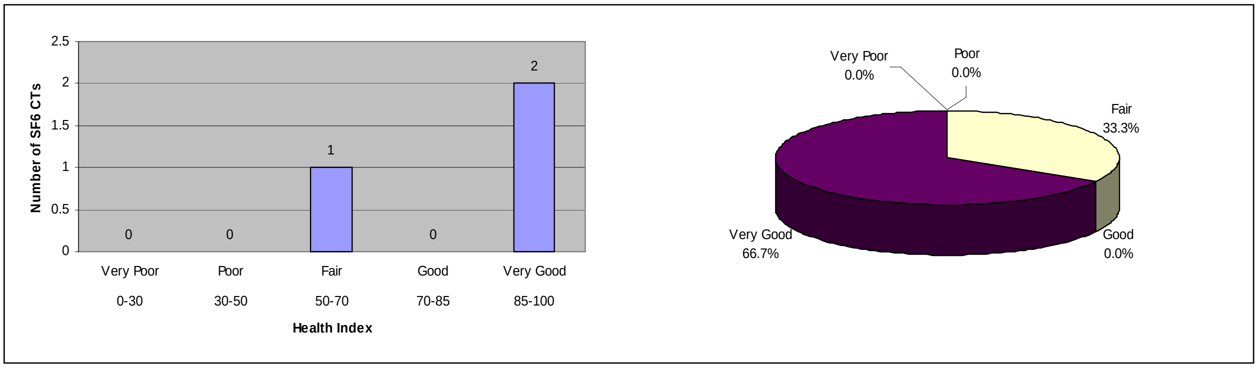


Figure 5.10: 2008 Health Index Result for SF_6 Filled Current Transformers

5.5.4 *Audit Findings*

The responsible asset planner has indicated that there are no additional end-of-life factors that need to be incorporated into the HI formulation.

The overall maintenance and condition assessment practices that continue to be used by Networks are very similar to the practices adopted by other utilities, and Networks approach continues to align with previously evaluated best practices.

5.6 Revenue Metering

Market rules require that every interface with a Market Participant (MP) requires revenue metering installations to record the energy and demand transaction amount. A metering installation is comprised of one multi-channel recorder connecting one or more meters and associated voltage and current transformers for each meter point. Each MP connecting to a transmission station would have one or more metering installations.

According to market rules, MPs are required to own their own revenue metering installations. At the start of the market in 2002, transitional arrangements were made for Networks to provide metering services to legacy installations until the earliest expiry date of any seal of any meter forming part of such metering installations. Following this, the MP would be responsible to make arrangements for their own metering installations. Once all of these transitional arrangements have expired, Networks will not own any revenue metering facilities. As a result of this program to exit from owning any revenue metering facilities, Networks no longer conducts condition assessments for this asset class.

5.7 Station Insulators

Insulators are used in transmission stations for termination of conductors at structures and to support buses or equipment. The types of insulators used in transmission stations are:

- Disc types for strain bus connections and for idler strings associated with strain buses
- Rigid support insulators mostly used for rigid bus support.

Insulators essentially isolate live apparatus from station structures and provide support for electrical conductors and equipment. Station insulators are subject to both electrical and mechanical stresses at the installation point. The electrical stresses are caused by the high voltage between live parts and ground during normal and abnormal conditions. Mechanical stresses include compression, torsion, tension and cantilever forces.

Networks recognizes that the failure of insulators are a significant issue and, as such, undertakes regular visual examination and thermographic testing to identify external and other damage to insulators. Networks approach to the management of insulators is very similar to other leading utilities, relying primarily on non-invasive visual inspection and thermographic testing to identify high risk insulators and candidates for replacement, with particular focus on mission critical stations.

5.7.1 Audit Findings

Networks does not record the inspection and test results of the "as found" condition of its station insulators, as this is just not practical or cost effective. Networks chooses to rely more on demographics and history of failures to assess status. Data is, therefore, not available to populate a Health Index. This approach has not changed from the 2006 ACA report and still remains consistent with the practices of other leading electric utilities.

5.8 Station Cables and Potheads

This asset consists of cables and potheads associated with equipment located within the confines of a transmission station, such as station service transformer feeds, transformer to switchgear connections, and capacitor bank connections. Networks manages transmission station cables and potheads typically with voltage between 13.8 kV to 44 kV. Cables and potheads are typically used when air insulated bus cannot be utilized because of space limitations.

5.8.1 2008 Health Index (HI) Results

Historically Networks has not collected information on cables and potheads and therefore data is not available to populate a HI. Consistent with Industry Best Practices, these assets are typically run to failure at which time they are repaired or replaced.

5.8.2 Audit Findings

The nature and reliability of cables and potheads has tended to result in minimal maintenance and condition assessment activity. The visual inspection practices undertaken by Networks continue to be consistent with the practices of other leading electric utilities where asset sustainment is not considered to be an investment driver.

5.9 Batteries and Chargers

Circuit breakers, motorized disconnect switches, transformer tap changers and, in particular, the protection, control and communication (Telecom) systems in transmission stations must be provided with a guaranteed source of power to ensure they can be operated under all system conditions, particularly during fault conditions. There is no known way to store AC power thus the only guaranteed instantaneous power source in switchyards must be DC, based on batteries.

5.9.1 Health Index (HI) Formulation

The HI formulation used by Networks in the 2006 condition assessment is included in Appendix II. The current HI formulation being used by Networks differs from that used in 2006, in that a new rule has been established for the "Battery Load Test" measure. Previously, if the Battery Load Test result returned a CR4 rating, the total HI score was divided by 4. Currently, if the Battery Load Test result returns a CR4 rating, the HI is set equal to zero.

5.9.2 Data Collection Methods

Data used in the HI calculation is collected via a documented program of field inspections and testing. Inspections are carried out on an annual basis. Data collected during field investigations is recorded on an electronic handheld device that shows all of the required inspections and tests as well as providing drop down menus for the selection of condition ratings. Information from the tablet computers is then uploaded into the a centralized database where the asset planner can subsequently access the data. The use of handheld devices and drop down menus ensures consistency in the data collection process.

The HI calculation is performed in a computerized tool called Asset Data Mart (ADM). The information for ADM is gathered from a number of Networks centralized databases and refreshed on a weekly basis.

5.9.3 2008 Health Index (HI) Results

The 2008 HI results presented by Networks for the Battery and Battery Charger Assets are shown in Figure 5.11 and Figure 5.12. Comparison of the 2008 HI results against those for 2006 shows that consistency is being maintained in the ACA process for the Batteries and Chargers asset group.

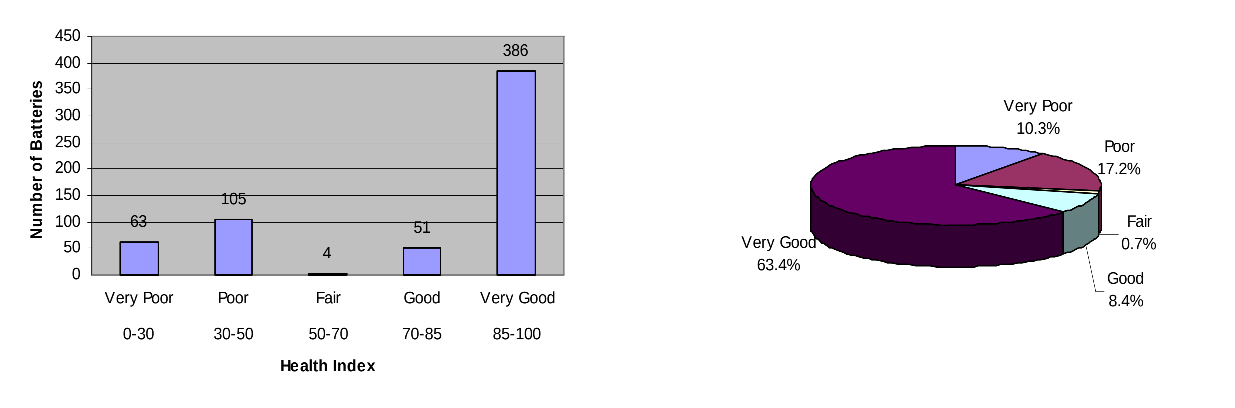


Figure 5.11: 2008 Health Index Result for Batteries

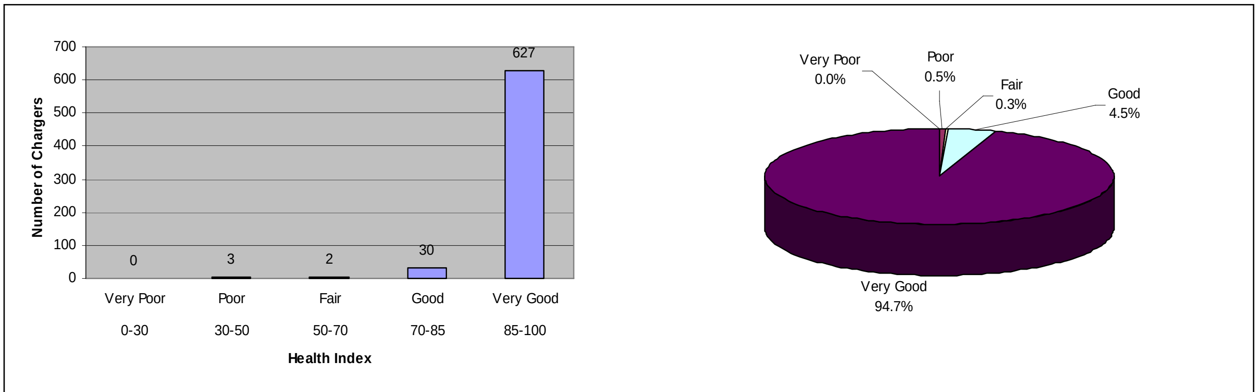


Figure 5.12: 2008 Health Index Result for Battery Chargers

5.9.4 Audit Findings

The responsible asset planner has indicated that there are no additional end-of-life factors other than those listed above that need to be incorporated into the HI formulation. The changes that have been made to the HI formulation provide a HI result that more accurately reflects the condition of the asset.

The change in formulation will have a small impact on the year over year comparisons, however updating the Health Index algorithm with all known end-of-life indicators would be considered consistent with the practice procedures

5.10 Station Grounding Systems

Grounding systems are designed to ensure safety of personnel and equipment in and around transmission stations. Grounding systems provide a means of ensuring a common potential between metal structures and equipment accessible to personnel so that hazardous step, touch, mesh and transferred voltages do not occur. In addition, effective grounding systems limit the damage to equipment during faults or surges and they ensure proper operation of protective devices such as relays and surge arresters.

5.10.1 Health Index (HI) Formulation

Networks does not have a HI formulation however it is expected that should a HI result be required, the formulation as documented in 2006 would be used.

5.10.2 Data Collection Methods

Networks has a program to evaluate the adequacy of station grounding facilities. These evaluations consist of soil resistivity measurements, full determination of the ground network, fall of potential measurements and application of a software based model to assess the potential rise, and step and touch potentials for a maximum fault level. Based on the results of these detailed grounding assessment surveys, specific issues and deficiencies are determined. These are classified as high, medium or low depending on the severity and risks associated with each deficiency. Using this HI system, the adequacy of station grounding systems could be determined and prioritized.

5.10.3 2008 Health Index (HI) Results

A HI result was not produced for 2008. In previous Asset Condition Assessment projects, HI results were inferred from available data to establish representative results.

5.10.4 Audit Findings

The nature and reliability of station grounding systems has tended to result in minimal maintenance and condition assessment activity. It was not seen as useful to repeat the estimated evaluation undertaken in 2006, as the results did not typically drive the investment decisions. The visual inspection practices undertaken by Networks continue to be consistent with the practices of other leading electric utilities.

Should it be desired to undertake asset sustainment programs for station grounding assets in the future, an intensive data collection project could be undertaken to establish a Health Index result.

5.11 Capacitor Banks

Capacitor Banks (capacitors) are static devices whose primary purpose in power systems is the compensation of inductive reactance of other system components. They are a static source of reactive power on the transmission system that balance the inductive demand on the system and provide the necessary voltage support needed for efficient power transmission. In general, system operators try to balance the capacitive and inductive demand on the system at all points on the system by switching shunt capacitors on or off as required.

5.11.1 Health Index (HI) Formulation

The HI formulation used by Networks in the 2006 condition assessment is included in Appendix II. The current HI formulation being used by Networks remains unchanged from that used in 2006.

5.11.2 Data Collection Methods

Data used in the HI calculation is collected via a documented program of field inspections and testing. Included in this documentation are definitions for the condition ratings that can be assigned against each inspection or test. Data collected during field investigations is recorded on an electronic handheld device that shows all of the required inspections and tests as well as providing drop down menus for the selection of condition ratings. Information from the tablet computers is then uploaded into a centralized database where the asset planner can subsequently access the data. The use of handheld devices and drop down menus ensures consistency in the data collection process.

5.11.3 2008 Health Index (HI) Results

The 2008 HI results presented by Networks for Capacitor Bank Assets are shown in Figure 5.13. Comparison of the 2008 HI results against those for 2006 shows that consistency is being maintained in the ACA process for the Capacitor Banks asset group.

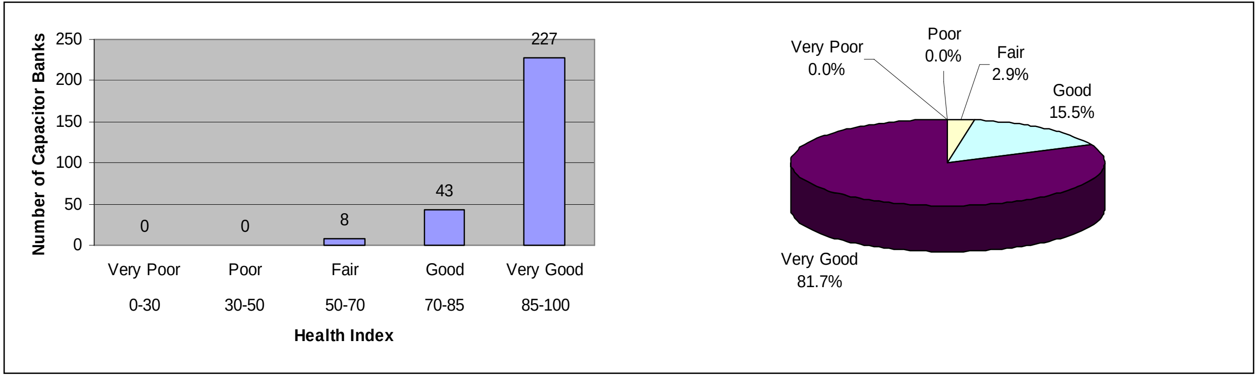


Figure 5.13: 2008 Health Index Results for Capacitor Banks

5.11.4 Audit Findings

The responsible asset planner has indicated that there are no new end-of-life factors that need to be incorporated into the HI formulation.

Networks practices continue to be in keeping with previously evaluated best practices.

5.12 Station Buildings

Networks owns a number of transmission station buildings of different types and sizes. These buildings include equipment and technical buildings, and administrative and services buildings. They have been constructed over a long period of time to meet the particular needs of the time and were constructed in accordance with the required building standards.

Responsibility for these assets has been transferred from the Asset Management Group to the Real Estate Group and therefore were not subject to any further examination during the process audit. It is assumed that in further iterations of Asset Condition Assessment, a determination will be made as to the need to include this asset in the process.

5.13 Fences

It is the practice of Networks to erect security fences around their electrical plant facilities, including transmission stations and exposed high voltage cable terminations. This practice is for the purpose of protecting the public from hazardous electrical contact, and to protect these facilities against intrusion and vandalism. The security fences can be of several types such as steel chain link, aluminum chain link, wood, masonry and Durisol.

Responsibility for these assets has been transferred from the Asset Management Group to the Real Estate Group and therefore were not subject to any further examination during the process audit. It is assumed that in further iterations of Asset Condition Assessment, a determination will be made as to the need to include this asset in the process.

5.14 Drainage and Geotechnical

The Transmission Station Drainage and Geotechnical asset class includes drainage facilities for the removal of surface and ground water, and civil facilities such as roads, yard subsurface and surface, and footings. Drainage is a practical and economical way of improving and maintaining firm, dry, stable subgrades for support of roads, railways, and foundations for structures and buildings and reducing step-and-touch potential.

5.14.1 Health Index (HI) Formulation

The HI formulation used by Networks in the 2006 condition assessment is included in Appendix II. The current HI formulation being used by Networks remains unchanged from that used in 2006.

5.14.2 Data Collection Methods

During the period from 1999 to 2001, data was collected during a targeted program of field inspections on the condition of drainage and geotechnical assets. Networks had a plan to gather new data on these assets in 2007, however this has not yet been completed.

5.14.3 2008 Health Index (HI) Results

A 2008 HI result was not produced by Networks for Drainage and Geotechnical. The reason for not producing a 2008 HI is that there has been no new data collected since the last time the HI was calculated.

5.14.4 Audit Findings

The responsible asset planner has indicated that there are no new end-of-life factors that need to be incorporated into the HI formulation. Data collection procedures should be examined as applicable to support the asset sustainment planning needs. However, since the input data has not been sufficiently changed, it is reasonable that an update of the 2006 HI is not produced.

5.15 Fire and Security Systems

The Security and Fire Protection asset class includes systems for protection of transmission station facilities owned by Networks from the threats of fire, break-ins and vandalism. Networks owns a large number of transmission stations and buildings of different types and sizes and has installed some form of security and fire protection measures for protection of the various facilities at each of these locations. The security systems include additional measures ranging from conventional door control security systems to video surveillance facilities. The fire protection systems are primarily of two types: those associated with buildings and those associated with equipment.

Responsibility for Security Systems has been transferred from the Asset Management Group to the Real Estate Group and therefore were not subject to any further examination during the process audit. It is assumed that in further iterations of Asset Condition Assessment, a determination will be made as to the need to include this asset in the process.

5.15.1 2008 Health Index (HI) Results

As was the case in 2006, Networks has not produced a 2008 HI result for Fire Systems. The reason for this is that there is not sufficient information available for conducting a condition assessment.

5.15.2 Audit Findings

In such cases, it is in keeping with industry best practices to not conduct Asset Condition Assessments where asset sustainment is not considered to be a key investment driver.

6. Priority 3 Assets

Networks does not generally conduct an Asset Condition Assessment on the Priority 3 assets for either of the following reasons:

- The Priority 3 assets are of low dollar value in terms of ongoing investments and it is not cost effective or practical to collect the information required to conduct an ACA for these assets.
- When these assets fail, risks are considered to be relatively low and managed processes exist to quickly identify and repair or replace assets that have failed or are about to fail.

A brief description of the Priority 3 assets and their end-of-life factors are outlined in the following sections.

6.1 Protection System Monitoring

Protection system monitoring devices, including annunciators, digital fault recorders (DFRs) and sequence of events recorders (SERs) are widely deployed in transmission stations to provide detailed information on protection operation. The annunciators currently in use are solid-state electronic devices and the DFRs and SERs microprocessor and PC based. The capability and sophistication of these devices has been rapidly developing over the past 15 years. As a result of this rapid development, issues of obsolescence, functionality, spare parts and support, particularly related to compatibility with modern IT and communication systems, are the main end-of-life factors. Physical condition is not normally a significant issue.

Although most such devices are relatively young, significant replacement or upgrading of units is required to address the issues mentioned above. Many of the more recent devices are self-monitoring and provide an automatic indication of any loss of functionality. In addition to this, functionality checks would normally be carried out in conjunction with protection testing and inspection cycles.

6.2 Station Buses

Station buses generally consist of rigid aluminum tube, solid copper tube or flexible ACSR conductors supported by insulators. These are robust, static devices that are subject to visual inspection and thermal imaging during routine substation inspection. Any indication of damage, deterioration or localized heating leads to further tests and if necessary remedial action. It is possible that corrosion, particularly of the aluminum buses, could result in significant degradation that would require replacement, but, in general, these items outlive other substation equipment and would normally be replaced only as part of major substation refurbishment or development.

6.3 Station Surge Protection

Typically utilities limit their assessment of surge arresters to visual inspection and thermographic testing on an annual basis. Any additional assessment would normally only be undertaken where there was a specific concern related to increasing or unacceptable failure rate or a suspicion of problems with a particular type or batch of arresters.

Surge arrester replacement is normally a result of failure or obvious deterioration or damage detected by visual inspection. If an increasing failure rate is observed, removal and full electrical assessment and destructive examination may be initiated. This can identify/confirm a generic failure process and may lead to a decision to pre-emptively replace batches of arresters at particular locations or in some cases to the definition of a maximum lifetime for particular types.

6.4 AC/DC Service Equipment

These are the supply systems that provide power to the auxiliary equipment in the station such as protection and control equipment, fans, pumps, heating, lighting etc. Generally these systems are treated as part of the station infrastructure and are inspected and functionally tested during routine station inspections, typically on a quarterly basis. In most cases, any loss of supply would automatically trigger an alarm. In the UK and North America most of these systems are dual feed arrangement to minimize the impact of any local supply problems.

As with other infrastructure components, observation of significant damage or deterioration or any loss of functionality detected from inspection or as a result of alarms are addressed by appropriate remedial action. Consideration for more significant intervention, i.e. refurbishment or replacement of systems would normally only occur if the level of ongoing work was high or if a specific report indicated serious degradation. In most cases there would not be a systematic condition assessment carried out. Such a program would only be undertaken if the company became aware of widespread problems via the routine inspection and referral processes.

Other than in these circumstances, end-of-life would normally be related to other activity in the substation, i.e. major development, renovation or replacement of major plant and equipment.

6.5 HV/LV Station Structures

The majority of transmission station structures are reinforced concrete, galvanized steel and some wood poles. These are subject to inspection as part of routine substation inspection, typically on a three-month cycle.

Degradation resulting from corrosion of the reinforcing bars in the concrete can be a very destructive process. Visual inspection can only detect this at a relatively advanced state. Deformation or cracking of the concrete is indicative of an advanced corrosion situation. Treatment is difficult and expensive, involving the removal of the concrete and treatment of the reinforcing bars. In most cases when evidence of such damage is noted the initial reaction is to make short-term repairs. These are not usually very successful and ultimately more significant refurbishment or replacement will be required. End-of-life for these structures can be defined by the presence of widespread damage (cracking of concrete spalling). Other than this, concrete structures would normally only be replaced as part of major substation refurbishment usually initiated by the need for replacement or refurbishment of the major plant or by significant development of the system.

The degradation of steel structures is mainly as a result of corrosion. The rate of degradation is very dependent on the environmental conditions to which the structures are subjected. Industrial pollution is a particular problem for galvanized steel.

For wood poles or structures the issues of degradation and assessment are the same as those for wood poles on overhead lines, which is addressed in asset class 3.1.9. Methods of assessment and procedures for determining end-of-life based on remnant strength are well established.

6.6 Heating, Ventilation and Air Condition

Traditionally, the approach to the control of the indoor environment in transmission stations has been one of a combination of heating and active ventilation. In more recent times and driven by station operating cost considerations, dehumidification systems have become more widely employed, either as an alternative to heating systems, or in combination with them. Active ventilation systems are installed to provide a pre-requisite number of air changes per hour, particularly to ameliorate the build-up of potentially hazardous gases or vapours in the stations, arising from both normal and abnormal operation.

A variety of electric heating systems are employed and these can include radiant heaters, convectors, storage heaters or hot air blowers. Control of such heaters can be automatic, via time switches or thermostats or they can be manually switched by station personnel.

Active ventilation systems are predominantly based on through flow fan systems, with appropriate inlet and extraction points and ductwork. Station air inlet can be via the dehumidification systems, where these are employed. Ventilation systems tend to run continuously.

Dehumidification systems, installed to either reduce heating loads or to substitute for heating, can either be desiccant based or mechanical, refrigeration type units. Such dehumidification systems tend to operate continuously in combination with the ventilation systems.

Maintenance of heating and ventilation systems is essentially time based and relates to visual and electrical safety inspections, together with the cleaning of ventilation grills, filters and ductwork. Dehumidification equipment is maintained and serviced in accordance with the suppliers' maintenance schedules.

This asset may be more appropriately classified as a Real Estate Asset and therefore may no longer require Condition Assessment planning processes. It is assumed that in further iterations of Asset Condition Assessment, a determination will be made as to the need to include this asset in the process.

6.7 Boilers and Pressure Vessels

The inspection and maintenance of boilers, pressure vessels and their associated pressure relief devices is a highly regulated activity and subject to the relevant statutory codes, standards and legislative requirements in the particular operating territory. For example, equipment will usually be designed in accordance with ASME codes, for the North American market. The relevant statutory bodies and legislation will govern the installation, pressure testing, commissioning, ongoing maintenance and inspection of pressure systems. The legislation will usually define a "competent person" for the purposes of performing such activities; in practice such competent persons will usually be employed by specialist engineering insurance companies, who will underwrite the insurance of the pressure systems.

Marking, identification, a series of regular and defined inspection and maintenance schedules, all supported by a formalized system of documentation and record keeping all comprise the essential pre-requisites of any pressure system operational schedule. The detailed implementation of this will vary, according to the particular territory.

6.8 Oil Containment Systems

Over the past 20 years there has been growing awareness of the need to contain oil spillage from major plants. Growing awareness of environmental issues and tightening of legislation and increased penalties have forced electric utilities to address this issue in a more systematic and consistent fashion. Prior to this period, oil containment was a feature for major transformers but the application was varied and non-uniform. Over the past 20 years, the onus has been on ensuring that the oil containment systems for all major transformers are to a uniformly high and acceptable standard. It is understood that for many leading electric utilities, this program has been completed. Several cases are known where the local environmental authorities have audited oil containment systems.

Maintenance and ongoing management of oil containment systems is generally limited to visual inspection as part of routine substation inspection with functional checks on pumps used to remove rainwater. As part of the program to ensure that oil containment systems are to a uniformly high and acceptable standard, an overall assessment of their condition would have been undertaken resulting in upgrading or replacement as necessary. As most systems will therefore have been subject to relatively recent assessment, and if necessary upgrade/refurbishment, condition based end-of-life would not normally be considered a significant issue. However, if a major defect or damage was detected during routine inspection a full assessment, and if necessary appropriate repair or replacement, would be undertaken.

6.9 Oil and Fuel Handling Systems

Hydro One owns and maintains transformer oil handling, storage and processing assets in Central Maintenance Services (CMS). Equipment being maintained will have the oil removed via Hydro One tankers and sent to the oil farm at CMS for processing. This work is provided in house. New transformers are ordered including oil as part of the project acquisition.

Fuel storage is provided on-site for back-up generators. Fuel supply and associated supply facilities is contracted out through tender. Ongoing monitoring of the condition of oil and fuel handling assets is done through visual inspection. Maintenance is planned and accomplished through Hydro One's sustainment program.

6.10 Microwave Radio Systems

Microwave radio systems comprising towers, antennae, radio and multiplex equipment are a traditional means of providing effective communication between major substation sites and central control facilities. They are widely used by electricity companies although to some extent they are being replaced by fibre optic communication systems. Typically a maintenance/inspection program consists of a six-month interval inspection of the mast and antennae. This is both to check alignment and to detect damage and assess condition. Damage or degradation sufficient to warrant need for repair, i.e. painting or structural steel member replacement, would be noted and appropriate action taken. If more widespread degradation was reported, an overall assessment may be carried out. If it was decided that the system required significant work to maintain its functionality and safety, it is likely that it would be replaced by an alternative communication means. However, as indicated above, the main reason for replacing systems would be the introduction of fibre optic or other modern systems with greater functionality rather than asset sustainment drivers.

Radios and power supply equipment are also typically subject to six-month inspection, including battery checks, plus an annual functional performance check against specifications in accordance with the manufacturer's recommendations. Any minor problems would be dealt with by repair. Major problems would probably lead to a decision to replace with an alternative system.

6.11 Fibre Optics

In the 1990s many electric utilities installed fibre optic links using either a wrap around on the overhead groundwire of their transmission lines, an underslung self-supporting cable or fibres integral with the overhead groundwire. In some cases these were comprehensive systems linking all the main sites in the company, in others it was limited to a few experimental links.

There were some initial problems related to the installation processes causing damage to the fibres and some difficulties with splices, but subsequently we believe that the systems have proved reliable and effective.

The hardware on the lines is subject to inspection as part of the routine overhead line inspections. Other than that any remedial work is as a result of component failures.

6.12 Metallic Cable

These are used to provide telecommunication channels for protection and control purposes. Based on UK and North American company experience, these are subject to periodic insulation resistance tests and continuity checks. These measures enable degradation to be detected and monitored, with unacceptable levels stipulated in the maintenance manuals. In many cases metallic cables are self-monitored; any indication that they are outside specified limits would trigger an alarm.

The frequency and content of the periodic tests varies depending on the application of the pilot cable.

6.13 Site Entrance Protection Systems

This category consists of equipment required to protect metallic telecommunication cables (Networks and those of the telephone companies) that enter high voltage transmission facilities. The predominant equipment type is the neutralizing transformer; other types include isolating transformers and optical isolators. The most important functions performed by this equipment are safety of people and sustaining the operation of teleprotection systems during power system faults.

In the UK these assets are classified as part of the grounding system for stations. They are therefore managed and maintained as part of the grounding system. However, in other electric utilities they are considered to be part of the Protection and Control or the Communications asset groups.

A typical UK electric utility maintenance manual requires an annual check of the system against manufacturer's specifications. However, in North America, site entrance protection equipment is typically inspected and tested on a 1 to 3-year cycle to assess general condition and to ensure that ground connections have not been damaged or disturbed. Failures are typically due to lightning, accidental mechanical damage or wiring changes made by others.

6.14 Teleprotection Tone Equipment

This equipment is a system utilizing telecommunication systems (usually owned by telecommunication companies) to send blocking or tripping signals to remote locations for protection purposes. The equipment owned by the electric utility is typically limited to the 'send and receive' multi-channel electronic devices in the transmission stations. The system is quite widely used as an alternative to metallic (pilot) wires.

Timing tests are carried out during commissioning and on watchdog monitors once the system has been commissioned. Some utilities carry out regular 'timing' tests to check the performance and functionality of the system. As with other electronic equipment these are repaired or replaced when failures occur. As they are multi-channel devices there is often some built in redundancy allowing flexibility in managing failures.

6.15 Line Steel Structures

Steel structures are subject to regular (often annual) inspection either by foot or helicopter patrol. The intervals depend on numerous criteria such as location with respect to density of population, environmentally sensitive areas and areas prone to vandalism. The inspections (described as safety and security inspections) are intended to detect significant defects and initiate remedial action as part of a maintenance activity.

More detailed inspections, designed to assess the condition and identify the need for significant refurbishment are undertaken much less frequently. These detailed inspections include inspecting and measuring the tower steel and associated foundation for corrosion. These are either initiated by a system referral (following an increasing defect level in the safety and security inspection or other recognition of poor condition) or on a regular time cycle. In the UK and in North America typical electric utilities may use a 15-year cycle. These condition assessments normally involve a detailed, ground based, inspection and a sample (typically 10%) climbing inspection. In some cases more frequent climbing inspections are undertaken on structures related to critical spans (major road crossings, etc.).

The major expenditures that may be required with respect to the continued safe usage of the steel structures usually involve protective coatings of the structures to prevent structural strength deterioration due to corrosion and also to appease neighbours living in the vicinity of the structures. The frequency of painting varies with location, 12 to15-year cycles were used widely in the UK but in recent times budgetary pressures have led to many utilities attempting to introduce a more variable condition based approach. In North America most utilities do not routinely paint galvanized structures. Increasingly, assessment of the need for painting is being incorporated into the general inspection cycle. Timely painting (before corrosion takes hold) can extend structure life almost indefinitely. One North American electric utility reported significant costs associated with the removal of lead based paint from previously painted steel structures before repainting could be carried out.

Working Together SAFELY

In many countries with less corrosive atmospheres steel structure painting is not a normal activity. In such conditions, structures are reported to perform satisfactorily for more than 60 years before corrosion becomes an issue. If inspection reveals significant corrosion and loss of metal, replacement of damaged members can be economically undertaken. Decisions to replace a complete structure due to condition would normally only be undertaken if there was very widespread and extensive corrosion. Decisions to repair or replace are either based on operational/safety considerations related to climbability, or structural assessment revealing an unacceptable loss of mechanical capability.

As the above discussion indicates, degradation and ultimate end-of-life is generally as a result of corrosion. Where corrosion is successfully prevented structures have a long lifetime. Many structures in the UK and in North America are now in excess of 60 years old and some concern has been expressed that they may be subject to some other significant long-term degradation process, such as metal fatigue. A recent review/research related to worldwide practices did not reveal any other obvious end-of life issues.

The condition of structure foundations is normally only considered for lines greater than 50 years old at the time of a proposed major refurbishment. There is some (limited) experience of footing corrosion leading to tower failures. Assessment is either by sample excavations or by use of a simple electrochemical technique (polarization resistance) that can be applied economically as a screening test to all structures. Experience in the UK has indicated that, for Pre-World War II towers, corrosion of footings may be a significant issue, particular for grillage type foundations. More general assessment of foundation capability on old lines has been undertaken by several utilities in different countries usually in response to specific structure failures. Retrospective application of modern design packages to existing lines can reveal designs that are unacceptably close to their limit.

The assignment of Geographic Positioning System (GPS) coordinates is an ongoing process in utilities that are looking at means of minimizing maintenance efforts, such as describing a physical location to a contractor or utility crews concerned with corrective maintenance on facilities.

The use of optical and laser instrumentation to define points of attachment for the insulators and conductor clamps are being introduced to assist in engineering calculations for conductor sags and operating temperatures.

The resistance-to-ground of steel structures affects step-and-touch potentials and the practices among North American utilities varies from "no routine measurements of the resistance-to-ground" to "repeat measurements on cycles ranging between 5 and 10 years". Others perform such measurements when line performance deteriorates, when lightning performance is adversely affected and when there is a plan to install lightning arresters to improve the line performance.

The above discussion is based mostly on North American and UK experience (with some input from other European countries, Australia, New Zealand and the Middle East). For instance, the nature and frequency of inspection and condition assessment in the UK is largely dictated by the rate of atmospheric corrosion. It is likely that this will be slower in Ontario (except in localized areas of industrial pollution) and therefore the longevity of towers would be expected to be greater and the frequency of inspection/assessment lower.

6.16 Line Shieldwire and Hardware

Shield wires are either smaller ACSR conductors or galvanized steel stranded conductors mounted above the phase conductors and solidly connected to ground through the tower steel or ground conductor. In either case corrosion is likely to be the major degradation process. Galvanized steel stranded conductors will typically suffer corrosion at a faster rate than the ACSR phase conductors. This is particularly true for galvanized steel stranded conductors. As with phase conductors assessment of degradation can be determined by mechanical testing of samples. Small sections of shieldwire would be removed from in-service lines and sent to an independent lab for assessment. A turns and tensile test would be carried out similar to phase conductors. Such testing would normally be undertaken when a specific problem was indicated either from visual inspection or based on experience of the longevity of similar conductors in specific locations. It should be noted that the rate of degradation is very dependent on environmental conditions. For galvanized steel the level of industrial pollution is particularly significant.

Lines are generally subjected to frequent (annual) inspection either by helicopter or on foot. Although it is difficult to detect conductor or shield wire degradation from a visual inspection, severe damage resulting in bulging or broken strands would be detected. Such an observation would then initiate a more significant investigation of the condition of the shield wire. Additionally, more detailed inspections are often undertaken on a periodic basis, when the steel structures are inspected. This would involve some climbing inspection. These may also reveal obvious evidence of shieldwire degradation.

Shieldwires are sometimes replaced due to higher fault current levels being experienced as a result of capacity changes in the system. In some cases this higher fault current is only experienced near transmission stations and therefore the replacement of the shieldwires is limited to a short distance from the station to, say, one kilometre from the station.

The major areas of maintenance and safety concerns center around hardware attached to the shieldwires to prevent damage due to vibration and/or galloping, damage at the clamp points due to vibration and damage caused by direct hit lightning strokes. Weights from some older types of vibration dampers are reported to fall off due to failure of the connection between the weights and the supporting stranded wires that attach to the shieldwire.

Steel stranded shieldwires corrode over time and when replacements are needed, alumoweld or other types of materials are used that are not as prone to corrosion. Shieldwire construction that incorporates fibre optical strands are frequently used in new construction or replacement projects in order to provide communications facilities for the utility or opportunities for renting dark fibres to other parties. As the degradation process is very sensitive to local environmental conditions, the most appropriate interval for inspections and tests should be based on shieldwire performance in the specific local conditions.

6.17 Line Insulators and Hardware

Line insulators are predominantly manufactured from brittle materials (porcelain or glass) or composite material more commonly referred to as polymeric. As previously discussed in the section covering transmission station insulators, it is very difficult to detect degradation prior to failure for such materials. There are a number of long term degradation processes involving moisture ingress, corrosion and cement growth within the body of the insulator that result in the build up of internal stresses ultimately leading to failure. However prior to failure there will be very little physical indication of a problem.

Even detection of cracked (failed) insulators is not straightforward. Under dry conditions a cracked insulator will behave very much like an intact insulator. Many attempts have been made to develop an effective means of detecting cracked insulators using non-invasive techniques such as radio frequency measurements, infra-red cameras, etc.

Generally these have not been very successful. It is believed that the only reliable means of detecting cracked insulators is by very detailed visual examination, direct resistance measurements of individual sheds or the application of a voltage across the shed. The problem is more difficult with porcelain than glass insulators as these tend to fail by means of a hairline crack that is difficult to detect. Glass insulators tend to shatter. Generally insulator lives tend to be long and, in many cases, will be in excess of that of the conductor (particularly in the UK where conductor life tends to be relatively short). In these cases it would be normal practice to replace insulators at the time of reconductoring. However in some cases (often related to batch problems with an insulator manufacturer) the insulator lifetime has been shorter. If the number of insulator failures becomes significant some more detailed assessment or proactive replacement may be undertaken.

Another significant issue related to insulators is damage/degradation of the U-bolts fixing the insulator to the tower cross arm. These are subject to constant movement resulting in particularly rapid corrosion and wear. In many cases it has been found that this type of damage to the U-bolts is faster than any other degradation process on an overhead line, i.e. these are the components that require replacement first. Their condition then becomes the benchmark that fixes the periodicity of the inspection/refurbishment cycle. Wear and corrosion of U-bolts can be detected by visual inspection but because the most severely effected area is at the interface of two components, effective determination of severity can only be achieved by a very close visual examination during a climbing inspection or by the use of gyro-stabilized binoculars from a helicopter.

As lines are inspected by helicopter or on foot on an annual basis there are many opportunities to examine insulators, however, it is difficult to obtain meaningful information from such inspections on the insulator or the U-bolts unless the inspection is carried out from a hovering helicopter with the appropriate inspection tools. Climbing inspections provide a closer opportunity at higher per unit costs. Frequency and timing of climbing inspections will be related to the local experience of the critical degradation processes, which are very sensitive to environmental conditions.

Networks also carries out an in-situ insulator testing program on its porcelain based insulator population on lines where defects are evident from either visual inspections or past failures.

Appendix I

Transformer Assets

An overall Health Index formulation for transformers is shown in the table below. The maximum score for seven (7) tests (all CR1) is 60.

Condition Criteria	Weighting	Condition Ratings	Factors	Maximum Score
DGA	3	1,2,3 or 4	3,2,1,0	9
Standard Oil Tests	4	1,2,3 or 4	3,2,1,0	12
Furan	3	1,2,3 or 4	3,2,1,0	9
Doble	3	1,2,3 or 4	3,2,1,0	9
Tapchanger Condition	3	1,2,3 or 4	3,2,1,0	9
Bushing/Ancillary Condition	2	1,2,3 or 4	3,2,1,0	6
Transformer Condition	2	1,2,3 or 4	3,2,1,0	6

Transformer Health Index Formulation

Gas Insulated Switchgear (GIS) Assets

The condition parameters and tests, together with their weightings for each individual group of circuit breaker, disconnect/ground switches, bushings and buses, comprising a specific GIS asset class, are listed in the table below.

Condition Criteria	**Weighting**	**Multiplying Factors**				**Component Scores (max)**			
		3	**2**	**1**	**0**	**Circuit Breaker**	**Disc./Grd Switch**	**Bushings/ Interfaces**	**Bus**
Environmental/Mechanical	3					NA	NA	9	9
Diagnostic Testing	3					9	9	9	9
Switching/Fault Duty	3					9	NA	NA	NA
Hydraulic/Pneumatic	3					9	9	NA	NA
Mechanism	3					9	9	NA	NA
Electrical Components	2					6	6	6	6
SF6 Leakage	3					9	9	9	9
SF6 Moisture	3					9	9	9	9
Internal Inspection	3					9	9	9	9
Resistor Switch	3					9	NA	NA	NA
Failures	3					9	9	9	9
Weaknesses	3					9	9	9	9
TOTAL (max)						**96/**	**87/**	**69 /**	**69 /**

GIS Asset Class Health Index Condition Rating Template

The overall health (condition) index for a complete GIS asset class installed at a specific sub-station, consisting of the appropriate circuit breakers, switches, bushings and buses, is shown in the table below.

GIS Asset Class: Overall Health Index Formulation		
No.	**Condition Criteria**	**Weighting**
1	Circuit Breakers (normalized score)	60%
2	Disconnect Switch (normalized score)	15%
3	Bushings/Interfaces (normalized score)	10%
4	Bus (normalized score)	15%
5	**GIS Asset Class Score**	100%

Overall Health Index Formulation for each GIS Asset Class

Oil Circuit Breakers Assets

The tests and weightings for OCBs are listed in the table below. As shown, the maximum score for a complete set of tests, i.e. assuming CR1 result in all 11 tests is 116 for HV breakers and 96 for LV breakers. Consequently, the Health Index for any given breaker would be the sum of the individual test point scores, which is then divided by 112 (or 96), and finally multiplied by 100.

Condition Criteria	**Number of Condition States**	**Importance Weighting**	**Multiplying Factors**					***Maximum Possible Score***
			4	**3**	**2**	**1**	**0**	
Bushing Condition	4	3	CR1	CR2	-	CR3	CR4	*12*
Bushing Leaks	4	3	CR1	CR2	-	CR3	CR4	*12*
Tank and Mech. Box	4	3	CR1	CR2	-	CR3	CR4	*12*
Control and Mechanism Components	4	2	CR1	CR2	-	CR3	CR4	*8*
Oil Leaks	4	2	CR1	CR2	-	CR3	CR4	*8*
Overall CB Condition	5	3	CR1	CR2	CR3	CR4	CR5	*12*
Change in Operating Characteristics	2	3	CR1	CR2	-	-	CR4	*12*
Doble Test (Not for LV breakers)	3	3	CR1	CR2	-	CR3	CR4	*12*
Mechanism and Linkages	4	3	CR1	CR2	-	CR3	CR4	*12*
Foundation Condition	5	2	CR1	CR2	CR3	CR4	CR5	*8*
Air Compressor storage tank recharge time (Not for LV breakers)	*4*	*2*	*CR1*	*CR2*	-	*CR3*	*CR4*	*8*

OCB Health Index Tests

Air Blast Circuit Breaker Assets

The tests and weightings for ABCBs are listed in the table below. As shown, the maximum score for a complete set of tests, i.e. assuming CR1 result in all 16 tests is 147. Therefore, the Health Index for any given breaker would be the sum of the individual test products divided by 147, multiplied by 100.

Test Number	Test	Test Importance	Test Weighting	Max possible CR value	Max possible score
1	Air leakage	High	4	3	12
2	Air consumption	High	4	3	12
3	Internal inspection of porcelains for tracking/ deterioration	High	4	3	12
4	Condition of bushings and porcelains	High	4	3	12
5	Time/travel	High	4	3	12
6	Extent of corrosion	Low	1	3	3
7	Condition of blast valves	Medium	2	3	6
8	Condition of contacts	Medium	2	3	6
9	HP air moisture content	High	4	3	12
10	Current path resistance	Medium	2	3	6
11	Condition of external connections	Medium	2	3	6
12	Capacitor oil leaks	High	4	3	12
13	Capacitance measurements	Low	1	3	3
14	Condition of mechanism box	Low	1	3	3
15	Condition of auxiliary switches, fill valves and relays	High	4	3	12
16	Years since major refurbishment	High	6	3	18

Air Blast Circuit Breaker Health Index Tests

HV/LV Switch Assets

The tests and weightings for disconnect switches are listed in the table below. As shown, the maximum score for a complete set of tests, i.e. assuming CR1 result in all 10 tests is 87. Therefore, the Health Index for any given switch would be the sum of the individual test products, which is then divided by 87, and finally multiplied by 100.

Condition Criteria	Condition Ratings	Importance Weighting	Multiplying Factors	Maximum Possible Score
General Condition	CR1, 2,3,4	2	3,2,1,0	6
Current Carrying Parts	CR1 or 4	4	3 or 0	12
Condition of Insulators	CR1, 2,3,4	3	3,2,1,0	9
Condition of Mechanism and Linkages	CR1 or 4	4	3 or 0	12
Condition of Switch – Corrosion	CR1, 2,3,4	3	3,2,1,0	9
Condition of Control Circuit	CR1, 2,3,4	2	3,2,1,0	6
Switch Material	Cu or Al	2	3 or 0	6
Bearings Changed after 20 years?	Yes or No	3	3 or 0	9
Type of Insulator	1,2,3	2	0,2,3	6
Operational Concerns	Yes or No	4	0 or 3	12

Disconnect Switch Health Index Tests

Protection & Control Assets

The health index formulation for protection system components, are shown in the table below.

Component	Test	Measure	CRs	Factor	States	Weight	Max
Primary Relays	1.1	Visual Inspections	CR1,2,3	2,1,0	3	2.5	5
	2.1	Calibration Drift	CR1 or 2	1,0	2	5	5
	3.1	MTBF	1,2,3,4,5	4,3,2,1,0	5	12.5	50
	4.1	Residual Life	1,2,3,4,5	4,3,2,1,0	5	5	20
	5.1	Non-Discretionary Obsolescence	CR1 -15	1-0	15	10	10
	6.1	Discretionary Obsolescence	1,2,3,4,5	1-0	5	5	5
	7.1	In Service Performance	CR1 to 48	1-0	48	5	5
				Maximum Score 100 HI = Score/ Max Score			
Auxiliary Relays	1.2	Rating based on MTBF	CR1,2,3	10,0.5,1	3	7	70
	2.2	Silver Migration	CR1,2,3,4	3,2,1,0	4	10	30
				Maximum Score 100 HI = Score/ Max Score			
Misc. Hardware & Connecting Equipment	1.3	Panel	CR1,2,3,4	4,2,0.4,0	4	10	40
	2.3	Wiring	CR1,2,3,4,5	4,3,2,1,0	5	10	40
	3.3	Terminations	CR1,2,3	2,1,0	3	10	20
				Maximum Score 100 HI = Score/ Max Score			

Protection System Components Health Index Formulation

The combination of the individual system components; Primary Measuring Relays, Auxiliary Relays and Miscellaneous Hardware and Connecting Equipment; that make up the overall protection system can similarly be aggregated into an overall Health Index. Since the condition of Primary Relays are the predominate factor in the heath of the protection system, a 95% weighting is applied. The overall Heath Index for Protection Systems is shown in the table below.

Protection Systems – Overall System Health Index				
#	Component	Sub-System HI	Factor	Max Score
1	Primary Relays	0 - 100	0.95	95
2	Auxiliary Relays	0 - 100	0.03	3
3	Misc. Hardware & Connecting Equipment	0 - 100	0.02	2
			Max Score: 100 HI = 100*Score/Max Score	

Protection System Health Index Formulation

Phase Conductor Assets

The Health Index formulation for Phase Conductors are listed in the table below.

Test	Measure	CRs	Factor	States	Weight	Max
1	Tension Test (If CR3=>HI/2, if CR4=>HI=0)	CR1,CR3 or CR4	1,0.5,0	3	1	1
2	Turns to Failure Test	# of Turns	40-0	3	2	80
3	Surface Condition	CR1-CR5	4,3,2,1,0	5	10	40
3a*	% Remaining Zinc	>70, 40-70, 10-40, 0-10	20, 14, 7, 0	4	1	20
3b*	Extent of Rust	CR1-CR5	10, 8, 5, 2, 0	5	1	10
3c*	Severity of Rust	CR1-CR5	10, 8, 5, 2, 0	5	1	10
			Max Score: 120 HI: 100*Score/MaxScore			

*Use Tests results from Measures 3a-c if available, otherwise use Surface Condition.

Phase Conductor Health Index Tests

Wood Pole Structure Assets

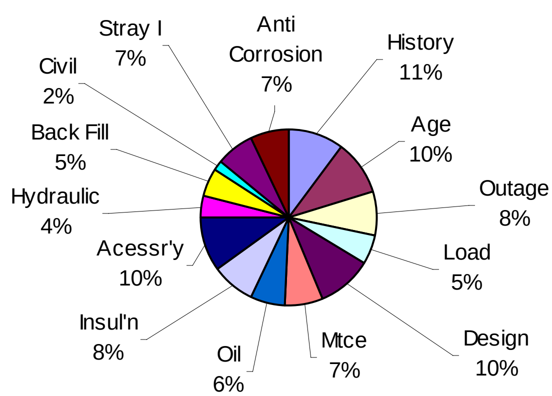
This Health Index formulation for wood pole structure assets is summarized in the table below.

Test No	Measure	CRs	Factor	States	Weight	Max
1	Woodpecker Damage/Pole Top Rot/Pole Surface Condition (HI/2 if "field" EOL)	CR1,2,3,4 or 5	4,3,2,1,0	5	5	20
2	Cross-Arm Condition	CR1,2,3,4 or 5	4,3,2,1,0	5	5	20
3	Pole Strength or the average of all Poles in the Structure (HI/2 if R_Strength < 65%)	0-100%	100-0	100	0.6	60
			Max Score: 100 HI: 100* Score / Max Score			

Summary of Wood Pole Structure Health Index Formulation

Underground Cable Assets

Fourteen (14) condition criteria have been established and condition ratings assigned as indicated in the figure and table below.



Pie Chart of Measures and Weights Used in HI Formulation

Test No	Measure	CRs	Factor	States	Weight	*Max*
1	Electrical History	CR1,4,7 or 10	10,7,4,1	4	10	*100*
2	Age	CR1 to 10	10 to 1	10	10	*100*
3	Outage Record	CR1-4,6,8 or 10	10,8,6,4-1	7	8	*80*
4	Loading History	CR2, 5 or 10	10, 5, 2	3	5	*50*
5	System Cable	CR1, 5 or 10	10, 5, 1	3	10	*100*
6	System Maintenance	CR1,4,7 or 10	10,7,4,1	4	7	*70*
7	Fluid Testing	CR1,5 or 10	10,5,1	3	6	*60*
8	Insulation Condition	CR1,4,6,8 or 10	10,8,6,4,1	5	8	*80*
9	Accessory Condition	CR1,3,5 or 10	10,5,3,1	4	10	*100*
10	Hydraulic History	CR1,4,6,8 or 10	10,8,6,4,1	5	4	*40*
11	Installation	CR1,4,8,9 or 10	10,9,8,4,1	5	5	*50*
12	Civil Structure	CR1,3 or 5	5,3,1	3	3	*15*
13	Stray Current	CR1,5,8 or 10	10,8,5,1	4	7	*70*
14	Corrosion	CR1,5,or 10	10,5,1	3	7	*70*
				Max Score: *HI: 100*Score/Max Score*		*985*

Condition Criteria and Weightings for Transmission Underground Cable Health Index

Transmission ROW Assets

The condition assessment criteria are assessed for each section of the line and an average for all sections is taken as representing the condition (for each criterion) for the line. These are then combined, as shown below, to derive an overall Health Index.

Condition Criteria	Weighting	Condition Ratings (1)	Factors	Maximum Score
Tree Clearance	1	CR1, CR2 or CR3	3,2,1	3
Tree Density	1	CR1 – CR4	3,2,1,0	3
Average Brush Height	1	CR1, CR2 or CR3	2,1,0	2
Average Brush Density	1	CR1 – CR4	3,2,1,0	3
Radial Line?	1	Y or N	3,0	3
Danger Trees	1	CR1, CR2 or CR3	3,2,1	3
Condition Total				17
Condition	75/17	0-17	N/A	75
Outages	25/4	0-4	N/A	25

Health Index Formulation for Transmission ROW

Appendix II

High-Pressure Air System Assets

Health Indices have been developed for the individual components and for the overall system are shown in the following tables.

Compressors						
#	Test or Inspection	Weighting	Answer	Condition Ratings	Factors	Max Score
1	Audible: Pump & Compressor Motor	1	CR1,CR4	1,4	3,0	3
2	Audible: Check for Leaks	2	CR1,CR3,CR4	1,3,4	3,1,0	6
3	Pump up Time Check	2	TP,TF	1,4	3,0	6
4	Compressor Run Hours	2	CR1,CR4	1,4	3,0	6
5	Check Indicators and Gauges	1	CR1,CR3,CR4	1,3,4	3,1,0	3
6	Coolant Leaks **	2	CR1,CR3,CR4	1,3,4	3,1,0	6
7	Gasket, Valves, Fittings and Welds	2	CR1,CR3,CR4	1,3,4	3,1,0	6
8	Oil Leaks	2	CR1,CR3,CR4	1,3,4	3,1,0	6
9	General Condition	2	CR1,CR4	1,4	3,0	6
10	Suction and Delivery Valves	2	CR1,CR4	1,4	3,0	6
11	Operation of Air Dampers	2	CR1,CR4	1,4	3,0	6
12	Operation of Dump Valves	2	CR1,CR4	1,4	3,0	6
13	Check Pressure and Temperature Switches	2	TP,TF	1,4	3,0	6
14	Cooling System: Check Fan/Pump Operation **	1	CR1,CR4	1,4	3,0	3
15	Inspect Intercooler/ Aftercooler Tubes	2	CR1,CR3,CR4	1,3,4	3,1,0	6
16	Dismantle Compressor and Check *	4	CR1,CR3,CR4	1,3,4	3,1,0	12
	*If CR4 then H1/2 ** Not for Air Cooled Compressors			Max Score: HI:		93 100* Score/Max

Health Index Formulation for Compressors

Dryers and Pressure Holding Valves						
#	**Test or Inspection**	**Weighting**	**Answer**	**Condition Ratings**	**Factors**	**Max Score**
1	Dryer & Valves – Audio Check for Leaks	2	CR1 or 4	1,4	3,0	6
2	Dryer & Valves – Hygrometer Calibration	1	TP or TF	1,4	3,0	3
3	Dryer & Valves – Pre and Afterfilter Condition	1	CR1 or 4	1,4	3,0	3
4	Dryer & Valves – Inspect Charcoal	1	CR1 or 4	1,4	3,0	3
5	Dryer & Valves – Dessicant in Dryer Tower	2	CR1 or 4	1,4	3,0	6
6	Dryer & Valves – Inspect Switching Valve	1	TP or TF	1,4	3,0	3
7	Dryer & Valves – Hygrometer Reading	4	TP or TF	1,4	3,0	12
8	Dryer & Valves – Test & Certify Safety Relief Valve	4	TP or TF	1,4	3,0	12
				Max Score:		48
				HI:		100* Score/Max

Health Index Formulation for Dryers and Pressure Holding Valves

Air Receivers and Relief Valves						
#	**Test or Inspection**	**Weighting**	**Answer**	**Condition Ratings**	**Factors**	**Max Score**
1	Receivers & Valves – Presence of Surface Rust	1	CR1,2,3 or 4	1,2,3,4	3,2,1,0	3
2	Receivers & Valves – Presence of Broken or Loose Supports	1	No or Yes	1,4	3,0	3
3	Receivers & Valves – Condition of Concrete Foundation	1	CR1,2,3,4 or 5	1,2,3,3,4	3,2,1,0	3
4	Receivers & Valves – Number of Audible Leaks	2	0,1-5 or >5	1,3,4	3,1,0	6
5	Receivers & Valves – Concern about Air Receiver	2	No or Yes	1,4	3,0	6
6	Receivers & Valves – Concern about Relief Valves	3	No or Yes	1,4	3,0	9
				Max Score:		30
				HI:		100* Score/Max

Health Index Formulation for Air Receivers and Relief Valves

Systems, Pipes and Valves						
#	**Test or Inspection**	**Weighting**	**Answer**	**Condition Ratings**	**Factors**	**Max Score**
1	Pipes & Valves – Motorized Ball Valves Operate as Required	1	Yes or No	1,4	3,0	3
2	Pipes & Valves – Condition of Pipe Footings	1	No or Yes	1,4	3,0	3
3	Pipes & Valves – Presence of Broken Pipe Supports	1	No or Yes	1,4	3,0	3
4	Pipes & Valves – Number of Audible Leaks	2	0,1-5 or >5	1,3,4	3,1,0	6
5	Pipes & Valves – Concern about Piping	2	No or Yes	1,4	3,0	6
6	Pipes & Valves – Concern about Control System	1	No or Yes	1,4	3,0	3
7	Pipes & Valves – Concern about Motor Starter Condition	1	No or Yes	1,4	3,0	3
8	Pipes & Valves – Concern about Power Cable & Wiring	1	No or Yes	1,4	3,0	3
9	Pipes & Valves – Concern about Motor Control Centre	1	No or Yes	1,4	3,0	3
10	Pipes & Valves – Air at Circuit Breakers meets Req. Dew Point	2	Yes or No	1,4	3,0	6
11	Pipes & Valves – Change in Freq. of System Purged	2	Lower-Same/Higher	1,1,4	3,0	6
12	Pipes & Valves – Concern about Health and Safety	2	No or Yes	1,4	3,0	6
13	Pipes & Valves – Concern about Overall System	3	No or Yes	1,4	3,0	9
14	Pipes & Valves – Number of Risk Type Valves (Clayton-Marks and Chromatic	4	0,1-10, 11-50, >50	1,2,3,4	3,2,1,0	14
				Max Score:		74
				HI:		100* Score/Max

Health Index Formulation for Systems, Pipes and Valves

HP Air System – Overall System Health Index				
#	**Component**	**Sub-System HI**	**Factor**	**Max Score**
1	Compressors	0 -100	0.3	30
2	Dryers and Pressure Holding Valves	0 – 100	0.3	30
3	System, Pipes and Valves	0 – 100	0.2	20
4	Air Receivers and Relief Valves	0 – 100	0.2	20
		Max Score:		100
		HI:		Sum of Scores

An Overall System Health Index for HPA Pressure Systems

SF_6 Circuit Breaker Assets

The Health Index formulation for SF_6 circuit breakers is shown in the following table.

SF_6 Circuit Breakers Health Index Formulation					
#	**Condition Criteria**	**Weighting**	**Condition Ratings**	**Factors**	**Max Score**
1	Compressor Condition Test Audible – Listen to Pump/Compressor/Motor	2	1,2,3,4	3,2,1,0	6
2	General Condition, Pick Worst of: A. Visual Inspection (General Condition) B. Visual Checks – Oil Leaks (AMHA)	2	1,2,3,4	3,2,1,0	6
3	Amount of SF_6 Gas Added	3	1,4	3,0	9
4	SF_6 Gas Moisture Content Test	3	1,4	3,0	9
5	Visual Check: Corrosion	2	1,2,3,4	3,2,1,0	6
6	Internal Inspection of Porcelain for Tracking/Deterioration	2	1,2,3,4	3,2,1,0	6
7	Auxiliary Switches and Contactors Check Condition	2	1,4	3,0	6
8	Mechanism, Pick Worst of: A. Check Mechanism/Linkages for Correct Operation B. Check Mechanism to Specification	3	1,4	3,0	9
9	Trip Test, Pick Worst of: A. Low voltage close test (75% of operating voltage) B. Low voltage trip test, T1&T2 (75% of operating voltage)	3	1,4	3,0	9
10	Number of Breaker Operations, Counter Reading	3	1,2,3,4	3,2,1,0	9
11	Inspect Contacts	3	1,2,3,4	3,2,1,0	9
12	Inspect Nozzle	3	1,2,3,4	3,2,1,0	9
13	Capacitance Measurement Test	2	1,4	3,0	6
14	Inspect Motor Commutator and Brushes	2	1,4	3,0	6
15	Coil Signature Test	3	1,4	3,0	9
16	Micro Ohm Test	3	1,4	3,0	9
17	Time Travel Test	3	1,4	3,0	9
			Max Score:		132
			HI:		100* Score/Max

Health Index Formulation for SF_6 Circuit Breakers

Metalclad Switchgear Assets

The Health Index formulation for a metalclad circuit breaker, for a metalclad bus, for a metalclad switch, and an overall Health Index formulation for a metalclad switchgear unit is the following tables.

Metal Clad: Circuit Breaker Health Index Formulation					
#	**Condition Criteria**	**Weighting**	**Condition Ratings**	**Factors**	**Max Score**
1	Audible (Corona Discharge)	3	1,2,3,4	3,2,1,0	9
2	Auxiliary Switches and Contactors	2	1,4	3,0	6
3	Insulation Condition	2	1,2,3,4	3,2,1,0	6
4	Mechanism Restrictions	3	1,4	3,0	9
5	Mechanism to Specifications	3	1,4	3,0	9
6	Trip Test, Pick Worst of: A. Low voltage close test (75% of operating voltage) B. Low voltage trip test, T1&T2 (75% of operating voltage)	3	1,4	3,0	9
7	Coil Signature	3	1,4	3,0	9
8	Rack in Mechanism	3	1,4	3,0	9
9	Manual Operation	2	1,2,3,4	3,2,1,0	6
10	Time/Travel Test	3	1,4	3,0	9
11	Micro-Ohm Test	3	1,4	3,0	9
12	Contact Wear	3	1,2,3,4	3,2,1,0	9
13	Nozzle Wear	3	1,2,3,4	3,2,1,0	9
14	Number of Breaker Operations, Counter Reading	3	1,2,3,4	3,2,1,0	9
15	Motor Commutator and Brushes*	2	1,4	3,0	6
16	Arc Chutes**	2	1,4	3,0	6
17	SF_6 Pressure and Temperature (amount of gas added) ***	3	1,4	3,0	9
18	Gasket, Valves, Fittings, Welds****	3	1,2,3,4	3,2,1,0	9
19	Dielectric Oil Test****	3	1,4	3,0	9
20	Vacuum Integrity*****	3	1,4	3,0	9
	* Note for Oil Breakers ** Only for Air-Magnetic Breakers *** Only for SF_6 Breakers **** Only for Oil Breakers ***** Only for Vacuum Breakers		Max Score: HI:		129-135 100* Score/Max

Health Index Formulation for Metalclad Circuit Breakers

Metal Clad: Bus Health Index Formulation					
#	Condition Criteria	Weighting	Condition Ratings	Factors	Max Score
1	Insulation Condition	2	1-4	3-0	6
2	Rack in Mechanism	3	1-4	3-0	9
3	Micro-Ohm Test	4	1-4	3-0	12
4	Air Cooling	2	1-4	3-0	6
5	Alignm. and Penetr. of Disconnects	2	1-4	3-0	6
6	Connections, Torque	2	1-4	3-0	6
7	Hi Pot Test	3	1,4	3,0	9
8	Megger Test	3	1,4	3,0	9
9	Partial Discharge Test	3	1,4	3,0	9
10	Corrosion	3	1-4	3-0	9
			Max Score:		81
			HI:		100* Score/Max

Health Index Formulation for Metalclad Buses

Metal Clad: Disconnect Switch Health Index Formulation					
#	Condition Criteria	Weighting	Condition Ratings	Factors	Max Score
1	Check Mechanism/Linkages for Correct Operation	3	1,4	3,0	9
2	Check Switch Condition by Manual Operation	2	1,4	3,0	6
3	Current Carrying Parts	3	1,2,4	3,2,0	9
4	Switch Contact Alignment	3	1,4	3,0	9
5	General Condition	3	1-4	3-0	9
			Max Score:		42
			HI:		100* Score/Max

Health Index Formulation for Metalclad Disconnecting Switches

Metal Clad: Overall Health Index Formulation		
#	Condition Criteria	Weighting
1	Breakers (normalized score for all)	70%
2	Bus (normalized score for bus)	20%
3	Disconnect Switches (normalized score for all)	10%
		Max Score: 100 HI: Sum of Scores

Overall Health Index Formulation for Metalclad Switchgear

Power Line Carrier Assets

The Health Index formulation for Power Line Carrier (PLC) assets is shown in the following table.

Condition Criteria	Weighting	Condition Ratings	Factors	Max Score
Physical Condition	3	1,2,3 or 4	3,2,1,0,	9
Ground Connection	3	1,2,3 or 4	3,2,1,0	9
Periodic Adjustment/Calibration	2	No or Yes	3,0	6
Increased Maintenance	3	1,2 or 3	3,1,0	9
DC Wiring Good Condition **(Indoor Only)**	2	Yes or No	3,0	6
Pass Specific Inspection Test?	3	Yes or No	3,0	9

Health Index formulation for PLC

High Voltage Instrument Transformer Assets

A separate Health Index is proposed for Oil CTs, Oil CVTs, Oil PTs and SF_6 CTs. These are shown in the following tables.

Health Index for Oil Filled CTs

Test	Measure	CRs	Factors	States	Weight	Max
1	Oil Levels	CR1,3 or 4	3,1,0	3	6	18
2	Bushing and Porcelain	CR1,2,3 or 4	3,2,1,0	4	2	6
3	Corrosion/Damage	CR1,2,3 or 4	3,2,1,0	4	2	6
4	External HV Connection	CR1 or 4	3,0	2	2	6
5	External Contamination of Bushing/Insulator	CR1,2,3 or 4	3,2,1,0	4	4	12
6	Fittings and Welds, Oil Leaks	CR1,2,3 or 4	3,2,1,0	4	6	18
7	Conduit, Wiring, etc.	CR1,2,3 or 4	3,2,1,0	4	2	6
8	Structure, Footings	CR1,2,3 or 4	3,2,1,0	4	2	6
9	Ground Connection	CR1 or 4	3,0	2	2	6
10	PF and Capacitance (if CR4 = > HI/2)	CR1,2,3 or 4	3,2,1,0	4	3	9
11	DGA (if CR4 = > HI/2)	CR1,2,3 or 4	3,2,1,0	4	3	9
12	Moisture (if CR4 = > HI/2)	CR1,2,3 or 4	3,2,1,0	4	3	9
			Max Score: 111 HI = 100 * Score/Max Score			

Health Index Formulation – Oil filled CT

Maximum score with all 12-condition criteria is 111. Health Index is actual score/111 X 100. Minimum possible score for valid Health Index is 78 (70%).

Health Index for Oil Filled CVTs

Test	Measure	CRs	Factors	States	Weight	Max
1	Bushing and Porcelain	CR1,2,3 or 4	3,2,1,0	4	3	9
2	Corrosion/Damage	CR1,2,3 or 4	3,2,1,0	4	3	9
3	External HV Connection	CR1 or 4	3,0	2	2	6
4	External Contamination of Bushing/Insulator	CR1,2,3 or 4	3,2,1,0	4	4	12
5	Fittings and Welds, Oil Leaks	CR1,2,3 or 4	3,2,1,0	4	6	18
6	Conduit, Wiring, etc.	CR1,2,3 or 4	3,2,1,0	4	2	6
7	Structure, Footings	CR1,2,3 or 4	3,2,1,0	4	2	6
8	Ground Connection	CR1 or 4	3,0	2	2	6
			Max Score: 72 HI = 100 * Score/Max Score			

Health Index Formulation – Oil filled CVT

Maximum score with all 8-condition criteria is 72. Health Index is actual score/72 X 100. Minimum possible score for valid Health Index is 50 (70%).

Health Index for Oil Filled PTs

Test	Measure	CRs	Factors	States	Weight	Max
1	Oil Levels	CR1, 3 or 4	3,1,0	3	6	18
2	Bushing and Porcelain	CR1,2,3 or 4	3,2,1,0	4	2	6
3	Corrosion/Damage	CR1,2,3 or 4	3,2,1,0	4	2	6
4	External HV Connection	CR1 or 4	3,0	2	2	6
5	External Contamination of Bushing/Insulator	CR1,2,3 or 4	3,2,1,0	4	4	12
6	Fittings and Welds, Oil Leaks	CR1,2,3 or 4	3,2,1,0	4	6	18
7	Conduit, Wiring etc	CR1,2,3 or 4	3,2,1,0	4	2	6
8	Structure, Footings	CR1,2,3 or 4	3,2,1,0	4	2	6
9	Ground Connection	CR1 or 4	3,0	2	2	6
10	PF and Capacitance (if CR4 = > HI/2)	CR1,2,3 or 4	3,2,1,0	4	3	9
11	DGA (if CR4 = > HI/2)	CR1,2,3 or 4	3,2,1,0	4	3	9
			Max Score: 102 HI = 100 * Score/Max Score			

Health Index Formulation – Oil Filled PT

Maximum score with all 11-condition criteria is 96. Health Index is actual score/102 X 100. Minimum possible score for valid Health Index is 71 (70%).

Health Index for SF6 Filled CTs

Test	Measure	CRs	Factors	States	Weight	Max
1	SF_6 Pressure	CR1 or 4	3,0	2	4	12
2	Bushing and Porcelain	CR1,2,3 or 4	3,2,1,0	4	3	9
3	Corrosion/Damage	CR1,2,3 or 4	3,2,1,0	4	2	6
4	External HV Connection	CR1 or 4	3,0	2	2	6
5	External Contamination of Bushing/Insulator	CR1,2,3 or 4	3,2,1,0	4	2	6
6	SF_6 Moisture	CR1 or 4	3,0	2	4	12
7	Conduit, Wiring, etc	CR1,2,3 or 4	3,2,1,0	4	2	6
8	Structure, Footings	CR1,2,3 or 4	3,2,1,0	4	2	6
9	Ground Connection	CR1 or 4	3,0	2	2	6
10	PF and Capacitance	CR1,2,3 or 4	3,2,1,0	4	4	12
11	SF_6 Leak Rate	CR1 or 4	3,0	2	6	18
			Max Score: 99 HI = 100 * Score/Max Score			

Health Index Formulation – SF_6 Filled CT

Maximum possible score with all 11 criteria is 99. Health Index is actual score/99 (or possible score with available information) X 100. Minimum possible score for valid Health Index is 69 (70%).

Battery and Charger Assets

The Health Index formulation for Battery and Charger assets is shown in the following tables.

Test	Measure (Test or Inspection)	CRs	Factors	States	Weight	Max
1.1	Battery Cells and Trays/Racks	CR1 or CR4	3,0	2	1	3
2.1	Electrolyte Level	CR1,CR3 or CR4	3,1,0	3	1	3
3.1	Battery Plate Condition (if CR4 = > HI2)	CR1,CR3,CR4	3,1,0	3	2	6
4.1	Impedance Test (if CR4 = > HI2)	CR1,2,3,4	3,2,1,0	4	2	6
5.1	Specific Gravity	CR1,CR3 or CR4	3,1,0	3	2	6
6.1	Voltage Test (if CR4 = > HI/2)	CR1 or CR4	3,0	2	2	6
7.1	Loose or Damaged Connections	CR1 or CR4	3,0	2	1	3
8.1	Straps/Cables Damage	CR1 or CR4	3,0	2	1	3
9.1	Equalize Charge	CR1 or CR4	3,0	2	1	3
10.1	Battery Load Test (if CR3 = > HI/2, if CR4 = > HI/4)	CR1,2,3,4	3,2,1,0	4	1	3
11.1	Condition of Jar Cover Seals	CR1 or CR4	3,0	2	1	3

Note:
Step 1. If CR4 in Tests 3.1 or 4.1, or if CR4 in Test 6.1, multiply initial HI by factor of 0.5.
Step 2. If CR3 in Test 10.1, apply a multiplication factor of 0.5 to HI calculated in Step 1, if CR4 in Test 10.1, apply a multiplication factor of 0.25 to HI calculated in Step 1

Health Index Formulation for Batteries

The Health Index has been formulated for chargers, as follows:

Test	Measure	CRs	Factors	States	Weight	Max
1.2	Calibration Check	CR1/TP,2,3,4/TF	3,2,1,0	4	1	3
2.2	Check Charger Voltmeter and Ammeter Readings	CR1/TP,2,3,4/TF	3,2,1,0	4	1	3
3.2	Check DC Float and Equalize Voltage	CR1/TP,2,3,4/TF	3,2,1,0	4	1	3
4.2	DC Output Ripple Test	CR1/TP,2,3,4/TF	3,2,1,0	4	1	3
5.2	Function Test – Alarm	CR1/TP,2,3,4/TF	3,2,1,0	4	1	3
6.2	Function Test	CR1/TP,2,3,4/TF	3,2,1,0	4	1	3
7.2	Inspect Current Carrying Parts	CR1/TP,2,3,4/TF	3,2,1,0	4	1	3

Health Index Formulation for Chargers

Capacitor Bank Assets

The Health Index formulation for a capacitor bank is shown in the following table.

Tx Capacitors Health Index Formulation						
#	**Condition Criteria**	**Weighting**	**Answer**	**Condition Ratings**	**Factors**	**Max Score**
1	General Condition	3	CR1,CR2,CR3,CR4	1,2,3,4	3,2,1,0	9
2	Condition of Capacitor Units	2	CR1,CR2,CR3,CR4	1,2,3,4	3,2,1,0	6
3	Type of Fuse	1	Other E, CL	1,2,4	3,2,0	3
4	Condition of Fuse	1	CR1,CR2,CR3,CR4	1,2,3,4	3,2,1,0	3
5	Type of Insulator	1	3,2,1	1,2,4	3,2,0	3
6	Condition of Insulator	1	CR1,CR2,CR3,CR4	1,2,3,4	3,2,1,0	3
7	Condition of Frame	1	CR1,CR2,CR3,CR4	1,2,3,4	3,2,1,0	3
8	Condition of Reactor	1	CR1,CR2,CR3,CR4	1,2,3,4	3,2,1,0	3
9	Suspected Defects	1	Other, Edisol or Dielektrol	1,4	3,2,1,0	3
	S			Max Score:		36
				HI:		100* Score/Max

Health Index Formulation for Capacitors

Drainage and Geotechnical Systems Assets

The Health Index formulation for transmission station drainage and geotechnical systems is shown in the following table.

Drainage and Geotechnical Health Index Formulation					
#	Condition Criteria	Weighting	Condition Ratings	Factors	Max Score
1	Drainage Inspections	6	A,B,C,D	3,2,1,0	18
2	Field Staff Reports on Draining and Geotechnical	2	No Issues/Some Issues	3,0	6
3	Road Condition	2	Good/Fair, Some Problems, More Serious Problems	3,1,0	6
4	Yard Condition	2	Good/Fair, Some Problems, More Serious Problems	3,1,0	6
5	Footings Condition	2	Good/Fair, Some Problems, More Serious Problems	3,1,0	6
6	Fence Condition	1	Good/Fair, Some Problems, More Serious Problems	3,1,0	3
7	Spill Containment Condition	1	Good/Fair, Some Problems, More Serious Problems	3,1,0	3
	S		Max Score:		48
			HI:		100* Score/Max

Health Index Formulation for Drainage and Geotechnical Systems

1235 North Service Road West
Oakville, Ontario, Canada L6M 2W2
Tel 905 469 3400 ◆ Fax 905 469 3404