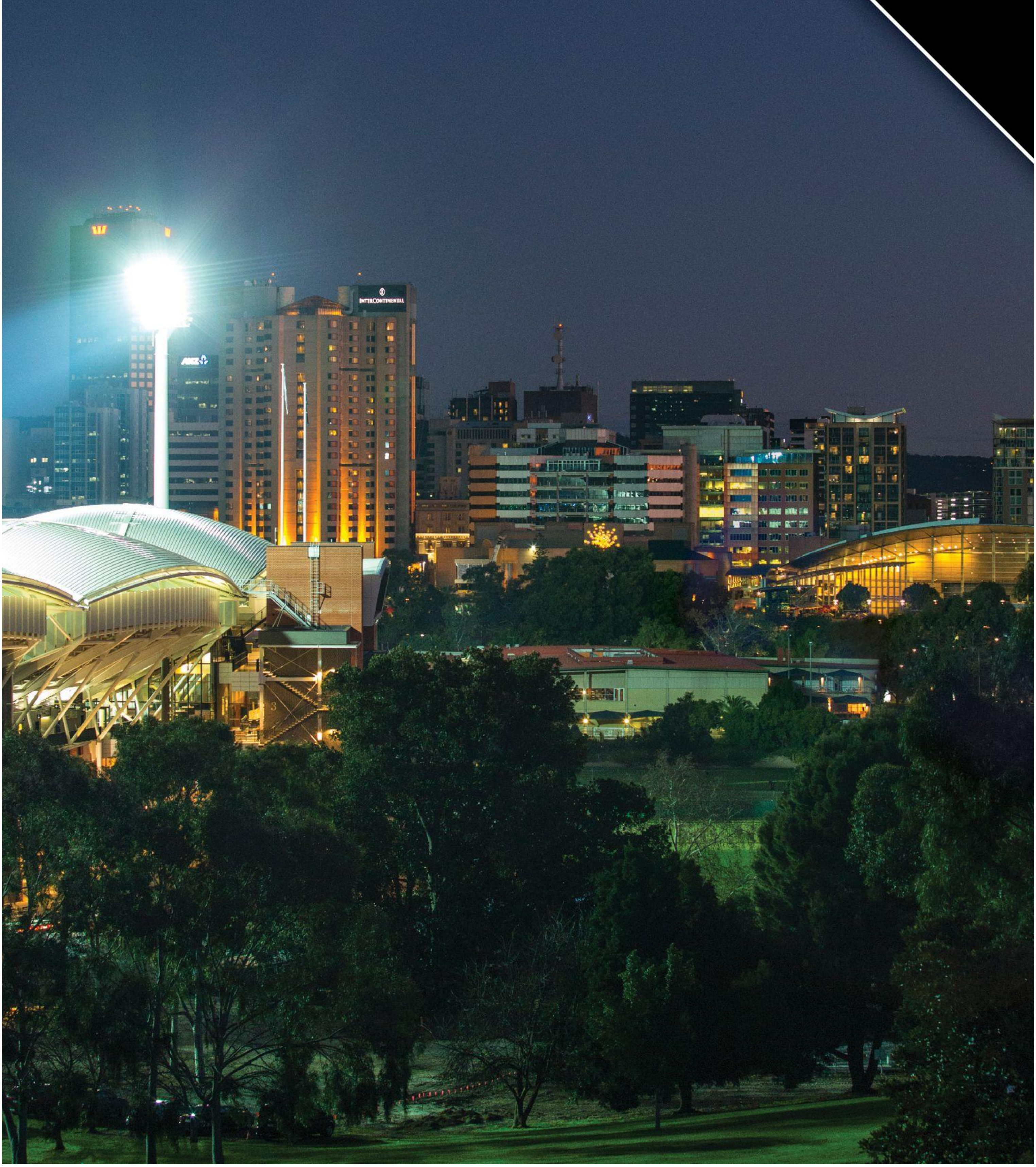
Attachment 20.74

SA Power Networks: CBRM Justification

October 2014



CBRM Justification

Sources of Inputs

24 October 2014

SA Power Networks

www.sapowernetworks.com.au

Contents

1. SCOPE

This document provides explanation of and justification for the CBRM models used to determine the replacement CAPEX for the 2015-2020 regulatory control period for Poles, Overhead Conductors, Substation Power Transformers and Substation Circuit Breakers.

The design decisions made for each model are explained, as well as how the settings have been assigned such that the models align with SA Power Networks' current operations.

Determination of the failure rates and consequence levels are also explained, in particular the sources of data used to determine the statistics and the assumptions made where information was unavailable or inadequate. The consequence values are expressed in $2013.

2. INTRODUCTION

In 2011 EA Technology was engaged to develop Condition Based Risk Management (CBRM) Models for Poles, Overhead Conductors, Substation Power Transformers and Substation Circuit Breakers. The models utilise information, knowledge, engineering experience and judgement for the identification and justification of targeted asset replacement.

CBRM determines the level of risk a particular asset exposes SA Power Networks to through the following steps:

1. **Define Asset Condition:** The condition of an asset is measured on a scale from 0.5 to 10, where 0.5 represents a brand new asset; this is defined as the Health Index (HI). Typically an asset with a HI beyond 7 has serious deterioration and advanced degradation processes now at the point where they cause failure. Determination of the HI is made by factoring age, location, duty, and measured condition points.
2. **Link Condition to Performance:** If an asset has a HI less than 4, its Probability of Failure (PoF) distribution is random. When the HI shows further degradation, a wear out curve is used to measure PoF against HI. Each asset class has unique events; every event is assigned a PoF model, which uses an individual failure rate based on network observations.
3. **Determine the Consequence of Failure:** The consequence of failure is divided into the following categories:
    - CAPEX: The Capital Expenditure required to remediate an event;
    - OPEX: The Operational Expenditure required to remediate an event;
    - Safety: The cost incurred due to death/injury to individual(s) as a result of an event;
    - Environment: The cost of environmental cleanup/penalties as a result of an event;
    - Reliability: Financial penalties imposed if an event causes an outage.

    The consequences are individually determined for all of the events associated with the asset using criteria such as location, number of customers, load profiles, SCONRRR category, and type/model.
4. **Determine Risk:** Risk is measured in financial units, it is determined by combining the PoF, consequence and criticality for every event. Criticality defines the significance of a fault/failure for an individual asset, and is determined for each of the categories listed in item 3.

CBRM also models non-condition events, which are independent of HI. These events are assigned to every asset and use a random failure based PoF model. An example of a non-condition event is third party damage from a car hit pole incident.

By forecasting every asset's condition, CBRM calculates the total risk, total number of failures and HI profile for an asset group based on the following investment scenarios:

1. **Do Nothing:** do not replace any assets in the group;
2. **Targeted Replacement:** nominate when assets are replaced/refurbished;
3. **Replace a fixed percentage of assets every year:** nominate the percentage of assets to be replaced every year and choose the priority to be HI, total risk or delta risk.

3. LIST OF ACRONYMS

Acronym	Definition
AER	Australian Energy Regulator
CAPEX	Capital Expenditure
CB	Circuit Breaker
CBD	Central Business District
CBRM	Condition Based Risk Management
CI	Customer Interruption
CM	Condition Monitoring
CML	Customer Minutes Lost
DCR	Dynamic Contact Resistance
DD	Distribution Defect
DGA	Dissolved Gas Analysis
FM	Fault Defect
GIS	Geospatial Information System
HBFRA	High Bush Fire Risk Area
HI	Health Index
HV	High Voltage
I2T	Accumulated Fault Energy
LAFA	Living Away From Home Allowance
LAFF	Load Above Firm Factor
LV	Low Voltage
MBFRA	Moderate Bush Fire Risk Area

Acronym	Definition
OPEX	Operational Expenditure
PAT	Priority Asset Data Collection Tool
PD	Partial Discharge
PoF	Probability Of Failure
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
SCONRRR	Standing Committee on National Regulatory Reporting Requirements
SD	Substation Defect
SF6	Sulphur Hexafluoride
SME	Subject Matter Expert
STPIS	Service Target Performance Incentive Scheme
SRBP	Synthetic Resin Bonded Paper
SWER	Single Wire Earth Return
TASA	Tapchanger Activity Signature Analysis
TC	Tapchanger
TEV	Temporary Earth Voltage
TX	Transformer
VCR	Value of Customer Reliability
WTI	Winding Temperature Indicator

4. DISTRIBUTION CONDUCTOR

4.1 HEALTH INDEX

4.1.1 Location Factor

The Location Factor models how the installation environment affects the distribution conductor's condition over time. For example, conductor located in the desert is less susceptible to corrosion when compared to conductor located on the coastline.

4.1.1.1 Constants

Setting Item	Value	Justification
Pollution Factor Default	1	Set to have no effect on HI where no pollution data available
Corrosion Default Factor	1	Set to have no effect on HI where no corrosion data available
Location Factor Increment	0.05	Satisfactory default established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

4.1.1.2 Pollution Factor

Based on SA Power Networks' operating experience, industrial pollution has no effect on conductor condition and is therefore not used in the model. For every record the pollution field has been left blank so the default factor of 1 is used.

4.1.1.3 Corrosion Factor

The corrosion zone indicates the impact corrosion will have on assets. Copper is less reactive than other conductor types, and as such calibration settings have been assigned accordingly.

CBRM models the different corrosion zones as a corrosion rating. The mapping from atmospheric corrosion zones to ratings is shown in the following table.

Corrosion Zone[1]	Corrosion Rating
Low	1
Moderate	2
High	3
Extreme	4

Corrosion factors were determined in workshops with EA Technology CBRM Experts, Conductor SME, Asset Strategy Engineers, and Manager Network Maintenance. The corrosion rating is assigned to a corrosion factor based on the corrosion zone and conductor material. The corrosion factors were determined by matching the actual lifespan of conductor materials in each corrosion zone.

[1] The corrosion zones have been renamed by the business since the creation of the CBRM models. The Severe corrosion Zone is now called Severe and the High Corrosion Zone is now called Very Severe.

Corrosion Rating Used	Conductor Material	Corrosion Factor	Justification
1	Aluminium	0.8	Conductor is located in low corrosion zone
1	AAAC	0.8	Conductor is located in low corrosion zone
1	Unknown	0.8	Conductor is located in low corrosion zone
1	ACSR	0.8	Conductor is located in low corrosion zone
1	SCGZ	0.8	Conductor is located in low corrosion zone
1	Steel	0.8	Conductor is located in low corrosion zone
1	AAC	0.8	Conductor is located in low corrosion zone
1	Copper	0.8	Conductor is located in low corrosion zone
2	Copper	1	Represents conductor located in severe corrosion zone
2	Aluminium	1	Represents conductor located in severe corrosion zone
2	Unknown	1	Represents conductor located in severe corrosion zone
2	AAAC	1	Represents conductor located in severe corrosion zone
2	SCGZ	1	Represents conductor located in severe corrosion zone
	SCAC	1	Corrosion zone unknown so set to have no effect on HI
	Silmalec	1	Corrosion zone unknown so set to have no effect on HI
	AAC	1	Corrosion zone unknown so set to have no effect on HI
	AAAC	1	Corrosion zone unknown so set to have no effect on HI
	SCGZ	1	Corrosion zone unknown so set to have no effect on HI
	Twisty	1	Corrosion zone unknown so set to have no effect on HI
3		1.2	Unknown conductor material in Very severe corrosion Zone
2	ACSR	1	Represents conductor located in severe corrosion zone
	Copper	1	Corrosion zone unknown so set to have no effect on HI
	Steel	1	Corrosion zone unknown so set to have no effect on HI
	Aluminium	1	Corrosion zone unknown so set to have no effect on HI
2	Steel	1	Represents conductor located in severe corrosion zone

Corrosion Rating Used	Conductor Material	Corrosion Factor	Justification
	ACSR	1	Corrosion zone unknown so set to have no effect on HI
2		1	Unknown conductor material in severe corrosion zone
1		1	Unknown conductor material in low corrosion zone
3	AAC	1.5	Represents conductor located in very severe corrosion zone
2	SCAC	1	Represents conductor located in severe corrosion zone
2	Silmalec	1	Represents conductor located in severe corrosion zone
2	AAC	1	Represents conductor located in severe corrosion zone
3	Copper	1.1	Copper in Very severe corrosion Zone less susceptible to corrosion than conductor made of other metals
4	Copper	1.2	Corrosion zone is not used in the model as the current asset definition will have too many zone crossings
3	Unknown	1.2	Unknown conductor material in very severe corrosion zone
3	AAAC	1.25	Represents conductor located in very severe corrosion zone
3	Aluminium	1.25	Represents conductor located in very severe corrosion zone
3	ACSR	1.25	Represents conductor located in very severe corrosion zone
3	SCAC	1.25	Represents conductor located in very severe corrosion zone
3	SCGZ	1.25	Represents conductor located in very severe corrosion zone
3	Steel	1.25	Represents conductor located in very severe corrosion zone
4	ACSR	1.75	Corrosion zone not used in the model as the current asset definition will have too many corrosion zone crossings
4	Aluminium	1.75	Corrosion zone not used in the model as the current asset definition will have too many corrosion zone crossings
4	AAAC	1.75	Corrosion zone not used in the model as the current asset definition will have too many corrosion zone crossings

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Corrosion Rating Used	Conductor Material	Corrosion Factor	Justification
4	Unknown	1.75	Corrosion zone not used in the model as the current asset definition will have too many corrosion zone crossings

4.1.2 Duty Factor

The Duty Factor models how hard an asset has worked in its operational life. Workshops between EA Technology CBRM experts, Conductor SME, Asset Strategy Engineers and the Manager Network Asset Management determined that electrical load does not affect conductor duty as it is the primary driver for design.

There are cases where conductor life may be slightly extended on the basis that surrounding structures provide wind breaks, and conversely there are cases where life may be slightly reduced on the basis that the surrounding environment does not provide wind breaks.

4.1.2.1 Constants

Setting Item	Value	Justification
Duty Factor Default	1	Set to have no effect on HI if the duty factor cannot be determined

4.1.2.2 Duty Factor

SCONRRR Category	Feeder Mean Wind Pressure	Overall Duty Factor	Justification
CBD	1	0.9	Low wind pressure
Urban	1	0.9	Low wind pressure
Rural Short	1	0.9	Low wind pressure
Rural Long	1	0.9	Low wind pressure
CBD	2	0.9	Typically CBD and Urban conductor are shielded by surrounding buildings
Urban	2	0.9	Typically CBD and Urban conductor are shielded by surrounding buildings
Rural Short	2	1	Although there is a lack of wind breaks in these areas, the line has been designed to withstand the wind pressure
Rural Long	2	1	Although there is a lack of wind breaks in these areas, the line has been designed to withstand the wind pressure
CBD	3	1	Typically CBD and Urban conductor are shielded by surrounding buildings
Urban	3	1	Typically CBD and Urban conductor are shielded by surrounding buildings
Rural Short		1	Used for case where no information available, therefore set to have no effect on HI
Rural Long		1	Used for case where no information available,

SCONRRR Category	Feeder Mean Wind Pressure	Overall Duty Factor	Justification
			therefore set to have no effect on HI
CBD		1	Used for case where no information available, therefore set to have no effect on HI
Urban		1	Used for case where no information available, therefore set to have no effect on HI
Rural Short	3	1.15	There are high gust speeds within these areas, and due insufficient presence of wind breaks, the conductor life will be slightly reduced
Rural Long	3	1.15	There are high gust speeds within these areas, and due insufficient presence of wind breaks, the conductor life will be slightly reduced

4.1.3 Faults

4.1.3.1 Constants

Setting Item	Value	Justification
Fault Factor Default	1	Set to have no effect on HI where no fault data available

4.1.3.2 Fault Factor

For each conductor asset, CBRM identifies the faults per km (fault density). The fault density is a condition factor, which is determined by identifying the total length of conductor, and number of faults caused by the asset. For example, high fault density indicates the asset is problematic. Fault records used are FM notifications recorded in the SAP database assigned with SAP codes relating to distribution conductor, and have been recorded within the last 5 years.

> Normalised FM Score by Length Minimum	<= Normalised FM Score by Length Maximum	Fm Factor	Justification
-1	0	1	Set to have no effect on HI, as no faults have ever occurred
0	1	1.05	Fault density is very small indicating that negligible number of faults have occurred
1	5	1.1	Fault density indicates that the asset has caused a moderate number of faults
5	15	1.2	Fault density indicates that the asset has caused a significant number of faults
15	100	1.4	Fault density indicates the asset is continually causing faults and is therefore problematic

4.1.4 Defects

CBRM uses two defect factors: Closed and Open. Closed defects represent completed repairs, and Open defects represent scheduled repairs.

4.1.4.1 Constants

Setting Item	Value	Justification
Defect Factor Default	0.95	Default where no defects recorded in last 5 years

4.1.4.2 Closed Defect Factor

For each asset, CBRM identifies the closed defects per km (closed defect density). The closed defect density is a condition factor which is determined by identifying the total length of conductor, and number of closed defects on the asset. For example, a high closed defect density indicates the asset is problematic. Closed defect records are DD notifications stored in SAP, which have a closed status, are assigned with SAP codes relating to distribution conductor, and have been recorded within the last 5 years.

> Normalised Closed Defects By Length Minimum	<= Normalised Closed Defects By Length Maximum	Closed Defects Factor	Justification
-1	0	0.9	This is an extremely rare circumstance in which no repairs have been required, meaning the asset is in better condition than anticipated. The HI adjusted to reflect this.
0	1	1	A defect density of 1 per km is considered normal for distribution conductor
1	2	1.1	The asset has experienced moderate repairs during its service life
2	5	1.25	Significant number of repairs have been undertaken on the conductor during its service life
5	1,000.00	1.5	Closed defect density indicates the asset continually needs to be repaired as it is problematic

4.1.4.3 Open Defects Factor

For each asset, CBRM identifies the open defects per km (open defect density). The open defect density is a condition factor which is determined by identifying the total length of conductor, and number of open defects found on the asset. For example, high open defect density indicates the asset is in poor condition and will experience failure if no repairs are undertaken in the near future. Open defect records are DD notifications stored in SAP, which have an open status, are assigned with SAP codes relating to distribution conductor, and have been recorded in the last 5 years.

> Normalised Open Defects By Length Minimum	<= Normalised Open Defects By Length Maximum	Open Defects Factor	Justification
-1	0	1	There are no scheduled repairs
0	1	1.05	This is a low defect density indicating that minimal repairs are scheduled
1	2	1.1	There are some scheduled repairs to be undertaken on the asset
2	5	1.25	There are significant repairs to be completed
5	10,000.00	1.5	Excessive repairs are to be completed indicating the asset is problematic

4.1.5 HI1

HI1 is primarily age driven however it does take into account the duty and location factor. After CBRM determines HI1, it applies condition information to determine the overall HI the asset stands at today.

4.1.5.1 Constants

Setting Item	Value	Justification
Average Life Default	50	Where insufficient information is available to determine average life, a conservative approach is used in which the shortest expected lifespan is assigned. The default life is rarely used because the size and type is known for most conductor assets
As New HI Default	0.5	HI of 0.5 indicates a brand new asset
HI1 Cap	5.5	HI of 5.5 indicates beginning of serious degradation. CBRM process caps the HI at this value if no condition information is available
Reliability Rating Default	2	Used if no reliability rating is available, and assigns the asset as having normal reliability
LogCalc	2.397895273	Model Constant set by EA Technology

4.1.5.2 Average Life

The average life of conductor depends on its size and type. Most conductors on the network are manufactured from either aluminium or copper material. Because copper is less reactive than aluminium, it has a longer lifespan.

There are copper conductors in service, which are as old as the network and in good condition. To model both the older good condition copper conductors as well as the deteriorating copper conductors there is an 80 year cap on average life.

The average life of distribution conductor was determined in workshops participated by EA Technology CBRM experts, Asset Strategy Engineers, and distribution conductor SME. The following table documents the average life for various conductor sizes and types.

Material	Size	Average Life
Aluminium / Steel	Thin	50
	Medium	60
	Thick	70
Copper	Thin	60
	Medium	80
	Thick	80

CBRM uses actual conductor size and types to determine the average life of each asset. The actual size and types populated in the calibration table are documented below.

Conductor Material	Cond. Size & Type	Average Life	Justification
Unknown	Unknown	50	Conservative approach is to use the shortest expected lifespan
Aluminium	7/0.102 AAC	50	Thin aluminium conductor
AAC	0.014 AAC	50	Thin aluminium conductor
AAC	0.0375 AAC	50	Thin aluminium conductor
AAC	0.07 AAC	50	Thin aluminium conductor
ACSR	Unknown	50	Thin aluminium conductor
ACSR	0.005 ACSR	50	Thin aluminium conductor
ACSR	0.025 ACSR	50	Thin aluminium conductor
ACSR	0.03 ACSR	50	Thin aluminium conductor

Conductor Material	Cond. Size & Type	Average Life	Justification
ACSR	0.06 ACSR	50	Thin aluminium conductor
AAC	28 AAC	50	Thin aluminium conductor
AAC	41 AAC	50	Thin aluminium conductor
ACSR	35 ACSR	50	Thin aluminium conductor
Copper	0.06 ACSR	50	Thin aluminium conductor
SCAC	3 ACSR	50	Thin steel conductor
SCGZ	0.0026 SCGZ	50	Thin steel conductor
SCGZ	3 SCGZ	50	Thin steel conductor
Twisty	0.025 Twisty	50	Thin aluminium conductor
AAC	185 AAC	50	Thin aluminium conductor
SCGZ	2 SCGZ	50	Thin steel conductor
Silmalec	0.1 AAC	70	Large aluminium conductor
Aluminium	0.1 ACSR	70	Large aluminium conductor
Copper	0.0125 Cu	60	Thin copper conductor
Copper	0.0225 Cu	60	Thin copper conductor
Copper	0.035 Cu	60	Thin copper conductor
ACSR	65 ACSR	60	Medium aluminium conductor
AAC	76 AAC	60	Medium aluminium conductor
ACSR	0.1 ACSR	60	Large aluminium conductor
ACSR	0.125 ACSR	60	Medium aluminium conductor
ACSR	0.15 ACSR	70	Large aluminium conductor
AAC	0.12 AAC	60	Large aluminium conductor
AAC	0.185 AAC	70	Thick aluminium conductor
AAC	0.28 AAC	70	Thick aluminium conductor
AAC	122 AAC	70	Thick aluminium conductor
AAC	178 AAC	70	Thick aluminium conductor

Conductor Material	Cond. Size & Type	Average Life	Justification
ACSR	0.225 ACSR	70	Thick aluminium conductor
ACSR	105 ACSR	70	Thick aluminium conductor
ACSR	144 ACSR	70	Thick aluminium conductor
ACSR	243 ACSR	70	Thick aluminium conductor
AAC	7/0.102 AAC	70	Thick aluminium conductor
AAC	300 AAC	70	Thick aluminium conductor
Aluminium	61/2.50--Flat	70	Thick aluminium conductor
Copper	0.06 Cu	80	Medium copper conductor
Copper	0.1 Cu	80	Medium copper conductor
Copper	0.15 Cu	80	Large copper conductor
Copper	0.2 Cu	80	Large copper conductor

4.1.5.3 As New HI

All conductor types are assigned an as new HI of 0.5, which indicates the asset is brand new.

4.1.6 Factor Value

The Factor Value is used to establish condition indicators to HI1, settings here include the default defect factor and reliability ratings.

4.1.6.1 Constants

Setting Item	Value	Justification
Reliability Rating Default	2	Refer to Section 4.1.6.3
Reliability Factor Default	1	Refer to Section 4.1.6.2
Defect Factor Default	0.95	If no SAP DD notifications have been recorded in the last 5 years the conductor is in better condition than anticipated

4.1.6.2 Reliability Factor

The Reliability Factor is used to identify problematic conductor types. Since the average life of the conductor type encapsulates its known performance on the network, all reliability ratings are set to assign a reliability factor of 1 (ie average reliability) and therefore have no effect on the HI.

4.1.6.3 Reliability Rating

As previously mentioned in Section 4.1.6.2, the average life of the conductor type encapsulates its known performance on the network, because of this, all of the reliability ratings have been set to indicate average reliability so there is no effect on the HI.

4.1.7 Failure Scenarios

Workshops undertaken with EA Technology CBRM Experts, Conductor SME and Asset Strategy Engineers identified that distribution conductor has the following failure scenarios:

- Fault: The conductor or its attachments fail, leading to conductor falling down and causing an outage;
- Repair: Inspectors identify that the conductor has defects which need repairing;
- Replacement: A significant proportion of the conductor needs to be replaced;
- Fire Start: The conductor starts a small bushfire; and
- Bush Fire: The conductor starts a major bushfire.

4.1.7.1 Constants

Annual fault rate was determined using HV database records. There is no way to determine if the faults were caused by condition or external events, to overcome this, a decision was made in workshops with EA Technology, Asset Strategy Engineers and Conductor SMEs to ratio Condition : Non Condition as 4 : 1 9ie 80% of failure related to condition and 20% due to other causes).

Setting Item	Value	Justification
No. Failures: Condition Conductor Fault	178	Total faults identified over the last 5 years with the exclusion of 66kV and zero customer interruption faults. HV database shows 931 conductor failures, and 178 fitting failures, leading to a total of 1086 failures, at an average of 217 per annum (over 5 years). Split 4:1 for condition vs non condition as there is no way to distinguish. HV database was used instead of SAP FMs as the information is a better source for faults.
No. Failures: Condition Repairs	761	Total conductor repairs identified over last 5 years recorded in SAP database, under SAP codes: LMD005=1429, LMC013=2190, LMD017=191: average annual repair jobs=761
No. Failures: Condition Replacement	154	SAP Records and conductor replacement log were used for the last 5 years. 715 LMC012 DDs are in SAP and 56 projects are in the replacement log, equating to an average of 154 projects annually
No. Failures: Condition Fire Start	0.055	Fire event rates are spread across all line assets using historic events recorded in the fire start database
No. Failures: Condition Bushfire	0.008	Fire event rates are spread across all line assets using historic events recorded in the fire start database

Setting Item	Value	Justification
No. Failures: Non-Condition Conductor Fault	42	Total faults identified over the last 5 years with the exclusion of 66kV and zero customer interruption faults. HV database shows 931 conductor failures, and 178 fitting failures, leading to a total of 1086 failures, at an average of 217 per annum (over 5 years). Split 4:1 for condition vs non condition as there is no way to distinguish. HV database was used instead of SAP FMs as information is a better source for faults.
No. Failures: Non-Condition Fire Start	0.092	Fire event rates are spread across all line assets using historic events recorded in the fire start database.
No. Failures: Non-Condition Bush Fire	0.014	Fire event rates are spread across all line assets using historic events recorded in the fire start database.
C Value: Condition Conductor Fault	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4
C Value: Condition Repairs	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4
C Value: Condition Replacement	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4
C Value: Condition Fire Start	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4
C Value: Condition Bushfire	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4
HI Lim: Condition Conductor Fault	4	Industry standard setting for HI where wear out begins
HI Lim: Condition Repairs	4	Industry standard setting for HI where wear out begins
HI Lim: Condition Replacement	4	Industry standard setting for HI where wear out begins
HI Lim: Condition Fire Start	4	Industry standard setting for HI where wear out begins
HI Lim: Condition Bushfire	4	Industry standard setting for HI where wear out begins
HI Avg: Condition Conductor Fault	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HI Avg: Condition Repairs	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HI Avg: Condition	4	Standard CBRM setting to maintain constant PoF equivalent to

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Replacement		HI=4 for HI < HI Lim
HI Avg: Condition Fire Start	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HI Avg: Condition Bushfire	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim

4.1.8 Year 0 HI & PoF

4.1.8.1 Constants

Setting Item	Value	Justification
New Asset HI	0.5	Indicates a brand new asset
Minimum Health Index	0.5	Indicates a brand new asset
End of Life HI	7	CBRM process defines HI of 7 represents an asset at end of life
HI Category Default	No Result	Used if the HI cannot be determined
Maximum Y0 HI	10	CBRM places a cap which the HI stands today at 10
Bush Fire Factor Default	0	Most assets are located in Non Bush Fire Risk Areas
Conductor Faults PoF Modifier Default	1	PoF does not depend on the conductor's voltage and therefore the modifier is set to have no effect ie '1' x PoF = PoF. Refer to Section 4.1.8.4

4.1.8.2 Bushfire Zone

BFRA_Level	Fire Risk Factor	Justification
No Fire Risk	0	No fire risk in this area
Non Bush Fire Risk Area	0	No fire risk in this area
Bush Fire Risk Area	1	Moderate Bush Fire Risk Area - Determined in workshop with Manager Network Asset Management and EA Technology CBRM Experts to use $1/10^{th}$ fire risk compared to HBFRA conductor
Bush Fire Risk	1	Moderate Bush Fire Risk Area - Determined in workshop with Manager Network Asset Management and EA Technology CBRM Experts to use $1/10^{th}$ fire risk compared to HBFRA

BFRA_Level	Fire Risk Factor	Justification
		conductor
High Fire Risk	10	High Bush Fire Risk Area - Determined in workshop with Manager Network Asset Management and EA Technology CBRM Experts to use 10x fire risk compared to MBFRA conductor
High Bush Fire Risk Area	10	High Bush Fire Risk Area - Determined in workshop with Manager Network Asset Management and EA Technology CBRM Experts to use 10x fire risk compared to MBFRA conductor

4.1.8.3 HI Category Y0
The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

4.1.8.4 Conductor Fault PoF Modifier
The settings have been assigned to have no effect on results because the probability of event does not directly depend on voltage.

4.1.8.5 Weighted Health Index Y0
The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

4.1.9 HI – Yn Health Index
HI – Yn represents the future forecasted condition of the asset at Year Yn.

4.1.9.1 Constants

Setting Item	Value	Justification
Yn	11	2014-2025
Minimum Health Index	0.5	Represents a brand new asset
Maximum Yn HI	15	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Ageing Reduction Factor Default	1	If an ageing reduction factor cannot be applied, its effect is excluded from the results
HI Category Default	No Result	Used if the HI cannot be determined
Ageing Constant from Y0 HI Maximum increase(multiplier)	1.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Minimum Age for	10	Satisfactory default established through EA

Setting Item	Value	Justification
Recalculated B		Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Ageing Constant Multiplier Cap	1.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

4.1.9.2 Age Reduction Factor

The age reduction factor models the increased life expectancy as conductor ages. The factors were provided by the CBRM Architect and have been developed from EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

Final Asset HI Y0 Minimum	Final Asset HI Y0 Maximum	Ageing Reduction Factor
0	0	1
0	2	1
2	5.5	1.5
5.5	10	1.5

4.1.9.3 Future HI Category

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

4.1.9.4 Weighted Health Index Yn

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

4.2 RISK

4.2.1 Yn & Interventions

4.2.1.1 Constants

Setting Item	Value	Justification
Yn	11	Aligns 2014-2025
Percentage Replacement	0.55	Derived percentage of total network distribution conductor length to be replaced annually so a constant risk profile is maintained.
% Replacement Ranking Column	Delta Risk	Prioritises based on difference in risk between existing asset and new asset
Replacement Default Cost	18000	Majority of conductor replacement is for 11kV lines
Portion of Route Length Replaced (%)	20	On average, SA Power Networks refurbishes 20% of a feeder

Setting Item	Value	Justification
Maximum Health Index for Non Replaced Assets	5	80% of remaining feeder has HI of 5 , representing the onset of wear out

4.2.1.2 Percentage Replacement - Replacement Cost

The unit costs for conductor replacement were determined using completed conductor project information from the past 5 years and applying an escalation factor due to changing aluminium prices. The escalation factor was determined from annual prices documented by the London Metal Exchange.

Voltage	% Replacement Program Costs (per km)
LV	30000
11kV	18000
7.6kV	18000
19kV	13500

4.2.1.3 Targeted Replacement - Replacement Cost

The costs assigned have no effect on results because a targeted replacement program is not used for replacement CAPEX justification.

4.2.2 New Asset

4.2.2.1 Constants

Setting Item	Value	Justification
New Asset HI	0.5	Represents a brand new asset
Average Life of New Asset	60	Determined in workshops with CBRM experts from EA Technology, Asset Strategy Engineers and Distribution Conductor SME

4.2.3 Criticality

Criticality is determined for each consequence category, it identifies the significance of a fault/failure, and is comprised of a number of weighting factors which represent relative severity.

4.2.3.1 Network Performance

Network Performance criticality represents the significance of the penalty imposed on SA Power Networks when the asset causes an unplanned outage.

4.2.3.1.1 *Constants*

Setting Item	Value	Justification
Life Support Customers Factor Default	1	If it cannot be determined that the feeder supplies/does not supply life support customers, no life support customers are assigned
NP Number of Phases Factor Default	1	SA Power Networks' operational experience has found that an outage usually occurs on one phase
Number of Reclosers Factor Default	1	If the number of reclosers is unknown, no reclosers are assigned as this is the most common occurrence
NP Minimum Factor	0.5	Satisfactory default established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
NP Maximum Factor	10	More emphasis is placed on Safety, Environment and Network Performance than CAPEX and OPEX

4.2.3.1.2 *Major Customer Factor*

Major customers represent high load customers such as factories and shopping centres. EA Technology's experience with over 30 Electrical Utilities in 10 countries worldwide has found that feeders supplying major customers are considered to be twice as significant as feeders that only supply residential customers.

4.2.3.1.3 *Life Support Customer Factor*

More emphasis is placed on feeders supplying life support customers. The values were provided by EA Technology and are based on their experience with over 30 Electrical Utilities in 10 countries worldwide.

> Life Support Customers Minimum	<= Life Support Customers Maximum	Life Support Customers Factor	Justification
-1	0	1	No effect as no life support customers on feeder
0	3	1.1	Default established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
3	5	1.2	Default established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

> Life Support Customers Minimum	<= Life Support Customers Maximum	Life Support Customers Factor	Justification
5	20	1.25	Default established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
20	10,000	1.3	Default established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

4.2.3.1.4 ***Number of Reclosers Factor***

Reclosers limit the number of customers affected by a fault and make it easier for emergency response to locate the fault leading to improved restoration times.

> Number of Reclosers Minimum	<= Number of Reclosers Maximum	Number of Reclosers Factor	Justification
-1	0	1.2	If no reclosers have been installed, all of the customers being supplied by the feeder experience an outage, and emergency response takes longer to locate the fault
0	1	1	Fewer customers are affected as a recloser has been installed, making it easier for emergency response to locate the fault
1	2	0.75	Fewer customers are affected as two reclosers have been installed, making it easier for emergency response to locate the fault
2	50	1	Used for data error, as feeders typically have a maximum of 2 reclosers. Factor of 1 conservatively assumes a single recloser is installed on the feeder

4.2.3.1.5 ***Number of Phases Factor***

SA Power Networks' operational experience has found that outages usually occur on one phase, therefore all phases are set to have the same significance.

4.2.3.2 OPEX

OPEX criticality represents the significance an event has on the Operational Expenditure required to remediate it.

4.2.3.2.1 *Constants*

Setting Item	Value	Justification
Opex Minimum Factor	0.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Opex Maximum Factor	5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Customer Type OPEX Factor Default	1	Most customers are located in Rural Short / Urban SCONRRR, therefore these regions are used if the customer type is unknown
Opex Number of Phases Factor Default	1	If the number of phases is unknown, the default is to use three phase as this is the most common configuration the network

4.2.3.2.2 *Customer Type Factor*

SCONRRR Category	Customer Type OPEX Factor	Justification
Urban	1	Set to have no effect based on SA Power Networks experience
Rural Short	1	Set to have no effect based on SA Power Networks experience
CBD	1.3	To allow for increased traffic management and switching costs associated with CBD
Rural Long	1.5	Deals with increased response time due to longer distance from nearest country depot

4.2.3.2.3 *Phases Factor*

Number of Phases	Opex Number of Phases Factor	Justification
1 Phase	2	Based on SA Power Networks' operational experience, SWER takes the longest time to repair
2 Phase	1	Same OPEX significance as three phase, which is average significance
4 Phase	0.75	4 Phase is LV, based on SA Power Networks' operational experience this is easier and quicker to fix than 1, 2 or 3 phase.
3 Phase	1	Average OPEX significance

4.2.3.3 CAPEX

CAPEX criticality represents the significance an event has on the Capital Expenditure required to remediate it.

4.2.3.3.1 Constants

Setting Item	Value	Justification
Customer Type CAPEX Factor Default	1	Sets factor default when customer type unknown to be the same as for Rural Short / Urban, as most customers are located in these regions
Capex Minimum Factor	0.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Capex Maximum Factor	5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Capex Number of Phases Factor Default	1	If the number of phases is unknown, the default is to use three phase as this is the most common configuration on the network

4.2.3.3.2 Customer Type Factor

SCONRRR Category	Customer Type CAPEX Factor	Justification
Urban	1	Set to have no effect based on SA Power Networks experience
Rural Short	1	Set to have no effect based on SA Power Networks experience
Rural Long	1.1	Deals with increased response time due to longer distance from nearest country depot
CBD	1.2	To allow for increased traffic management and switching costs associated with CBD

4.2.3.3.3 Phases Factor

Number of Phases	Capex Number of Phases Factor	Justification
1 Phase	2	SA Power Networks' operational experience has found that SWER has the longest repair times
4 Phase	0.75	4 Phase is LV, based on SA Power Networks' operational experience, this is the easiest to fix
2 Phase	1	Same CAPEX significance as three phase, which is average significance

Number of Phases	Capex Number of Phases Factor	Justification
3 Phase	1	Average significance

4.2.3.4 Environment

Environmental criticality represents the significance asset failure has on the environment.

4.2.3.4.1 *Constants*

Setting Item	Value	Justification
Environmentally Sensitive Area Factor Default	1	Sets factor default when type unknown to be the same as Environment Rating '3', which is the norm for average environmental consequences
Env Minimum Factor	1	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Env Maximum Factor	10	More emphasis placed on Safety, Environment and Network Performance
Environment Number of Phases Factor Default	1	If the number of phases is unknown, the default is to use three phase as this is the most common configuration on the network.

4.2.3.4.2 *Environmentally Sensitive Area Factor*

Environmentally Sensitive Area	Environmentally Sensitive Area Factor	Justification
1	0.5	Area 3 rating set as the norm for Average Environmental consequences per failure, adjusting down for 1 or 2 and up for 4..
2	0.7	Area 3 rating set as the norm for Average Environmental consequences per failure, adjusting down for 1 or 2 and up for 4.
3	1	Norm for Average Environmental consequences per failure, established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide 4.
4	2	Area 3 rating set as the norm for Average Environmental consequences per failure, adjusting down for 1 or 2 and up for 4.

4.2.3.4.3 *Phases Factor*

Number of Phases	Environment Number of Phases Factor	Justification
1 Phase	1	Norm for Average Environmental consequences per failure, established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
4 Phase	1	Number of phases 1 set as the norm for Average Environmental consequences per failure, adjusting appropriately for 2, 3 and 4 phases.
2 Phase	1.5	Number of phases 1 set as the norm for Average Environmental consequences per failure, adjusting appropriately for 2, 3 and 4 phases.
3 Phase	2	Number of phases 1 set as the norm for Average Environmental consequences per failure, adjusting appropriately for 2, 3 and 4 phases.

4.2.3.5 Safety

Safety criticality represents the significance the asset has on public and employee safety.

4.2.3.5.1 *Constants*

Setting Item	Value	Justification
Customer Type Default Factor	1	Refer to Section 4.2.3.5.2
Safety Minimum Factor	0.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Safety Maximum Factor	10	More emphasis placed on Safety, Environment and Network Performance than CAPEX and OPEX

4.2.3.5.2 *Customer Type Factor*

Provides facility to factor customer type by SCONRRR category, all regions have equal significance on safety, therefore this factor is not used.

4.2.4 Average Cost of Fault

4.2.4.1 Network Performance

Network Performance consequences are the penalties imposed on SA Power Networks whenever an outage occurs. It is important to note that Major Events are excluded, as no penalty is imposed because they exceed the maximum SAIDI threshold.

Distribution conductors supply radial feeders, and as such have outage penalties in accordance with the STPIS.

4.2.4.1.1 *Constants*

Setting Item	Value	Justification
11kV Risk Default	Yes	SA Power Networks' operational experience has found that most faults incurring STPIS penalties occur on 11kV feeders

4.2.4.1.2 *Constants by Customer Type*

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
Value of CML	15.99	0.68	0.73	0.74	Determined using STPIS Rates and customer numbers obtained from the Network Performance and Regulatory Manager. CML is defined as SAIDI / Number of customers. • CBD: $77,432/4,799; • Urban: $431,766/584,615; • Rural Short: $79,115/110,021; • Rural Long: $96,760/143,337
Value of CI	1462	94	84	62	Determined using STPIS Rates and customer numbers obtained from the Network Performance and Regulatory Manager. CI is defined as SAIFI Incentive Rate / Number of customers, where SAIFI rate is converted from 0.01 interruption to 1 interruption. • CBD: $70,783*100/4799; • Urban: $359,393*100/584615; • Rural Short: $90,873*100/110021; • Rural Long: $134,597*100/143337.
Avg. No. CIs Per Fault	1	1	1	1	By definition, each customer on the feeder is interrupted during a fault
NP Avg Duration of Outage (mins) LV: Condition Conductor Fault	75	75	75	75	This was determined from records stored in the OMS for the years last 5 years
NP Avg Duration of Outage (mins) LV: Condition	0	0	0	0	Planned outage during this event. No STPIS consequence is imposed

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
Repairs					
NP Avg Duration of Outage (mins) LV: Condition Replacement	0	0	0	0	Planned outage during this event. No STPIS consequence is imposed
NP Avg Duration of Outage (mins) LV: Condition Fire Start	0	0	0	0	A small bushfire is a major event, this means that no STPIS consequence is imposed
NP Avg Duration of Outage (mins) LV: Condition Bush Fire	0	0	0	0	A bushfire is a major event, this means that no STPIS consequence is imposed
NP Avg Duration of Outage (mins) LV: Non-Condition Conductor Fault	75	75	75	75	This was determined from records stored in the HV database for the last 5 years
NP Avg Duration of Outage (mins) LV: Non-Condition Fire Start	0	0	0	0	A small bushfire is a major event, this means that no STPIS consequence is imposed
NP Avg Duration of Outage (mins) LV: Non-Condition Bush Fire	0	0	0	0	A bushfire is a major event, this means that no STPIS consequence is imposed
NP Avg Duration of Outage (mins) 11kV: Condition Conductor Fault	75	75	75	75	This was determined from records stored in the HV database for the last 5 years
NP Avg Duration of Outage (mins) 11kV: Condition Repairs	0	0	0	0	Planned outage during this event. No STPIS consequence is imposed
NP Avg Duration of Outage (mins) 11kV: Condition Replacement	0	0	0	0	Planned outage during this event. No STPIS consequence is imposed

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
NP Avg Duration of Outage (mins) 11kV: Condition Fire Start	0	0	0	0	A small bushfire is a major event, this means that no STPIS consequence is imposed
NP Avg Duration of Outage (mins) 11kV: Condition Bush Fire	0	0	0	0	A bushfire is a major event, this means that no STPIS consequence is imposed
NP Avg Duration of Outage (mins) 11kV: Non-Condition Conductor Fault	75	75	75	75	This was determined from records stored in the HV database for the last 5 years
NP Avg Duration of Outage (mins) 11kV: Non-Condition Fire Start	0	0	0	0	A small bushfire is a major event, this means that no STPIS consequence is imposed
NP Avg Duration of Outage (mins) 11kV: Non-Condition Bush Fire	0	0	0	0	A bushfire is a major event, this means that no STPIS consequence is imposed

4.2.4.1.3 *Number of Customers Default*

It is rare that default customer numbers need to be assigned, as the most of the feeder customer numbers are known. The default values were determined in workshops with EA Technology CBRM experts, conductor SME and Asset Strategy Engineers by categorising the customer numbers by region and voltage.

Type of Site Used	NP Risk Band	Number of Customers Used
Rural Long	LV	5
Rural Short	LV	10
CBD	LV	20
Urban	LV	50
CBD	11kV	100
Rural Long	11kV	400

CBRM Justification

Type of Site Used	NP Risk Band	Number of Customers Used
Rural Short	11kV	1350
Urban	11kV	2500

4.2.4.1.4 *NP Risk Band*

NP Risk band assigns STPIS consequences to the corresponding build type rather than voltage.

4.2.4.2 OPEX

OPEX consequences are the Operational Expenditure required in response to an event.

4.2.4.2.1 *Constants*

Setting Item	Value	Justification
Voltage Consequence Band Default	11kV	SA Power Network's operational experience has found that faults usually occur on 11kV lines

4.2.4.2.2 *Voltage Group Constants*

Setting Item	11kV	LV	SWER	Justification
Opex Avg. Consequence: Condition Conductor Fault	1000	500	1000	Determined from Orders recorded against SAP FM Notifications created within the last 5 years
Opex Avg. Consequence: Condition Repair	600	300	750	Determined from Orders recorded against SAP DD Notifications created within the last 5 years
Opex Avg. Consequence: Condition Replacement	0	0	0	All of conductor replacement is CAPEX
Opex Avg. Consequence: Condition Fire Start	2000000	2000000	2000000	A minor bushfire costs the business $2M, this value was determined by the Manager Network Asset Management
Opex Avg. Consequence: Condition Bushfire	250000000	250000000	250000000	A Catastrophic bushfire costs the business $250M, this value was determined by the Manager Network Asset Management
Opex Consequence: Non-Condition Conductor Fault	1000	500	1000	Determined from Orders recorded against SAP FM Notifications created within the last 5 years

Setting Item	11kV	LV	SWER	Justification
Opex Avg. Consequence: Non-Condition Fire Start	20000000	20000000	20000000	A minor bushfire costs the business $2M, this value was determined by the Manager Network Asset Management
Opex Avg. Consequence: Non-Condition Bush Fire	250000000	250000000	250000000	A Catastrophic bushfire costs the business $250M, this value was determined by the Manager Network Asset Management

4.2.4.2.3 *Financial Risk Band*

Based on SA Power Networks experience, OPEX is dependent on build type rather than voltage. The Financial Risk Band assigns the build type to each line voltage.

Voltage	Financial Risk Band	Justification
LV	LV	LV Build Type
11kV	11kV	11kV Build Type
19kV	SWER	SWER Build Type
7.6kV	11kV	11kV Build Type

4.2.4.3 CAPEX

CAPEX consequences are the Capital Expenditure required in response to an event.

4.2.4.3.1 *Constants*

Setting Item	Value	Justification
Opex : Capex Ratio	1	Based on SA Power Networks' operational experience CAPEX and OPEX are valued equally
Voltage Consequence Band Default	11kV	Majority of faults occur on 11kV distribution network

4.2.4.3.2 *Financial Risk Band*

Based on SA Power Networks experience, CAPEX is dependent on build type rather than voltage. The Financial Risk Band assigns the build type to each line voltage.

Voltage	Financial Risk Band	Justification
LV	LV	LV Build Type
11kV	11kV	11kV Build Type

Voltage	Financial Risk Band	Justification
19kV	SWER	SWER Build Type
7.6kV	11kV	11kV Build Type

4.2.4.3.3 *Voltage Group Constants*

Setting Item	11kV	LV	SWER	Justification
Capex Avg. Consequence: Cost of Conductor Fault	1000	50	1000	Determined from Orders recorded against SAP FM Notifications created within the last 5 years
Capex Avg. Consequence: Condition Repair	1000	500	1000	Determined from Orders recorded against SAP DD Notifications created within the last 5 years
Capex Avg. Consequence: Cost of Replacement	60000	50000	65000	Used completed conductor project information and escalation factor for metal prices for the last 5 years
Capex Avg. Consequence: Cost of Fire Start	0	0	0	Not used
Capex Avg. Consequence: Cost of Bushfire	0	0	0	Not used
Capex Avg. Consequence: Cost of Non-Condition Conductor Fault	1000	50	1000	Determined from Orders recorded against SAP FM Notifications for the last 5 years
Capex Avg. Consequence: Non-Condition Fire Start	0	0	0	Not used
Capex Avg. Consequence: Non-Condition Bush Fire	0	0	0	Not used

4.2.4.4 SAFETY

4.2.4.4.1 *Consequences*

The safety consequences are valued in monetary terms, and have been assessed by establishing a value of a safety event in terms of its adverse cost on society. CBRM uses the following consequences to determine safety risk:

- Minor – The event leads to an individual requiring medical treatment only;
- Major – The event incurs a lost time injury;
- Fatality – The event causes death or permanent disability.

EA Technology established the values for the three consequence types through collaboration with the Network Asset Management Group from SA Power Networks, the process that was used is outlined in Section 2 of Attachment A.

4.2.4.4.2 *Average Consequences*

The average safety consequences look at the frequency of all the events across all models, their determination is outlined in Section 3 of Attachment A.

4.2.4.5 Environment

4.2.4.5.1 *Consequences*

Five significant environmental consequences have been identified that could arise as a result of a network asset failure:

- Loss of oil;
- Emission of SF6 gas into the atmosphere;
- A significant fire with smoke pollution;
- The production of contaminated waste; and
- Major disturbance such as traffic congestion or noise.

CBRM assigns a monetary value to the environmental consequences based on trading values for carbon emissions. The overall process that was used to determine this is outlined in Section 2 of Attachment A.

4.2.4.5.2 *Failure Scenario Constants*

The average safety consequences look at the frequency of all the events across all models, their determination is outlined in Section 3 of Attachment A.

4.3 FEEDERS

Feeder calibration data is used for the determination of the Open/Closed Defect and Fault condition factors for each asset.

4.3.1 Feeder Data Constants

Setting Item	Value	Justification
Major Customers Priority Default	1	Sets Major Customers default equivalent to ‘No’ if Major Customers information unknown
Default Fault Score	1	If the fault score cannot be determined, a conservative approach is used by assuming no faults have ever occurred

4.3.2 HI Y0 Category

These settings are used to generate reports in the CBRM front end client, they are assigned with default values provided by EA Technology and have no effect on results.

4.3.3 HI Yn Category

These settings are used to generate reports in the CBRM front end client, they are assigned with default values provided by EA Technology and have no effect on results.

4.3.4 Percentage Replacement HI Category

These settings are used to generate reports in the CBRM front end client, they are assigned with default values provided by EA Technology and have no effect on results.

4.3.5 Targeted Intervention Category

These settings are used to generate reports in the CBRM front end client, they are assigned with default values provided by EA Technology and have no effect on results.

4.3.6 SCONRRR Priority

These settings are used to generate reports in the CBRM front end client, they are assigned with default values provided by EA Technology and have no effect on results.

4.3.7 Major Customers Priority

Major Customer	Major Customers Priority	Justification
No	0	Converts Major Customer (Yes or No) to (1 or 0) for calculation purposes
Yes	1	Converts Major Customer (Yes or No) to (1 or 0) for calculation purposes

4.3.8 Fault Score

SAP FM notifications recorded against conductor within the last 5 years are used to determine the cumulative fault score, which is then converted to the fault density by normalising the score against the conductor length. For each fault, its contribution towards the cumulative score depends on the FM problem code.

Fault Score	Justification
0	Fault has no effect on conductor condition
0.5	Cannot identify level of significance fault has on conductor condition
1	Fault is fully relevant to conductor condition

4.3.9 Defect Score

SAP DD Notifications recorded against conductor within the last 5 years are used to determine the cumulative defect score which is converted to defect density by normalising the score against the conductor length.

Defect Priority	Defect Score	Justification
4	0.5	Represents to condition monitor, defect does not have direct impact on short term reliability
3	1	Defect has impact on mid term reliability
2	1.5	Defect has impact on short to mid term reliability
1	2	Defect impacts short term reliability
Z	1	Z code does not necessarily mean the defect identifies poor condition, only fire risk, repair is of highest priority

4.3.10 Open/Closed Status

The determination of whether a SAP DD notification is open or closed is determined by checking if a NOCO flag has been assigned to its status.

5. SUBTRANSMISSION CONDUCTOR

5.1 HEALTH INDEX

5.1.1 Location Factor

The Location factor models how the installation environment affects the subtransmission conductor's condition over time. For example, conductor located in the desert is less susceptible to corrosion when compared to conductor located on the coastline.

5.1.1.1 Constants

Setting Item	Value	Justification
Pollution Factor Default	1	Used when the pollution factor cannot be determined, and is set to have no effect on the HI
Corrosion Default Factor	1	Used when the corrosion factor cannot be determined, and is set to have no effect on the HI
Location Factor Increment	0.05	Determined as satisfactory value in workshops with EA Technology CBRM Experts, Asset Strategy Engineers and Conductor SME

5.1.1.2 Pollution Factor

Based on SA Power Networks' operating experience, industrial pollution has no effect on conductor condition and its effect on HI is not used. For every record the pollution field has been left blank so the default factor of 1 is used.

5.1.1.1 Corrosion Factor

The corrosion zone indicates the impact corrosion will have on assets. Copper is less reactive than other conductor types, and as such calibration settings have been assigned accordingly.

CBRM models the different corrosion zones as a corrosion rating. The mapping between the zones and ratings is shown in the following table.

Corrosion Zone	Corrosion Rating
Low	1
Moderate	2
High	3
Extreme	4

Corrosion factors were determined in workshops with CBRM Experts, Conductor SME, Asset Strategy Engineers, and Manager Network Maintenance. The corrosion rating is assigned to a corrosion factor based on the corrosion zone and conductor material. The corrosion factors were determined by matching the known or expected lifespan of conductor materials in each corrosion zone.

Corrosion Rating Used	Conductor Material	Corrosion Factor	Justification
1	ACSR	0.9	Conductor is located in low corrosion zone
1	Aluminium	0.9	Conductor is located in low corrosion zone
1	AAAC	0.9	Conductor is located in low corrosion zone
1	Unknown	0.9	Conductor is located in low corrosion zone
1	Copper	0.8	Copper conductor is located in low corrosion zone and is less reactive than other conductor materials
2	Copper	1	Represents conductor located in severe corrosion zone
2	AAAC	1	Represents conductor located in severe corrosion zone
2	Aluminium	1	Represents conductor located in severe corrosion zone
2	ACSR	1	Represents conductor located in severe corrosion zone
2	Unknown	1	Represents conductor located in severe corrosion zone
	AAAC	1	Unknown corrosion zone, set to have no effect on the result
	AAC	1	Unknown corrosion zone, set to have no effect on the result
	ACSR	1	Unknown corrosion zone, set to have no effect on the result
	Aluminium	1	Unknown corrosion zone, set to have no effect on the result
	Copper	1	Unknown corrosion zone, set to have no effect on the result
	Steel	1	Unknown corrosion zone, set to have no effect on the result
	Twisty	1	Unknown corrosion zone, set to have no effect on the result
1		1	Unknown conductor in low corrosion zone
1	Twisty	1	Twisty conductor more susceptible to corrosion
2		1	Unknown conductor in severe corrosion zone
2	AAC	1	Represents conductor located in severe corrosion zone

Corrosion Rating Used	Conductor Material	Corrosion Factor	Justification
2	Steel	1	Represents conductor located in severe corrosion zone
2	Twisty	1	Represents conductor located in severe corrosion zone
3		1	Unknown conductor in Very severe corrosion zone
3	AAC	1	Represents conductor located in very severe corrosion zone
3	Copper	1.1	Copper conductor has longer life than other types in very severe corrosion zone
4	Copper	1.2	Corrosion zone not used in the model as the current asset definition will have too many corrosion zone crossings
3	AAAC	1.1	Represents conductor located in very severe corrosion zone
3	ACSR	1.2	Represents conductor located in very severe corrosion zone
3	Aluminium	1.2	Represents conductor located in very severe corrosion zone
3	Unknown	1.2	Represents conductor located in very severe corrosion zone
4	Unknown	1.5	Corrosion zone not used in the model as the current asset definition will have too many corrosion zone crossings

5.1.2 Duty Factor

The Duty Factor models how hard an asset has worked during its operational life. Workshops between EA Technology CBRM experts, Conductor SME, Asset Strategy Engineers and the Manager Network Asset Management determined that electrical load does not affect conductor duty as it is the primary driver for design.

There are cases where conductor life may be slightly extended on the basis that surrounding structures provide wind breaks, and conversely there are cases where life may be slightly reduced on the basis that the surrounding environment does not provide wind breaks.

5.1.2.1 Constants

Setting Item	Value	Justification
Duty Factor Default	1	Sets no effect on HI where no duty data available

5.1.2.2 Duty Factor

SCONRRR Category	Feeder Mean Wind Pressure	Overall Duty Factor	Justification
CBD	1	0.9	Determined as satisfactory value in workshop with EA Technology CBRM Experts, Asset Strategy Engineers and Conductor SME
Urban	1	0.9	Low wind pressure
Rural Short	1	0.9	Low wind pressure
Rural Long	1	0.9	Low wind pressure
CBD	2	0.9	Typically CBD and Urban conductor are shielded by surrounding buildings
Urban	2	0.9	Typically CBD and Urban conductor are shielded by surrounding buildings
Rural Short	2	1	Although there is a lack of wind breaks in these areas, the line has been designed to withstand the wind pressure
Rural Long	2	1	Although there is a lack of wind breaks in these areas, the line has been designed to withstand the wind pressure
CBD	3	1	Typically CBD and Urban conductor are shielded by surrounding buildings
Urban	3	1	Typically CBD and Urban conductor are shielded by surrounding buildings
RURAL LONG		1	Used for case where no information available, therefore set to have no effect on HI
Rural Short		1	Used for case where no information available, therefore set to have no effect on HI
Urban		1	Used for case where no information available, therefore set to have no effect on HI
Rural Short	3	1.15	There are high gust speeds within these areas, and due to insufficient presence of wind breaks, the conductor life will be slightly reduced
Rural Long	3	1.15	There are high gust speeds within these areas, and due to insufficient presence of wind breaks, the conductor life will be slightly reduced

5.1.3 Faults

5.1.3.1 Constants

Setting Item	Value	Justification
Fault Factor Default	1	Set to have no effect on HI where no fault data available

5.1.3.2 Fault Factor

The subtransmission fault factor is determined using the same method as distribution conductor, which is documented in Section 4.1.3.2. SA Power Network's operational history has found that subtransmission conductor is less prone to faults as the system is inherently redundant, this has been reflected in the normalised score bands.

> Normalised FM Score by Length Minimum	<= Normalised FM Score by Length Maximum	FM Factor	Justification
-1	0	1	Set to have no effect on HI as no faults have ever occurred
0	1	1.05	Fault density is very small indicating that negligible number of faults have occurred
1	2	1.1	Fault density indicates that the asset has caused a moderate number of faults
2	4	1.2	Fault density indicates that the asset has caused a significant number of faults
4	1,000.00	1.4	Regularly causing faults and is therefore problematic

5.1.4 Defects

Similarly to Distribution Conduction, CBRM uses two defect factors: Closed and Open. Closed defects represent completed repairs, and Open defects represent scheduled repairs.

5.1.4.1 Constants

Setting Item	Value	Justification
Defect Factor Default	1	Set to have no effect on HI

5.1.4.2 Closed Defect Factor

The closed defect factor is determined using the same method as distribution conductor, which is documented in Section 4.1.4.2.

> Normalised Closed Defects By Length Minimum	<= Normalised Closed Defects By Length Maximum	Closed Defects Factor	Justification
-1	0	1	No repairs have been undertaken
0	1	1.05	This is a low defect density indicating that minimal repairs have been required
1	2	1.1	The asset has experienced moderate repairs during its service life
2	5	1.25	Significant number of repairs have been undertaken on the conductor during its service life
5	1,000.00	1.5	Closed defect density indicates the asset needs to be repaired on a regular basis as it is problematic

5.1.4.3 Open Defect Factor

The open defect factor is determined using the same method as distribution conductor, which is documented in Section 4.1.4.3.

> Normalised Open Defects By Length Minimum	<= Normalised Open Defects By Length Maximum	Open Defects Factor	Justification
-1	0	1	There are no scheduled repairs
0	1	1.05	This is a low defect density indicating that minimal repairs are scheduled
1	2	1.1	There are some scheduled repairs to be undertaken on the asset
2	5	1.25	There are significant repairs to be completed
5	1,000.00	1.5	Excessive repairs are to be completed indicating the asset is problematic

5.1.5 HI1

HI1 is primarily age driven however it does take into account the duty and location factor. After CBRM determines HI1, it applies condition information to determine the overall HI the asset stands at today.

5.1.5.1 *Constants*

Setting Item	Value	Justification
Average Life Default	55	Where insufficient information is available to determine average life, a conservative approach is used in which the shortest lifespan is to be assigned. The default life is rarely used because the size and type is known for most conductor assets
As New HI Default	0.5	HI of 0.5 indicates a brand new asset
HI1 Cap	5.5	HI of 5.5 indicates beginning of serious degradation. CBRM process caps the HI at this value if no condition information is available
Reliability Rating Default	1	Used if no reliability rating is available, and assigns the asset as having normal reliability
LogCalc	2.397895273	Constant CBRM uses to determine HI

5.1.5.2 *Average Life*

The average life of subtransmission conductors was determined using the same method as distribution, which is documented in Section 4.1.5.2. The following table documents the average life for various conductor size and types.

Material	Size	Average Life
Aluminium	Thin	50
	Medium	60
	Thick	70
Copper	Thin	60
	Medium	80
	Thick	80

Conductor Material	Cond. Size & Type	Average Life	Justification
ACSR	0.015 ACSR	50	Thin aluminium conductor
ACSR	0.025 ACSR	50	Thin aluminium conductor
ACSR	0.03 ACSR	50	Thin aluminium conductor
ACSR	0.06 ACSR	50	Thin aluminium conductor

Conductor Material	Cond. Size & Type	Average Life	Justification
AAC	3.25 AAC	50	Thin aluminium conductor
ACSR	3.75 ACSR	50	Thin aluminium conductor
ACSR	35 ACSR	50	Thin aluminium conductor
Aluminium	0.06 ACSR	50	Thin aluminium conductor
Twisty	0.025 Twisty	50	Thin Conductor
ACSR	65 ACSR	60	Medium aluminium conductor
Aluminium	0.1 ACSR	70	Thick aluminium conductor
Steel	0.1 ACSR	70	Thick aluminium conductor
AAC	76 AAC	60	Medium aluminium conductor
Copper	0.0225 Cu	60	Thin copper conductor
Copper	0.025 Twisty	60	Thin copper conductor
Copper	0.035 Cu	60	Thin copper conductor
AAC	0.12 AAC	70	Thick aluminium conductor
AAC	122 AAC	70	Thick aluminium conductor
AAAC	0.1 Silmalec AAAC	60	Thin copper conductor
ACSR	0.1 ACSR	60	Thick aluminium conductor
ACSR	0.10S ACSR	60	Medium aluminium conductor
ACSR	0.12 AAC	60	Thick aluminium conductor
ACSR	0.12 ACSR	60	Thick aluminium conductor
ACSR	0.15 ACSR	70	Thick aluminium conductor
ACSR	0.225 ACSR	70	Thick aluminium conductor
ACSR	0.35 ACSR	70	Thick aluminium conductor
ACSR	0.5 ACSR	70	Thick aluminium conductor
ACSR	105 ACSR	70	Thick aluminium conductor
ACSR	144 ACSR	70	Thick aluminium conductor
ACSR	243 ACSR	70	Thick aluminium conductor

Conductor Material	Cond. Size & Type	Average Life	Justification
ACSR	244 ACSR	70	Thick aluminium conductor
AAAC	337 AAAC	70	Thick aluminium conductor
AAAC	586 AAAC	70	Thick aluminium conductor
AAC	300 AAC	70	Thick aluminium conductor
ACSR	508 ACSR	70	Thick aluminium conductor
ACSR	586 ACSR	70	Thick aluminium conductor
Copper	0.06 CU	80	Medium copper conductor
Copper	0.1 Cu	80	Thick copper conductor
Copper	0.1 Cu Double Circuit	80	Thick copper conductor
Copper	0.10 CU	80	Thick copper conductor
Copper	0.10CU	80	Thick copper conductor
Copper	0.15 Copper	80	Thick copper conductor
Copper	0.15 CU	80	Thick copper conductor
Copper	0.2 Copper	80	Thick copper conductor
Copper	0.2 Cu	80	Thick copper conductor
Copper	0.225 Double Circuit Copper	80	Thick copper conductor
Copper	0.25 Copper	80	Thick copper conductor
Copper	0.25 Double Circuit Copper	80	Thick copper conductor
Copper	0.3 Copper	80	Thick copper conductor
Copper	2.7 Copper	80	Thick copper conductor

5.1.5.3 As New HI
All conductor types are assigned an as new HI of 0.5, which indicates the asset is brand new.

5.1.6 Factor Value
Factor value is used to establish condition indicators to HI1, settings here include the default defect factor and reliability ratings.

5.1.6.1 Constants

Setting Item	Value	Justification
Reliability Rating Default	1	Refer to Section 5.1.6.3
Reliability Factor Default	1	Refer to Section 5.1.6.2
Defect Factor Default	1	Default where no SAP DD notification has been recorded in last 5 years

5.1.6.2 Reliability Factor

The Reliability Factor is used to identify problematic conductor types. Since the average life of the conductor type encapsulates its known performance on the network, all reliability ratings are set to assign a reliability factor of 1 (ie average reliability) and therefore have no effect on the HI.

5.1.6.3 Reliability Rating

As previously mentioned in Section 5.1.6.2, the average life of the conductor type encapsulates its known performance on the network, because of this, all of the reliability ratings have been set to indicate average reliability so there is no effect on the HI.

5.1.7 Failure Scenarios

Workshops undertaken with EA Technology CBRM Experts, Conductor SME and Asset Strategy Engineers identified that distribution conductor has the following failure scenarios:

- Fault: The conductor or its attachments fail, leading to conductor falling down and causing an outage;
- Repair: Inspectors identify that the conductor has defects which need repairing;
- Replacement: A significant proportion of the conductor needs to be replaced;
- Fire Start: The conductor starts a small bushfire; and
- Bush Fire: The conductor starts a major bushfire.

5.1.7.1 Constants

The HV database only contains records which impose STPIS penalties on SA Power Networks. When a fault occurs on subtransmission conductor no STPIS penalty is imposed as the fault either exceeds the SAIDI threshold for Major Events, or is bypassed using redundant lines. Subtransmission faults are documented in the SAP FM database, which is the only source of fault history available.

There is no way to determine if the faults were caused by condition or external events, so to overcome this, a decision was made in workshops with EA Technology, Asset Strategy Engineers and Conductor SME to ratio Condition : Non Condition as 4 : 1

Setting Item	Value	Justification
No. Failures: Condition Conductor Fault	20	SAP FM records created in the last 3 years show approximately 20-30 faults occur annually. Split 4:1 for condition and non condition. Earlier years could not be used as the data quality has improved in recent years
No. Failures: Condition Repairs	95	Total conductor repairs identified over last 5 years recorded in SAP database, under SAP codes:

Setting Item	Value	Justification
		LMD005=129, LMC013=343, LMD017=3: average repair jobs=95 per annum
No. Failures: Condition Replacement	2	The conductor replacement log documents the replacement projects undertaken for subtransmission conductor. Over the last 5 years, an average of two subtransmission conductor replacement projects have been completed annually
No. Failures: Condition Fire Start	0.018	Fire event rates are spread across all line assets using historic events recorded in the fire start database.
No. Failures: Condition Bushfire	0.003	Fire event rates are spread across all line assets using historic events recorded in the fire start database.
No. Failures: Non-Condition Conductor Fault	6	SAP FM database shows approximately 20-30 subtransmission conductor faults have occurred annually for the last 5 years. Split 4:1 for condition and non condition. SAP FM database is used instead of the HV database as most subtransmission faults have SAIDI exceeding Major Event threshold, or bypassed with redundant lines.
No. Failures: Non-Condition Fire Start	0.023	Fire event rates are spread across all line assets using historic events recorded in the fire start database.
No. Failures: Non-Condition Bush Fire	0.003	Fire event rates are spread across all line assets using historic events recorded in the fire start database.
C Value: Condition Conductor Fault	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4.
C Value: Condition Repairs	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4.
C Value: Condition Replacement	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4.
C Value: Condition Fire Start	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4.
C Value: Condition Bushfire	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4.
HI Lim: Condition Repairs	4	Industry standard setting for HI indicating onset of wear out
HI Lim: Condition Replacement	4	Industry standard setting for HI indicating onset of wear out

Setting Item	Value	Justification
HI Lim: Condition Fire Start	4	Industry standard setting for HI indicating onset of wear out
HI Lim: Condition Bushfire	4	Industry standard setting for HI indicating onset of wear out
HI Avg: Condition Conductor Fault	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HI Avg: Condition Repairs	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HI Avg: Condition Replacement	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HI Avg: Condition Fire Start	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HI Avg: Condition Bushfire	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HI Lim: Condition Conductor Fault	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim

5.1.8 Year 0 HI & PoF

5.1.8.1 Constants

Setting Item	Value	Justification
New Asset HI	0.5	Indicates a brand new asset
Minimum Health Index	0.5	Indicates a brand new asset
End of Life HI	7	CBRM process defines HI of 7 as representing an asset at end of life
HI Category Default	No Result	Used if HI cannot be determined
Maximum Y0 HI	10	CBRM caps today's HI to a value of 10
Bush Fire Factor Default	0	Most assets are located in Non Bush Fire Risk Areas

5.1.8.2 Bushfire Zone

BFRA_Level	Fire Risk Factor	Justification
No Fire Risk	0	No fire risk in this area
Non Bush Fire Risk Area	0	No fire risk in this area
Bush Fire Risk	1	Moderate Bush Fire Risk Area – Determined in workshop with Manager Network Asset Management and EA Technology CBRM Experts to use 1/10th fire risk compared to HBFRA conductor
Bush Fire Risk Area	1	Moderate Bush Fire Risk Area – Determined in workshop with Manager Network Asset Management and EA Technology CBRM Experts to use 1/10th fire risk compared to HBFRA conductor
High Bush Fire Risk Area	10	High Bush Fire Risk Area - Determined in workshop with Manager Network Asset Management and EA Technology CBRM Experts to use 10x fire risk compared to MBFRA conductor
High Fire Risk	10	High Bush Fire Risk Area - Determined in workshop with Manager Network Asset Management and EA Technology CBRM Experts to use 10x fire risk compared to MBFRA conductor

5.1.8.3 HI Category Y0
The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

5.1.8.4 Weighted Health Index Y0
The settings have been assigned to have no effect on results because the probability of event does not directly depend on voltage.

5.1.9 HI – Yn Health Index
HI – Yn represents the forecast future condition of the asset at Year Yn.

5.1.9.1 Constants

Setting Item	Value	Justification
Yn	11	2014-2025
Minimum Health Index	0.5	Represents a brand new asset
Maximum Yn HI	15	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Ageing Reduction Factor Default	1	If an ageing reduction factor cannot be applied, its effect is excluded from the results

Setting Item	Value	Justification
HI Category Default	No Result	Used for the case where HI cannot be determined
Ageing Constant from Y0 HI Maximum increase(multiplier)	1.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Minimum Age for Recalculated B	10	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Ageing Constant Multiplier Cap	1.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

5.1.9.2 Age Reduction Factor

The age reduction factor models the increased life expectancy as conductor ages. The factors and HI band were provided by the CBRM Architect and have been developed from EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

Final Asset HI Y0 Minimum	Final Asset HI Y0 Maximum	Ageing Reduction Factor
0	0	1
0	2	1
2	5.5	1.5
5.5	10	1.5

5.1.9.3 Future HI Category

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

5.1.9.4 Weighted Health Index Yn

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

5.2 RISK

5.2.1 Interventions

5.2.1.1 Constants

Setting Item	Value	Justification
Yn	11	Aligns 2014-2025
Percentage Replacement	0.35	Derived percentage of total network subtransmission conductor length to be replaced annually so a constant risk profile is maintained.

Setting Item	Value	Justification
% Replacement Ranking Column	Delta Risk	Prioritises based on difference in risk between existing and new asset
Replacement Default Cost	40000	Average unit cost of 66kV and 33kV replacement project
Portion of Route Length Replaced (%)	20	On average, SA Power Networks refurbishes 20% of a feeder
Maximum Health Index for Non Replaced Assets	4	80% of remaining feeder has a maximum HI of 4, representing the conductor is still in reasonable condition. A lower maximum HI for subtransmission conductor is used as SA Power Networks' operational experience has found that subtransmission feeders last longer than distribution types.

5.2.1.2 Percentage Replacement - Replacement Cost

The unit cost for 33kV conductor replacement was determined using completed conductor projects over the last 5 years and applying an escalation factor due to changing aluminium prices. The escalation factor was determined from annual prices documented by the London Metal Exchange.

The unit cost for 66kV conductor replacement was determined based on SA Power Networks' known operational experience, in which 1 Km route length costs $200,000. The cost of 1 Km conductor length is approximately 1/3rd of route length, which is $60,000.

5.2.1.3 Target Replacement – Replacement Cost

The costs assigned have no effect on results because a targeted replacement program is not used to justify replacement CAPEX.

5.2.1.4 New Asset

5.2.1.4.1 *Constants*

Setting Item	Value	Justification
New Asset HI	0.5	Represents a brand new asset
Average Life of New Asset	60	Determined in workshops with CBRM experts from EA Technology, Asset Strategy Engineers and Subtransmission Conductor SME

5.2.2 Criticality

Criticality is determined for each consequence category, it identifies the significance of a fault/failure, and is comprised of a number of weighting factors which represent relative severity.

5.2.2.1 Network Performance

Network Performance criticality represents significance of the penalty imposed on SA Power Networks when the asset causes an unplanned outage.

5.2.2.1.1 *Constants*

Setting Item	Value	Justification
Life Support Customers Factor Default	1	Sets factor when number of life support customers is unknown to be the same as no life support customers are supplied by the feeder
Customer Number NP Factor Default	1	Subtransmission fault affects many customers regardless of feeder SCONRRR
Customer Type Default Factor	1	Number of direct HV customers supplied by subtransmission line is generally small, amount of load lost is more significant
NP Minimum Factor	0.5	Satisfactory default established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
NP Maximum Factor	10	More emphasis is placed on Safety, Environment and Network Performance than CAPEX and OPEX

5.2.2.1.2 *Customer Type Factor*

Subtransmission fault places load at additional risk, which is independent of feeder SCONRRR, all settings have been assigned to have equal significance.

5.2.2.1.3 *Life Support Customer Factor*

More emphasis is placed on feeders supplying life support customers than those that do not. The values were provided by EA Technology and are based on their experience with over 30 Electrical Utilities in 10 countries worldwide.

> Life Support Customers Minimum	<= Life Support Customers Maximum	Life Support Customers Factor	Justification
-1	0	1	No life support customers. Has no effect on risk
0	3	1.1	Default established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
3	5	1.2	Default established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
5	20	1.25	Default established through EA Technology's

> Life Support Customers Minimum	<= Life Support Customers Maximum	Life Support Customers Factor	Justification
			past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
20	10,000	1.3	Default established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

5.2.2.1.4 *Number of Customers Factor*

Number of direct HV customers supplied by subtransmission line is generally small, amount of load lost is more significant as it places additional risk on the network. All settings have been assigned to have equal significance.

5.2.2.1.5 *Major Customer Factor*

Major customers represent high load customers such as factories and shopping centres. EA Technology's experience with over 30 Electrical Utilities in 10 countries worldwide has found that feeders supplying major customers are twice as significant as feeders that only supply residential customers.

5.2.2.2 OPEX

OPEX criticality represents the significance an event has on the Operational Expenditure required to remediate it.

5.2.2.2.1 *Constants*

Setting Item	Value	Justification
Opex Minimum Factor	0.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Opex Maximum Factor	5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Customer Type OPEX Factor Default	1	Most customers are located in Rural Short / Urban, therefore these regions are used if the customer type is unknown

5.2.2.2.2 *Customer Type Factor*

SCONRRR Category	Customer Type OPEX Factor	Justification
Urban	1	Set to have no effect based on SA Power Networks experience
Rural Short	1	Set to have no effect based on SA Power Networks experience
CBD	1.3	To allow for increased traffic management and switching costs associated with CBD
Rural Long	1.5	Deals with increased response time due to distance from nearest country depot

5.2.2.3 CAPEX

CAPEX criticality represents the significance an event has on the Capital Expenditure required to remediate it.

5.2.2.3.1 *Constants*

Setting Item	Value	Justification
Customer Type CAPEX Factor Default	1	Sets factor default when customer type unknown to be the same as for Rural Short / Urban, as most customers are located in these regions
Capex Minimum Factor	0.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Capex Maximum Factor	5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

5.2.2.3.2 *Customer Type Factor*

SCONRRR Category	Customer Type CAPEX Factor	Justification
Urban	1	Set to have no effect based on SA Power Networks experience
Rural Short	1	Set to have no effect based on SA Power Networks experience
Rural Long	1.05	Deals with increased response time due to distance from nearest country depot
CBD	1.1	Increased switch costs and traffic control, CBD subtransmission is n-1 hence easier to switch than CBD distribution

5.2.2.1 Environment

Environmental criticality represents the significance the asset has on the environment when an event occurs.

5.2.2.1.1 *Constants*

Setting Item	Value	Justification
Environmentally Sensitive Area Factor Default	1	Sets factor default when type unknown to be the same as Environment Rating '3', which is the norm for average environmental consequences based on EA Technology Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Env Minimum Factor	1	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Env Maximum Factor	10	More emphasis placed on Safety, Environment and Network Performance than CAPEX and OPEX

5.2.2.1.2 *Environmentally Sensitive Area Factor*

Environmentally Sensitive Area	Environmentally Sensitive Area Factor	Justification
1	0.5	Area 3 rating set as the norm for Average Environmental consequences per failure, adjusting down for 1 or 2 and up for 4.
2	0.7	Area 3 rating set as the norm for Average Environmental consequences per failure, adjusting down for 1 or 2 and up for 4.
3	1	Norm for Average Environmental consequences per failure, established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide 4.
4	2	Area 3 rating set as the norm for Average Environmental consequences per failure, adjusting down for 1 or 2 and up for 4.

5.2.2.2 Safety Factor

Safety criticality represents the significance the asset has on public and employee safety.

5.2.2.2.1 *Constants*

Setting Item	Value	Justification
Customer Type Default Factor	1	Default set to have no effect
Safety Minimum Factor	0.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Safety Maximum Factor	10	More emphasis placed on Safety, Environment and Network Performance than CAPEX and OPEX

5.2.2.2.2 *Customer Type Factor*

Provides facility to adjust by SCONRRR category, all regions have equal significance on safety.

5.2.3 Average Cost of a Fault

5.2.3.1 Network Performance

Network Performance consequences are the penalties imposed on SA Power Networks whenever an outage occurs. It is important to note that a significant proportion of the subtransmission conductor network is redundant, which means that a failure does not typically result in an outage. When a section of redundant line fails however, its load is no longer redundant, this load is classed as load put at additional risk. CBRM uses a direct calculation of the load put at additional risk and converts this to a dollar value using VCR.

A LAFF is then applied to the load at additional risk. The LAFF is a factor which uses a cubic relationship to quantify the additional risk when the load is above firm capacity of the network, it is calibrated to offset the Risk Factor (described in Section 5.2.3.1.4) with a value representing 1 for fully redundant and 20 for non redundant.

Network Performance consequences for radial (non redundant) subtransmission conductor is determined using VCR because the outage will have SAIDI exceeding the Major Event threshold therefore having no penalty imposed.

5.2.3.1.1 *Constants*

Setting Item	Value	Justification
CVALNP	0.037	Gives a 20:1 relationship between LAFF and % load above firm capacity
KVALNP	1	Gives a 20:1 relationship between LAFF and % load above firm capacity
Default Asset Redundancy	Redundant	A significant proportion of the subtransmission conductor network is redundant
LAFF Value Default for Non-Redundant Assets	1	Conservative approach is used in which assets with unknown LAFF are assumed to be fully redundant
Load Lost/Add. Risk Default	5	Sets a default value of 5MVA of load lost where actual load at additional risk is unknown. This value was determined in workshops with EA Technology CBRM Experts, Asset

Setting Item	Value	Justification
		Strategy Engineers, and Subtransmission Planning

5.2.3.1.2 *VCR Constants*

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
VCR ($) Redundant Assets	95700	47800	47800	47800	As per AER STPIS Report
Power Factor Redundant Assets	0.9	0.9	0.9	0.9	Recommended by the Manager Network Planning
Load Factor Redundant Assets	0.4	0.4	0.4	0.4	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
VCR ($) Non Redundant Assets	95700	47800	47800	47800	As per AER STPIS Report
Load Factor Non Redundant Assets	0.4	0.4	0.4	0.4	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Power Factor Non Redundant Assets	0.9	0.9	0.9	0.9	Recommended by the Manager Network Planning

5.2.3.1.3 *Non Redundant Constants*

Duration of non redundant outages has been derived using outages recorded in the HV database.

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
NP Avg. Restoration Time (hrs): Non Redundant Condition Conductor Fault	1.25	3	2.5	1.5	Determined from all available records in the HV database
NP Avg. Restoration Time (hrs): Non Redundant Condition Repair	0	0	0	0	This is a planned outage, and as such does not result in a STPIS penalty
NP Avg. Restoration	0	0	0	0	This is a planned outage, and as

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
Time (hrs): Non Redundant Condition Replacement					such does not result in a STPIS penalty
NP Avg. Restoration Time (hrs): Non Redundant Condition Fire Start	0	0	0	0	This is a major event, load at additional risk does not apply to bushfires as the network requires rebuilding.
NP Avg. Restoration Time (hrs): Non Redundant Condition Bush Fire	0	0	0	0	This is a major event, load at additional risk does not apply to bushfires as the network requires rebuilding.
NP Avg. Restoration Time (hrs): Non Redundant Non-Condition Conductor Fault	1.25	3	2.5	1.5	Determined from records stored in the HV database
NP Avg. Restoration Time (hrs): Non Redundant Non-Condition Bush Fire	0	0	0	0	This is a major event, load at additional risk does not apply to bushfires as the network requires rebuilding.
NP Avg. Restoration Time (hrs): Non Redundant Non-Condition Fire Start	0	0	0	0	This is a major event, load at additional risk does not apply to bushfires as the network requires rebuilding.
NP Avg. Repair/Replace Time Factor: Non Redundant Condition Conductor Fault	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Condition Repair	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Condition Replacement	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Condition	1	1	1	1	Entire restoration time is to undertake repair or replacement

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
Fire Start					
NP Avg. Repair/Replace Time Factor: Non Redundant Condition Bush Fire	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Non-Condition Conductor Fault	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Non-Condition Fire Start	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Non-Condition Bush Fire	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Risk Factor: Non Redundant Condition Conductor Fault	1	1	1	1	100% of load is lost when a fault occurs on a non redundant line
NP Avg. Risk Factor: Non Redundant Condition Repair	1	1	1	1	100% of load is lost when a fault occurs on a non redundant line
NP Avg. Risk Factor: Non Redundant Condition Replacement	1	1	1	1	100% of load is lost when a fault occurs on a non redundant line
NP Avg. Risk Factor: Non Redundant Condition Fire Start	1	1	1	1	100% of load is lost when a fault occurs on a non redundant line
NP Avg. Risk Factor: Non Redundant Condition Bush Fire	1	1	1	1	100% of load is lost when a fault occurs on a non redundant line
NP Avg. Risk Factor: Non Redundant Non-Condition Conductor Fault	1	1	1	1	100% of load is lost when a fault occurs on a non redundant line

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
NP Avg. Risk Factor: Non Redundant Non-Condition Fire Start	1	1	1	1	100% of load is lost when a fault occurs on a non redundant line
NP Avg. Risk Factor: Non Redundant Non-Condition Bush Fire	1	1	1	1	100% of load is lost when a fault occurs on a non redundant line

5.2.3.1.4 *Redundant Constants*

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
NP Avg. Restoration Time (hrs): Redundant Condition Conductor Fault	2.5	6	5	3	These values were determined in workshops with EA Technology CBRM Experts, Asset Strategy Engineers and Subtransmission Planning
NP Avg. Restoration Time (hrs): Redundant Condition Repair	0	0	0	0	Switching is undertaken to bypass the conductor during repairs
NP Avg. Restoration Time (hrs): Redundant Condition Replacement	0	0	0	0	Switching is undertaken to bypass the conductor during replacement
NP Avg. Restoration Time (hrs): Redundant Condition Fire Start	0	0	0	0	This is a major event, load at additional risk does not apply to bushfires as the network requires rebuilding.
NP Avg. Restoration Time (hrs): Redundant Condition Bush Fire	0	0	0	0	This is a major event, load at additional risk does not apply to bushfires as the network requires rebuilding.
NP Avg. Restoration Time (hrs): Redundant Non-Condition Conductor Fault	2.5	6	5	3	These values were determined in workshops with EA Technology CBRM Experts, Asset Strategy Engineers and Subtransmission Planning
NP Avg. Restoration Time (hrs): Redundant Non-Condition Fire	0	0	0	0	This is a major event, load at additional risk does not apply to bushfires as the the

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
Start					network requires rebuilding.
NP Avg. Restoration Time (hrs): Redundant Non-Condition Bush Fire	0	0	0	0	This is a major event, load at additional risk does not apply to bushfires as the network requires rebuilding.
NP Avg. Repair/Replace Time Factor: Redundant Condition Conductor Fault	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Condition Repair	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Condition Replacement	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Condition Fire Start	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Condition Bush Fire	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Non-Condition Conductor Fault	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Non-Condition Fire Start	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Non-Condition Bush Fire	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Risk Factor: Redundant Condition Conductor Fault	0.05	0.05	0.05	0.05	Redundant load lost is valued as 1/20th of Non Redundant Load. Satisfactory default established through EA

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
					Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Condition Repair	0.05	0.05	0.05	0.05	Redundant load lost is valued as 1/20th of Non Redundant Load. Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Condition Replacement	0.05	0.05	0.05	0.05	Redundant load lost is valued as 1/20th of Non Redundant Load. Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Condition Fire Start	0.05	0.05	0.05	0.05	Redundant load lost is valued as 1/20th of Non Redundant Load. Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Condition Bush Fire	0.05	0.05	0.05	0.05	Redundant load lost is valued as 1/20th of Non Redundant Load. Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Non-Condition Conductor Fault	0.05	0.05	0.05	0.05	Redundant load lost is valued as 1/20th of Non Redundant Load. Satisfactory default

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
					established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Non-Condition Fire Start	0.05	0.05	0.05	0.05	Redundant load lost is valued as 1/20th of Non Redundant Load. Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Non-Condition Bush Fire	0.05	0.05	0.05	0.05	Redundant load lost is valued as 1/20th of Non Redundant Load. Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

5.2.3.2 OPEX

OPEX consequences are the Operational Expenditure required in response to an event.

5.2.3.2.1 *Constants*

Setting Item	Value	Justification
Voltage Consequence Band Default	33kV	Biggest proportion of subtransmission feeders operate at 33kV

5.2.3.2.2 *Voltage Group Constants*

Setting Item	33kV	66kV	Justification
Opex Avg. Consequence: Condition Conductor Fault	1300	1300	Determined from Orders recorded against SAP FM Notifications for the last 5 years
Opex Avg. Consequence: Condition Repair	700	2000	Determined from Orders recorded against SAP DD Notifications for the last 5 years
Opex Avg.	0	0	All of conductor replacement is CAPEX

Setting Item	33kV	66kV	Justification
Consequence: Condition Replacement			
Opex Avg. Consequence: Condition Fire Start	2000000	2000000	A minor bushfire costs the business $2M, this value was determined by the Manager Network Asset Management
Opex Avg. Consequence: Condition Bushfire	250000000	250000000	A Catastrophic bushfire costs the business $250M, this value was determined by the Manager Network Asset Management
Opex Consequence: Non-Condition Conductor Fault	1300	1300	Determined from Orders recorded against SAP FM Notifications for the last 5 years
Opex Avg. Consequence: Non-Condition Bush Fire	250000000	250000000	A Catastrophic bushfire costs the business $250M, this value was determined by the Manager Network Asset Management
Opex Avg. Consequence: Non-Condition Fire Start	2000000	2000000	A minor bushfire costs the business $2M, this value was determined by the Manager Network Asset Management

5.2.3.2.3 *Voltage Band*

Based on SA Power Networks experience OPEX is dependent on build type rather than voltage. The Voltage Band assigns the build type to each line voltage.

Voltage	Voltage Consequence Band	Justification
33kV	33kV	33kV Build Type
66kV	66kV	66kV Build Type
132kV	66kV	66kV Build Type

5.2.3.3 CAPEX

CAPEX consequences are the Capital Expenditure required in response to an event.

5.2.3.3.1 *Constants*

Setting Item	Value	Justification
Opex:Capex Ratio	1	Based on SA Power Networks' operational experience CAPEX and OPEX are valued equally
Voltage Consequence Band Default	33kV	Biggest proportion of subtransmission feeders operate at 33kV

5.2.3.3.2 *Voltage Group Constants*

Setting Item	33kV	66kV	Justification
Capex Avg. Consequence: Cost of Conductor Fault	1500	1500	Determined from Orders recorded against SAP FM Notifications for the last 5 years
Capex Avg. Consequence: Condition Repair	4000	4000	Determined from Orders recorded against SAP DD Notifications for the last 5 years
Capex Avg. Consequence: Cost of Replacement	118000	200000	66kV conductor projects typically cost around 200k. For 33kV, completed conductor project information and escalation factor for metal prices for the last 5 years was used
Capex Avg. Consequence: Cost of Fire Start	0	0	Not used
Capex Avg. Consequence: Cost of Bushfire	0	0	Not used
Capex Avg. Consequence: Cost of Non-Condition Conductor Fault	1500	1500	Determined from Orders recorded against SAP FM Notifications for the last 5 years
Capex Avg. Consequence: Non-Condition Fire Start	0	0	Not used
Capex Avg. Consequence: Non-Condition Bush Fire	0	0	Not used

5.2.3.3.3 *Voltage Band*

Based on SA Power Networks experience CAPEX is dependent on build type rather than voltage. The Voltage Band assigns the build type to each line voltage.

Voltage	Voltage Consequence Band	Justification
33kV	33kV	33kV Build Type
66kV	66kV	66kV Build Type
132kV	66kV	66kV Build Type

5.2.3.4 SAFETY

5.2.3.4.1 *Consequences*

The safety consequences are valued in monetary terms, and have been assessed by establishing a value of safety event in terms of its adverse cost on society. CBRM uses the following consequences to determine safety risk:

- Minor – The event leads to an individual requiring medical treatment only;
- Major – The event incurs a lost time injury;
- Fatality – The event causes death or permanent disability.

EA Technology established the values for the three consequence types through collaboration with the Network Asset Management Group from SA Power Networks, the process that was used is outlined in Section 2 of Attachment A.

5.2.3.4.2 *Average Consequences*

The average safety consequences look at the frequency of all the events across all models, their determination is outlined in Section 3 of Attachment A.

5.2.3.5 Environment

5.2.3.5.1 *Consequences*

Five significant environmental consequences have been identified that could arise as a result of a network asset failure:

- Loss of oil;
- Emission of SF6 gas into the atmosphere;
- A significant fire with smoke pollution;
- The production of contaminated waste; and
- Major disturbance such as traffic congestion or noise.

CBRM assigns a monetary value to the environmental consequences based on trading values for carbon emissions. The overall process that was used to determine this is outlined in Section 2 of Attachment A.

5.2.3.5.2 *Failure Scenario Constants*

The average safety consequences look at the frequency of all the events across all models, their determination is outlined in Section 3 of Attachment A.

5.3 FEEDERS

Feeder calibration data is used for the determination of the Open/Closed defect and Fault condition factors for each asset.

5.3.1 Feeder Constants

Setting Item	Value	Justification
Feeders Ranking	Y0 Risk	This is used for reporting, it has no effect on the result
HI Category Default	No Result	Used when the HI cannot be determined

5.3.2 Feeder Data Constants

Setting Item	Value	Justification
SCONRR Priority Default	1	SCONRRR represents load per Km (load density). If the SCONRRR is unknown for a particular feeder a conservative approach in which the lowest load density is assigned
Major Customers Priority Default	1	Sets Major Customers default equivalent to 'No' when Major Customers information unknown
Default Fault Score	1	If the fault score cannot be determined, a conservative approach is used by assuming no faults have ever occurred

5.3.3 HI Y0 Category

These settings are used to generate reports in the CBRM front end client, they are assigned with default values provided by EA Technology and have no effect on results.

5.3.4 HI Yn Category

These settings are used to generate reports in the CBRM front end client, they are assigned with default values provided by EA Technology and have no effect on results.

5.3.5 Percentage Replacement HI Category

These settings are used to generate reports in the CBRM front end client, they are assigned with default values provided by EA Technology and have no effect on results.

5.3.6 Target Intervention Category

The CBRM front end uses these settings for reporting purposes. These have no effect on the results.

5.3.7 SCONRRR Priority

The SCONRRR category is based on load per km, the priority is assigned in the following order of precedence: CBD, Urban, Rural Long and Rural Short.

5.3.8 Major Customers Priority

Major Customer	Major Customers Priority	Justification
No	0	Converts Major Customer (Yes or No) to (1 or 0) for calculation purposes
Yes	1	Converts Major Customer (Yes or No) to (1 or 0) for calculation purposes

5.3.9 Fault Score

SAP FM notifications recorded against conductor within the last 5 years are used to determine the cumulative fault score for which is then converted to the fault density by normalising the score against the conductor length. For each fault, the fault score depends on the FM problem code.

Fault Score	Justification
0	Fault has no effect on conductor condition
0.5	Cannot identify level of significance fault has on conductor condition
1	Fault is fully relevant to conductor condition

5.3.10 Defect Score

SAP DD Notifications recorded against conductor with the last 5 years are used to determine the cumulative defect score which is then converted to the defect densities by normalising the score against the conductor length.

Defect Priority	Defect Score	Justification
4	0.5	Represents to condition monitor, defect does not have direct impact on short term reliability
3	1	Defect has impact on mid term reliability
2	1.5	Defect has impact on short to mid term reliability
1	2	Defect impacts short term reliability
Z	1	Z code does not necessarily mean the defect identifies poor condition, only fire risk, repair is of highest priority

5.3.11 Open/Closed Status

The determination of whether a SAP DD notification is open or closed is determined by checking if a NOCO flag has been assigned to the status.

6. POLES

6.1 Health Index

The Pole HI is determined from the following interim HIs:

- HI2 – Determined by combining HI1 with the defect factor;
- HI2a – Determined from condition measurements recorded in PAT; and
- HI2b – Determined from corrosion measurements.

CBRM combines the interim HIs by using HI2a to cap HI2b, calling the capped HI HI2a/b. If HI2a/b is higher than HI2, Year0 HI is assigned with HI2a/b, otherwise Year0 HI is assigned with average of HI2 and HI2a/b.

6.1.1 Location Factor

The Location Factor models how the installation environment affects the pole's condition over time. For example, poles located in the desert are less susceptible to atmospheric corrosion than poles located on the coastline.

6.1.1.1 Constants

Setting Item	Value	Justification
Pollution Factor Default	1	Set to have no effect on HI where no pollution data available
Ground Corrosion Zone Factor Default	1	Set to have no effect on HI where no ground corrosion data available
Atmospheric Corrosion Zone Default	1	Set to have no effect on HI where no atmospheric corrosion data available
Location Factor Increment	0.05	Satisfactory default established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Use Feeder Corrosion Yes/No	No	The pole's actual corrosion zone is used instead of the feeder's.

6.1.1.2 Pollution Factor

Based on SA Power Networks' operating experience, industrial pollution has no effect on pole condition and therefore has no effect on HI. For every record the pollution field has been left blank so the default factor of 1 is used.

6.1.1.3 Atmospheric Corrosion Zone

The corrosion zone indicates the impact corrosion will have on assets.

CBRM assigns a corrosion value to each corrosion zone. The mapping between the zones and ratings is shown in the following table.

Corrosion Zone	Corrosion Rating
Low	1
Moderate	2
High	3
Extreme	4

6.1.1.4 Atmospheric Corrosion Factor

Corrosion factors were determined in workshops with EA Technology CBRM Experts, Pole SME, Asset Strategy Engineers, and Manager Network Maintenance. The corrosion factor is assigned to the corresponding corrosion rating. The corrosion factors are based on the actual lifespan of poles in each corrosion zone, so that rather than use average lives for each corrosion zone, a standard average life is used for every pole, which modulated to its expected life according to the corrosion zone.

Corrosion Rating	Value
1	0.75
2	1
3	1.25
4	2

6.1.2 Pole Equipment

Pole equipment accounts for the wind loading a pole experiences as a consequence of supporting pole top assets. The factors were determined in workshops with EA Technology CBRM experts, Pole SME and Asset Strategy Engineers.

Setting Item	Value	Justification
BB Power Duty Factor Value	1.1	Equipment places moderate wind loading on the pole
Capacitor Duty Factor Value	1.1	Equipment places moderate wind loading on the pole
OH HV Recloser Duty Factor Value	1.1	Equipment places moderate wind loading on the pole
OH HV Sectionaliser Duty Factor Value	1.1	Equipment places moderate wind loading on the pole
OH HV Switch Duty Factor Value	1.1	Equipment places moderate wind loading on the pole
OH HV Term Joint Duty Factor Value	1.15	Equipment places high wind loading on the pole

Setting Item	Value	Justification
OH LV Switch Duty Factor Value	1.05	Equipment places low wind loading on the pole
OH LV Term Joint Duty Factor Value	1.1	Equipment places moderate wind loading on the pole
OH Tx Duty Factor Value	1.15	Equipment places high wind loading on the pole
OH-UG HV Joint Duty Factor Value	1.05	Equipment places low wind loading on the pole
OH-UG LV Joint Duty Factor Value	1	Equipment has no effect on wind loading
Public Light Duty Factor Value	1.05	Equipment places low wind loading on the pole
Regulator Duty Factor Value	1.15	Equipment places high wind loading on the pole

6.1.3 Duty Factor

Duty factor models how hard an asset has worked in its operational life. Workshops between EA Technology CBRM experts, Pole SME, Asset Strategy Engineers and the Manager Network Asset Management determined that most poles are designed to survive in their dedicated wind zones.

There are certain types of poles which have a reduced or extended life, these being service poles and transmission poles. Service poles are significantly smaller than all other poles and as a consequence they experience more mechanical stress in windy conditions. Transmission poles are significantly larger than every other pole and therefore experience minimal mechanical stress in all wind conditions.

6.1.3.1 Constants

Setting Item	Value	Justification
Default Size Function	Line	If the size function cannot be determined, it is assigned to be a line pole
Default Function Factor	1	If the function factor of a pole cannot be determined its effect on HI is ignored
Default Voltage Factor	1	If the voltage factor of a pole cannot be determined its effect on HI is ignored

6.1.3.2 Size Function

The size function is determined from the pole features stored in the GIS database. If a pole feature has no size function information, it is assigned as a line pole. This is deemed to be acceptable as the majority of HV poles on the network are line type poles.

6.1.3.3 Function Factor

Function Used	Function Factor	Justification
Tpole	0.95	Subtransmission Poles contain more steel than all other types and therefore experience less mechanical stress in all wind conditions
Dpole	1	Factor is set to 1 as the pole size has been chosen based on its function and environmental stresses
Line Pole	1	Factor is set to 1 as the pole size has been chosen based on its function and environmental stresses
Turnback/ Brace Pole	1	Factor is set to 1 as the pole size has been chosen based on its function and environmental stresses
Transformer Pole	1	Factor is set to 1 as the pole size has been chosen based on its function and environmental stresses
Angle Pole	1	Factor is set to 1 as the pole size has been chosen based on its function and environmental stresses
Dead End Pole	1	Factor is set to 1 as the pole size has been chosen based on its function and environmental stresses
Line	1	Factor is set to 1 as the pole size has been chosen based on its function and environmental stresses
Service Pole	1.1	Due to the smaller size of a service pole, it will experience more mechanical stress during windy conditions
Spole	1.1	Due to the smaller size of a service pole, it will experience more mechanical stress during windy conditions
Npole	1.2	Non ETSA pole, these are not built to the same standards, SA Power Networks' operational experience has found these have a tendency to fail pre maturely in windy conditions

6.1.3.4 Voltage Factor

Voltage factor is used to model the wind loading. Pole height is proportional to the line voltage it supports, and the majority of wind loading is exerted onto the pole by the conductor and pole top assets. This means that taller (higher voltage) poles will experience greater wind loading.

Max GIS Feeder Voltage	Voltage Factor	Justification
LV_LINE	0.85	The lower height of service poles reduces the amount of wind load they experience
LV_SERVICE	0.85	The lower height of service poles reduces the amount of wind load they experience

Max GIS Feeder Voltage	Voltage Factor	Justification
19kV	0.95	SWER poles have one phase of conductor, and therefore experience less wind loading
7.6kV	1	Pole experiences typical level of wind loading
11kV	1	Pole experiences typical level of wind loading
66kV	1.1	Higher voltage pole experiences a higher level of wind loading
33kV	1.1	Higher voltage pole experiences a higher level of wind loading

6.1.4 Defects

6.1.4.1 Constants

Setting Item	Value	Justification
Defect Factor Default	1	Used for the case where the defect factor cannot be determined, so there is no effect on HI
Defect Default Score	1	Used for the case where no defects have been identified, so there is no effect on HI

6.1.4.2 Defect Factor

Every pole defect stored in SAP is assigned a geocode, which is used to match the defect to its corresponding pole by using geospatial queries executed in GIS. CBRM identifies the associated defects with each pole and calculates a cumulative defect score.

> Overall Defect Score Minimum	<= Overall Defect Score Maximum	Defect Factor	Justification
0	0	1	This is a common occurrence, it means that the pole has never needed repairs, the factor is set to have no effect on HI
0	1	1.05	The pole required a minor repair during its service life
1	3	1.1	Multiple minor or significant repairs have been undertaken
3	5	1.2	Multiple significant repairs have been undertaken
5	10	1.3	Consistent repairs are required indicating the pole is at risk of failure

> Overall Defect Score Minimum	<= Overall Defect Score Maximum	Defect Factor	Justification
10	100	1.5	Persistent repairs are required indicating the pole could fail in the near future

6.1.4.3 Defect Score

Each defect has a score associated with it, which contributes towards the overall cumulative score. The defect score depends on the Coding Code and Priority of the DD notification recorded against the pole in SAP, and was determined in workshops with the EA Technology CBRM Experts, Pole SME, and Asset Strategy Engineers. CBRM uses all SAP DD notifications created in the last 5 years assigned with SAP codes related to poles.

Defect Coding Code Text	Defect Priority	Defect Score	Justification
POLE AGE PRTY4	1	0	This coding code is a placeholder for when a new pole is found on a network, it does not reflect condition
POLE AGE PRTY4	2	0	This coding code is a placeholder for when a new pole is found on a network, it does not reflect condition
POLE AGE PRTY4	3	0	This coding code is a placeholder for when a new pole is found on a network, it does not reflect condition
POLE ANGLE-TERM-T/OFF <50%	3	0.5	This identifies that a pole has minor corrosion
POLE LINE PLATE <50 %	3	0.5	This identifies that a pole has minor corrosion
POLE SERVICE <50%	3	0.5	This identifies that a pole has minor corrosion
FOOTING	3	0.5	This identifies that the pole footing has been damaged/exposed
POLE ANGLE TERM-T/OFF DAMAGED	3	0.5	This identifies that the pole has experienced minor structural damage
POLE LINE DAMAGED	3	0.5	This identifies that the pole has experienced minor structural damage
POLE SERVICE DAMAGED	3	0.5	This identifies that the pole has experienced minor structural damage

Defect Coding Code Text	Defect Priority	Defect Score	Justification
POLE LINE >50% RUSTED	3	0.5	This identifies that the pole has experienced significant corrosion, however remediation can be undertaken between 6 months to 2 years
POLE SERVICE >50%	3	0.5	This identifies that the pole has experienced significant corrosion, however remediation can be undertaken between 6 months to 2 years
POLE OTHER	3	0.5	Cannot determine impact on poles condition
POLE ANGLE-TERM-T/OFF >50%	3	0.5	This identifies that the pole has experienced significant corrosion, however remediation can be undertaken between 6 months to 2 years
POLE ANGLE-TERM-T/OFF <50%	2	1	This identifies that the pole has experienced minor corrosion which will need remediation within the next 6 months
POLE LINE PLATE <50 %	2	1	This identifies the pole needs to be plated in the next 6 months
POLE SERVICE <50%	2	1	This identifies the service pole has minor corrosion to be fixed in the next 6 months
FOOTING	2	1	This identifies damaged/exposed footing to be fixed in the next 6 months
POLE ANGLE TERM-T/OFF DAMAGED	2	1	This identifies the pole has experienced structural damage to be fixed in the next 6 months
POLE LINE DAMAGED	2	1	This identifies the pole has experienced structural damage to be fixed in the next 6 months
POLE SERVICE DAMAGED	2	1	This identifies the pole has experienced structural damage to be fixed in the next 6 months
POLE LINE >50% RUSTED	2	1	Pole has significant corrosion to be fixed in the next 6 months
POLE SERVICE >50%	2	1	Pole has significant corrosion to be fixed in the next 6 months
POLE OTHER	2	1	Established during workshops with EA Technology
POLE ANGLE-	2	1	Pole has significant corrosion to be fixed in the the

Defect Coding Code Text	Defect Priority	Defect Score	Justification
TERM-T/OFF >50%			next 6 months
FOOTING	4	1	Condition monitoring needs to be undertaken on the pole footing
POLE ANGLE-TERM-T/OFF <50%	4	1	Condition monitoring to be undertaken on the pole corrosion
POLE ANGLE-TERM-T/OFF >50%	4	1	Pole has significant corrosion
POLE LINE >50% RUSTED	4	1	Condition monitoring to be undertaken on the pole corrosion
POLE LINE DAMAGED	4	1	Condition monitoring to be undertaken on the damaged pole
POLE LINE PLATE <50 %	4	1	Condition monitoring to be undertaken for plating determination
POLE SERVICE >50%	4	1	Condition monitoring to be undertaken on pole corrosion
POLE SERVICE DAMAGED	4	1	Condition monitoring to be undertaken on pole damage
POLE ANGLE TERM-T/OFF DAMAGED	4	1	Condition monitoring to be undertaken on pole damage
POLE OTHER	4	1	Cannot identify overall impact on pole condition
POLE LINE >50% RUSTED	Z	2	Rusted pole exposes a fire start risk
POLE ANGLE TERM-T/OFF DAMAGED	Z	2	Damaged pole exposes a fire start risk
POLE ANGLE-TERM-T/OFF >50%	Z	2	Rusted pole exposes a fire start risk
FOOTING	1	2	Damaged/exposed footing exposes a bushfire risk

Defect Coding Code Text	Defect Priority	Defect Score	Justification
POLE ANGLE TERM-T/OFF DAMAGED	1	2	Damaged pole likely to fail, fix within 1 month
POLE LINE DAMAGED	1	2	Damaged pole likely to fail, fix within 1 month
POLE SERVICE DAMAGED	1	2	Damaged pole likely to fail, fix within 1 month
POLE LINE >50% RUSTED	1	2	Corroded pole likely to fail, fix within 1 month
POLE SERVICE >50%	1	2	Corroded pole likely to fail, fix within 1 month
POLE OTHER	1	2	Pole was likely to fail, fix within 1 month
POLE ANGLE-TERM-T/OFF >50%	1	2	Corroded pole likely to fail, fix within 1 month
POLE ANGLE-TERM-T/OFF <50%	1	2	Corroded pole likely to fail, fix within 1 month
POLE LINE PLATE <50 %	1	2	Pole needs to be plated in 1 month, or it may fail
POLE SERVICE <50%	1	2	Corroded pole likely to fail, fix within 1 month

6.1.5 Corrosion

CBRM uses corrosion measurements to determine the minimum and maximum possible HI of a pole.

6.1.5.1 Constants

Setting Item	Value	Justification
Problem Code Minimum HI Default	0.5	HI of 0.5 indicates the asset is brand new
Problem Code Maximum HI Default	10	HI of 10 indicates the pole is at end of life

6.1.5.2 HI 2(b) Measured Corrosion HI

Inspectors measure and record joist corrosion for every inspected pole. Originally the measurement was stored in a SAP defect that represented a pole asset, until recently when the PAT was commissioned. Each pole record in CBRM has a field which stores the joist corrosion measurement.

The joist corrosion measurement is the best indicator of condition because SA Power Networks' operational experience has found that corroded poles are more likely to fail. The corrosion measurement is converted to a HI2(b), indicating a HI based on corrosion. HI2(b) is combined with the age, duty and location based HI to determine an overall HI for each pole. There is a cap placed on HI2(b) to account for inconsistencies with corrosion measurement and a visual assessment, HI2(a) is used to determine this cap, and is further explained in Section 6.1.6.1.

The corrosion bands to HI score were determined in workshops with EA Technology CBRM Experts, Poles SME, and Asset Strategy Engineers.

> SAP Description % Corroded Minimum	<= SAP Description % Corroded Maximum	HI 2 (b) Measured Corrosion HI
-1	5	1
5	10	2
10	20	3
20	30	4
30	40	5.5
40	50	7
50	70	8
70	80	9
80	90	10
90	100	10

6.1.5.3 Problem Code Minimum HI

Defects assigned with the following problem codes can be used to identify the minimum HI for their corresponding pole.

SAP Prob. Code	Problem Code Minimum HI	Justification
CORRODED < 50%	0.5	Best case the pole is in brand new condition
DAMAGE	0.5	Pole is damaged, however unable to determine the extent
INADEQUATE	0.5	Pole is possibly inadequate for its use, however unable to determine its actual condition
CORRODED >50%	5	At best the pole is beginning to significantly wear out

6.1.5.4 Problem Code Maximum HI

Defects recorded under the following problem codes can be used to identify the maximum HI for the corresponding pole.

SAP Prob. Code	Problem Code Maximum HI	Justification
CORRODED <50%	5.5	At worst the pole is beginning to significantly wear out
CORRODED >50%	10	At worst the pole needs to be replaced
DAMAGE	10	At worst the pole needs to be replaced

6.1.6 Condition

6.1.6.1 HI 2(a) Highest Score HI

During recent inspections it has been made mandatory for inspectors to record an overall subjective assessment of the pole, which CBRM uses to determine the pole's worst case condition based HI by capping HI2(b). The condition map was decided in workshops participated by EA Technology CBRM Experts, Poles SME, and Asset Strategy Engineers.

Highest Condition Score	HI 2(a) Highest Score HI	Justification
1	0.5	Indicates very good condition pole
2	3	Indicates average condition pole
3	5	Indicates ageing pole
4	8	Pole is experiencing significant degradation

6.1.7 HI1

HI1 is primarily age driven however it does take into account the duty and location factor. After CBRM determines HI1, it applies condition information to determine the overall HI the asset stands at today.

6.1.7.1 Constants

Setting Item	Value	Justification
Average Life Default	60	Where insufficient information is available to determine average life, the average life of a service pole is assigned, as the majority of poles on the network provide a service function
As New HI Default	0.5	HI of 0.5 indicates a brand new asset
HI1 Cap	5.5	HI of 5.5 indicates beginning of serious degradation. CBRM process caps the HI at this value if no condition information is available
Plated Average Life	20	This is based on SA Power Networks' Operational Experience

Setting Item	Value	Justification
Plated As New HI	3	The condition of a recently refurbished pole is half way between brand new and wear out

6.1.7.2 Average Life

The average life of a pole depends on its size and type.

The size of an individual Stobie pole is determined by its height and channel width. The following map converts the size to a value between 1 and 7:

	Height	0 to 10	11 to 13	14 to 17	18 to 20	21 to 23	>23
Width	5	1	1	1	1	1	1
	6 to 15	2	2	3	4	5	7
	16 to 20	2	2	3	5	5	7
	21 to 25	2	2	3	5	6	7
	26 to 35	2	2	4	5	6	7
	36 to 50	2	2	4	6	6	7
	51 to 65	2	2	4	6	6	7
	>65	2	2	4	7	7	7

SAP Pole Size	Average Life	Justification
WOOD	35	The industry standard life of wooden poles is used here. It is rare to find a wooden pole on the network
TELECOM	35	These poles are the same as wooden poles, the industry standard life of wooden poles is used here. It is rare to find a wooden pole on the network
TOWER	60	This is based on SA Power Networks' operational experience, it is important to note that there are only 5 towers used in the network
TRAM_IRON	80	Based on SA Power Networks' operational experience in consultation with the poles SME
TUBULAR POLE	60	Based on SA Power Networks' operational experience in consultation with the poles SME
GALV_BOX	60	Based on SA Power Networks' operational experience in consultation with the poles SME
H_IRON	60	Based on SA Power Networks' operational experience in consultation with the poles SME
LATTICE	60	Based on SA Power Networks' operational experience in consultation with the poles SME

SAP Pole Size	Average Life	Justification
RAIL	60	Based on SA Power Networks' operational experience in consultation with the poles SME
TUB	60	Based on SA Power Networks' operational experience in consultation with the poles SME
1	60	Based on SA Power Networks' operational experience in consultation with the poles SME
2	65	Based on SA Power Networks' operational experience in consultation with the poles SME
3	70	Based on SA Power Networks' operational experience in consultation with the poles SME
4	75	Based on SA Power Networks' operational experience in consultation with the poles SME
5	80	Based on SA Power Networks' operational experience in consultation with the poles SME
6	85	Based on SA Power Networks' operational experience in consultation with the poles SME
7	90	Based on SA Power Networks' operational experience in consultation with the poles SME

6.1.7.3 As New HI

The as new HI for every pole is set to 0.5, to indicate it is brand new.

6.1.8 Failure Scenarios

Workshops undertaken with EA Technology CBRM Experts, Poles SME and Asset Strategy Engineers identified that poles have the following failure scenarios:

- Pole Break: The pole falls over;
- Replacement: Inspections determine the pole needs to be replaced;
- Plating: Inspections determine the pole needs to be plated;
- Fire Start: The pole falls over and starts a small bushfire; and
- Bush Fire: The pole falls over and starts a major bushfire.

Setting Item	Value	Justification
Total Asset Population Count	740001	There are approximately 740000 poles in the network
No. Failures: Condition Pole Break	50	Failure records in SAP indicate that 60 unassisted failures occurred in 2012, 80 in 2011, and 30 in 2010. Average of approx 50 per annum. Did not use pre 2010 data as information from

Setting Item	Value	Justification
		2010 onwards is better
No. Failures: Condition Bushfire	0.0007	Fire event rates are spread across all line assets using historic events recorded in the fire start database
No. Failures: Condition Fire Start	0.0046	Fire event rates are spread across all line assets using historic events recorded in the fire start database
No. Failures: Condition Replacement	1425	SAP DD notification records indicate 2266 replacements were completed in 2011, and 1239 replacements in 2010. Average annual replacements prior to this is 850 (2009-2005). Average of 850, 2266 and 1239 is approximately 1425[2]
No. Failures: Condition Plated	2330	SAP records indicate 2574 platings were completed in 2011, and 2070 completed in 2010, this indicates an average of 2330 platings annually. Last two years used, as plating is a more common practice on the network now. [3]
No. Failures: Non-Condition Pole Break	40	Based on SAP FM records, and the fact there is a rising trend of non condition events i.e. 2009: 23, 2010: 35, 2011: 39 and 2012: 36. Car hit poles are excluded as the cost is recoverable.
No. Failures: Non-Condition Fire Start	0.006	Fire event rates are spread across all line assets using historic events recorded in the fire start database
No. Failures: Non-Condition Bush Fire	0.001	Fire event rates are spread across all line assets using historic events recorded in the fire start database
C Value: Condition Pole Break	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4
C Value: Condition Bushfire	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4
C Value: Condition Fire Start	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4
C Value: Condition Replacement	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4
C Value: Condition Plated	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4
HI Lim: Condition Pole Break	4	Industry standard setting for HI where wear out phase begins
HI Lim: Condition Bushfire	4	Industry standard setting for HI where wear out phase begins

[2] To be reviewed as part of next CBRM update based on 2012, 2013 and 2014 data
[3] To be reviewed as part of next CBRM update based on 2012, 2013 and 2014 data

Setting Item	Value	Justification
HI Lim: Condition Fire Start	4	Industry standard setting for HI where wear out phase begins
HI Lim: Condition Replacement	4	Industry standard setting for HI where wear out phase begins
HI Lim: Condition Plated	4	Industry standard setting for HI where wear out phase begins
HI Avg: Condition Pole Break	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HI Avg: Condition Bushfire	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HI Avg: Condition Fire Start	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HI Avg: Condition Replacement	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HI Avg: Condition Plated	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim

6.1.9 Year 0 HI & PoF

6.1.9.1 Constants

Setting Item	Value	Justification
New Asset HI	0.5	Indicates a brand new asset
Minimum Health Index	0.5	Indicates a brand new asset
End of Life HI	7	CBRM process defines HI of 7 represents an asset at end of life
HI Category Default	No Result	Used if the HI cannot be determined
Maximum Y0 HI	10	CBRM caps today's HI to a value of 10
Bush Fire Factor Default	0	Most poles do not exist in MBFRA/HBFRA
Non-Condition PoF Probability: Fire Start Default	1	Basic unity default for PoF modifier for no net emphasis
Non-Condition PoF Probability: Bushfire Default	1	Basic unity default for PoF modifier for no net emphasis

6.1.9.2 Bushfire Zone

The Bushfire Zone is determined by matching the pole's geocode with regions defined in SA Power Networks' GIS.

GIS Bush Fire Risk	Fire Risk Factor	Justification
No Fire Risk	0	No fire risk in this area
Non Bush Fire Risk Area	0	No fire risk in this area
Bush Fire Risk	1	Moderate Bush Fire Risk Area - Determined in workshop with Manager Network Asset Management and EA Technology CBRM Experts to use 1/10th fire risk compared to HBFRA pole
Bush Fire Risk Area	1	Moderate Bush Fire Risk Area - Determined in workshop with Manager Network Asset Management and EA Technology CBRM Experts to use 1/10th fire risk compared to HBFRA pole
High Bush Fire Risk Area	10	High Bush Fire Risk Area - Determined in workshop with Manager Network Asset Management and EA Technology CBRM Experts to use 10x fire risk compared to MBFRA pole
High Fire Risk	10	High Bush Fire Risk Area - Determined in workshop with Manager Network Asset Management and EA Technology CBRM Experts to use 10x fire risk compared to MBFRA pole

6.1.9.3 External Probability Fire Start

GIS Bush Fire Risk	Non-Condition PoF Probability: Fire Start	Justification
No Fire Risk	0	No fire risk in this area
Bush Fire Risk	1	Moderate Bush Fire Risk Area - Determined in workshop with Manager Network Asset Management and EA Technology CBRM Experts to use 1/10th fire risk compared to HBFRA pole
High Fire Risk	10	High Bush Fire Risk Area - Determined in workshop with Manager Network Asset Management and EA Technology CBRM Experts to use 10x fire risk compared to MBFRA pole

6.1.9.4 External Probability Bush Fire

GIS Bush Fire Risk	Non-Condition PoF Probability: Bushfire	Justification
No Fire Risk	0	No fire risk in this area
Bush Fire Risk	1	Moderate Bush Fire Risk Area - Determined in workshop with Manager Network Asset Management and EA Technology CBRM Experts to use 1/10th fire risk compared to HBFRA pole
High Fire Risk	10	High Bush Fire Risk Area - Determined in workshop with Manager Network Asset Management and EA Technology CBRM Experts to use 10x fire risk compared to MBFRA pole

6.1.9.5 HI Category Y0

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

6.1.9.6 Weighted Health Index Y0

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

6.1.10 Yn Health Index

HI - Yn represents the future forecasted condition of the asset at Year Yn.

6.1.10.1 Constants

Setting Item	Value	Justification
Yn	11	2014-2025
Minimum Health Index	0.5	Represents a brand new asset
Maximum Yn HI	15	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Ageing Reduction Factor Default	1	If an ageing reduction factor cannot be applied, this value will be assigned leading to no effect on result
HI Category Default	No Result	Used if the HI cannot be determined
Ageing Constant from Y0 HI Maximum increase(multiplier)	1.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Minimum Age for Recalculated B	10	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

Setting Item	Value	Justification
Ageing Constant Multiplier Cap	1.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

6.1.10.2 Ageing Reduction Factor

The age reduction factor models the increased life expectancy as a pole ages. The factors were provided by the CBRM Architect and have been developed from EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

Final Asset HI Y0 Minimum	Final Asset HI Y0 Maximum	Ageing Reduction Factor
0	0	1
0	2	1
2	5.5	1.5
5.5	10	1.5

6.1.10.3 Future HI Category

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

6.1.10.4 Weighted Health Index Yn

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

6.2 RISK

6.2.1 Yn & Interventions

6.2.1.1 Constants

Setting Item	Value	Justification
Yn	11	Aligns 2014-2025
Percentage Intervention Per Year	1.2	Percentage of total pole population to be replaced/refurbished annually to maintain constant risk profile
% Replacement Ranking Column	Delta Risk	Prioritises based on difference in risk between existing asset and new asset
Replacement Default Cost	10000	Refer to Section 6.2.1.4
Average Life of New Asset	60	The average life of a service pole is assigned, because the majority of poles (including HV and LV) provide a service function
As New Duty Factor	1	The new pole is designed to meet the conditions

Setting Item	Value	Justification
		exposed to it by its environment
Plated Base HI	4	After refurbishment, the pole's condition is improved to be somewhere between brand new and the onset of wear out
Average Life of New Asset	60	The average life of a service pole is assigned, as the majority of poles on the network provide a service function
As New Duty Factor	1	The new pole is designed to meet the conditions exposed to it by its operating environment
Cost of Plating	1000	Refer to Section 6.2.1.4
HI As New Plated	3	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
New Asset HI	0.5	CBRM assigns a brand new asset with a HI if 0.5
Average Life of Plated Asset	20	Based on SA Power Networks' operational experience in consultation with the poles SME

6.2.1.2 Common Settings

Common settings have been assigned to set the percentage replacement to split annual interventions into 50% plating and 50% replacement. These values were determined by the Pole SME such that they align with SA Power Network's current operations.

6.2.1.3 Percentage Replacement Intervention Cost

Intervention costs are based on SA Power Networks' operating experience.

Intervention Applied	% Replacement Program Costs	Justification
Plated	1000	11kV plating cost used as most poles are 11kV type
Replacement	10000	11kV replacement cost used as most poles are 11kV type

6.2.1.4 Target Intervention Replacement Cost

Targeted intervention program is not used for pole CAPEX justification.

6.2.2 Criticality

Criticality is determined for each consequence category, it identifies the significance of a fault/failure, and is comprised of a number of weighting factors which represent relative severity.

6.2.2.1 *Network Performance*

Network Performance criticality represents significance of the penalty imposed on SA Power Networks when the asset causes an unplanned outage.

6.2.2.1.1 *Constants*

Setting Item	Value	Justification
Major Customers Factor Default	1	Most poles do not supply major customers
Life Support Customers Factor Default	1	Most poles do not supply customers on life support
Default Number of Circuits Factor	1	Most poles carry one feeder
NP Minimum Factor	0.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
NP Maximum Factor	10	More emphasis is placed on Network Performance, Safety and Environment than CAPEX and OPEX

6.2.2.1.2 *Pole Equipment*

The significance that pole equipment has on Network Performance is determined based on the fact that there are critical assets which take longer to restore. For example, a regulator is a critical asset towards network performance, it takes longer to restore than a less critical asset such as an LV switch.

6.2.2.1.3 *Number of Circuits Factor*

Number of Circuits Copy	Number of Circuits Factor	Justification
1	1	Only one phase needs to be restored
2	1.1	Multiple phases are to be restored
3	1.25	Multiple phases are to be restored
4	1.5	Multiple phases are to be restored

6.2.2.1.4 *Life Support Customer Factor*

More emphasis is placed on feeders supplying life support customers. The values were provided by EA Technology and are based on their experience with over 30 Electrical Utilities in 10 countries worldwide.

> Feeders: Life Support Customers Minimum	<= Feeders: Life Support Customers Maximum	Life Support Customers Factor	Justification
-1	0	1	No effect as no life support customers on the feeder

> Feeders: Life Support Customers Minimum	<= Feeders: Life Support Customers Maximum	Life Support Customers Factor	Justification
0	3	1.25	Default established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
3	5	1.5	Default established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
5	20	1.75	Default established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
20	10,000	2	Default established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

6.2.2.1.5 *Major Customer Factor*

Major customers represent high load customers such as factories and shopping centres. EA Technology's experience with over 30 Electrical Utilities in 10 countries worldwide has found that feeders supplying major customers are twice as significant as feeders that only supply residential customers.

6.2.2.1.6 *Highest Voltage on Pole*

The settings are used for reporting, and have no effect on results.

6.2.2.2 OPEX

OPEX criticality represents the significance an event has on the Operational Expenditure required to remediate it.

6.2.2.2.1 *Constants*

Setting Item	Value	Justification
Default Number of Circuits OPEX Factor	1	Set to have no effect on risk by default
OPEX Minimum Factor	0.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
OPEX Maximum Factor	5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

6.2.2.2.2 *Number of Circuits Factor*

Factors have assigned based the fact that it takes longer to restore more circuits, as well as the increased probability of fire starts when multiple conductors are down.

Number of Circuits Copy	Number of Circuits OPEX Factor
1	1
2	1.25
3	1.5
4	1.75

6.2.2.3 CAPEX

CAPEX criticality represents the significance an event has on the Capital Expenditure required to remediate it.

6.2.2.3.1 *Constants*

Setting Item	Value	Justification
Default Number of Circuits CAPEX Factor	1	Conservative approach to assume 1 circuit is on the pole if number of circuits cannot be determined
Capex Minimum Factor	0.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Capex Maximum Factor	5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

6.2.2.3.2 *Pole Equipment*

The significance that pole equipment has on Network Performance is determined based on the fact that some pole top assets are more expensive to repair/replace than others.

6.2.2.3.3 *Number of Circuits Factor*
Poles supporting more circuits have a longer restoration time and require more restoration materials.

Number of Circuits Copy	Number of Circuits CAPEX Factor
1	1
2	1.25
3	1.5
4	2

6.2.2.4 Environment
Environmental criticality represents the significance the asset has on the environment when an event occurs. It is dependent on the types of equipment supported by the pole

6.2.2.4.1 *Constants*

Setting Item	Value	Justification
Environmentally Sensitive Area Factor Default	1	Set to have the norm average as per the table below if the area cannot be determined
Env Minimum Factor	1	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Env Maximum Factor	10	More emphasis is placed on Network Performance, Safety and Environment than CAPEX and OPEX

6.2.2.4.2 *Pole Equipment*
Poles supporting oil filled assets have more significance on the environment because the assets may leak/spill.

6.2.2.4.3 *Environmentally Sensitive Area Factor*

Environmentally Sensitive Area	Environmentally Sensitive Area Factor	Justification
1	0.5	Area 3 rating set as the norm for Average Environmental consequences per failure, adjusting down for 1 or 2 and up for 4.
2	0.7	Area 3 rating set as the norm for Average Environmental consequences per failure, adjusting down for 1 or 2 and up for 4.
3	1	Norm for Average Environmental consequences per failure, established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10

Environmentally Sensitive Area	Environmentally Sensitive Area Factor	Justification
		countries worldwide 4.
4	2	Area 3 rating set as the norm for Average Environmental consequences per failure, adjusting down for 1 or 2 and up for 4.

6.2.2.5 Safety

Safety criticality represents the significance the asset has on public and employee safety.

6.2.2.5.1 *Constants*

Setting Item	Value	Justification
Default LV Shared Line Factor	1	If it cannot be determined if the pole supports both HV and LV lines the conservative approach is used to assume No
Safety Minimum Factor	0.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Safety Maximum Factor	10	More emphasis is placed on Network Performance, Safety and Environment than CAPEX and OPEX

6.2.2.5.2 *Pole Equipment*

The significance that pole equipment has on public and employee safety depends on its size. For example if comparing the risk of a pole top transformer falling down to a switch falling down it is clear that the transformer exposes public and employees to a greater level of risk. Poles supporting larger and heavier assets have been assigned more significance with regard to safety to reflect this.

6.2.2.5.3 *LV Shared on Pole Factor*

This factor is used to account for the possibility of HV being injected into the LV supply when the pole falls over.

LV Shared Line Copy	LV Shared Line Factor	Justification
No	1	There is no significance on safety if the pole does not support both HV and LV lines
Yes	1.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

6.2.3 Average Cost of a Fault

6.2.3.1 Network Performance

Network Performance consequences are the penalties imposed on SA Power Networks whenever an outage occurs. It is important to note that poles support both distribution and subtransmission conductor.

The failure of a pole supporting redundant subtransmission conductor does not typically result in an outage. When a section of redundant conductor fails however, its load is no longer redundant, this load is classed as load put at additional risk. CBRM uses a direct calculation of the load put at additional risk and converts this to a dollar value using VCR.

A LAFF is then applied to the load put at additional risk. The LAFF is a factor which uses a cubic relationship to quantify the additional risk when the load is above firm capacity of the network, it is calibrated to offset the Risk Factor (described in Section 6.2.3.1.4) with a value representing 1 for fully redundant and 20 for non redundant. These values are based on EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

Network Performance consequences for distribution (non redundant) poles is determined using the same methodology as distribution conductor in which the STPIS is used.

Network Performance consequences for radial subtransmission (non redundant) poles is determined using VCR because the outage will have SAIDI exceeding the Major Event threshold therefore having no STPIS penalty imposed.

6.2.3.1.1 *Constants*

Setting Item	Value	Justification
CVALNP	0.037	Gives a 20:1 relationship between LAFF and % load above firm capacity.
KVALNP	1	Gives a 20:1 relationship between LAFF and % load above firm capacity.
Type of Site Default	Urban	
Default Asset Redundancy	Redundant	If it cannot be determined that the pole is redundant, the conservative approach is used to assume full redundancy
LAFF Value Default for Non-Redundant Assets	1	Non-Redundant assets have no contingency on failure
Lost Load or Load at Additional Risk Default	5	Determined in workshops with EA Technology CBRM Experts, Asset Strategy Engineers, and Subtransmission Planning
11kV No. Customers Default	100	Used if no HV customers can be allocated to the pole. Determined in workshops with EA Technology CBRM Experts, Asset Strategy Engineers, and Poles SME

CBRM Justification

Setting Item	Value	Justification
LV No. Customers Default	20	Used if on LV customers can be allocated to the pole. Determined in workshops with EA Technology CBRM Experts, Asset Strategy Engineers, and Poles SME

6.2.3.1.2 *VCR Constants*

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
VCR ($) Redundant Assets	95700	47800	47800	47800	As per AER STPIS Report
Power Factor Redundant Assets	0.9	0.9	0.9	0.9	Recommended by the Manager Network Planning
Load Factor Redundant Assets	0.4	0.4	0.4	0.4	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
VCR ($) Non Redundant Assets	95700	47800	47800	47800	As per AER STPIS Report
Load Factor Non Redundant Assets	0.4	0.9	0.9	0.9	Determined in workshops with EA Technology CBRM Experts, Asset Strategy Engineers, and Subtransmission Planning
Power Factor Non Redundant Assets	0.9	0.4	0.4	0.4	Recommended by the Subtransmission Planning Manager

6.2.3.1.3 *Non Redundant Constants*

Duration of non redundant outages has been derived using outages recorded in the HV database.

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
NP Avg. Restoration Time (hrs): Non Redundant Condition Pole Break	2	5	5	4	Determined from records stored in the HV database for the past 5 years
NP Avg. Restoration Time (hrs): Non Redundant Condition Replacement	0	0	0	0	Condition replacement involves a planned outage

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
NP Avg. Restoration Time (hrs): Non Redundant Condition Plated	0	0	0	0	This is a planned outage, and as such does not result in a STPIS penalty
NP Avg. Restoration Time (hrs): Non Redundant Condition Fire Start	0	0	0	0	This is a planned outage, and as such does not result in a STPIS penalty
NP Avg. Restoration Time (hrs): Non Redundant Condition Bush Fire	0	0	0	0	This is a major event, no network performance penalty applies to bushfires as the network requires rebuilding.
NP Avg. Restoration Time (hrs): Non Redundant Non-Condition Pole Break	2	5	5	4	Determined from records stored in the HV database
NP Avg. Restoration Time (hrs): Non Redundant Non-Condition Bush Fire	0	0	0	0	This is a major event, no network performance penalty applies to bushfires as the network requires rebuilding.
NP Avg. Restoration Time (hrs): Non Redundant Non-Condition Fire Start	0	0	0	0	This is a major event, no network performance penalty applies to bushfires as the network requires rebuilding.
NP Avg. Repair/Replace Time Factor: Non Redundant Condition Pole Break	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Condition Replacement	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Condition Plated	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Condition Fire Start	1	1	1	1	Entire restoration time is to undertake repair or replacement

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
NP Avg. Repair/Replace Time Factor: Non Redundant Condition Bush Fire	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Non-Condition Pole Break	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Non-Condition Fire Start	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Non-Condition Bush Fire	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Risk Factor: Non Redundant Condition Pole Break	1	1	1	1	100% of load is lost when a non redundant line fails
NP Avg. Risk Factor: Non Redundant Condition Replacement	1	1	1	1	100% of load is lost when a non redundant line fails
NP Avg. Risk Factor: Non Redundant Condition Plated	1	1	1	1	100% of load is lost when a non redundant line fails
NP Avg. Risk Factor: Non Redundant Condition Fire Start	1	1	1	1	100% of load is lost when a non redundant line fails
NP Avg. Risk Factor: Non Redundant Condition Bush Fire	1	1	1	1	100% of load is lost when a non redundant line fails
NP Avg. Risk Factor: Non Redundant Non-Condition Pole Break	1	1	1	1	100% of load is lost when a non redundant line fails
NP Avg. Risk Factor: Non Redundant Non-Condition Fire Start	1	1	1	1	100% of load is lost when a non redundant line fails

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
NP Avg. Risk Factor: Non Redundant Non-Condition Bush Fire	1	1	1	1	100% of load is lost when a non redundant line fails

6.2.3.1.4 *Redundant Constants*

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
NP Avg. Restoration Time (hrs): Redundant Condition Pole Break	2	5	5	4	Determined from records stored in the HV database
NP Avg. Restoration Time (hrs): Redundant Condition Replacement	0	0	0	0	This is a planned outage, and as such does not result in a STPIS penalty
NP Avg. Restoration Time (hrs): Redundant Condition Plated	0	0	0	0	This is a planned outage, and as such does not result in a STPIS penalty
NP Avg. Restoration Time (hrs): Redundant Condition Fire Start	0	0	0	0	This is a major event, load at additional risk does not apply to bushfires as the network requires rebuilding.
NP Avg. Restoration Time (hrs): Redundant Condition Bush Fire	0	0	0	0	This is a major event, load at additional risk does not apply to bushfires as the network requires rebuilding.
NP Avg. Restoration Time (hrs): Redundant Non-Condition Pole Break	2	5	5	4	Determined from records stored in the HV database
NP Avg. Restoration Time (hrs): Redundant Non-Condition Fire Start	0	0	0	0	This is a major event, load at additional risk does not apply to bushfires as the network requires rebuilding.
NP Avg. Restoration Time (hrs): Redundant Non-Condition Bush Fire	0	0	0	0	This is a major event, load at additional risk does not apply to bushfires as the network requires rebuilding.
NP Avg. Repair/Replace Time Factor: Redundant Condition Pole Break	1	1	1	1	Entire restoration time is to undertake repair or replacement

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
NP Avg. Repair/Replace Time Factor: Redundant Condition Replacement	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Condition Plated	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Condition Fire Start	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Condition Bush Fire	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Non-Condition Pole Break	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Non-Condition Fire Start	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Non-Condition Bush Fire	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Risk Factor: Redundant Condition Pole Break	0.05	0.05	0.05	0.05	Redundant load lost is valued as 1/20th of Non Redundant Load. Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Condition Replacement	0.05	0.05	0.05	0.05	Redundant load lost is valued as 1/20th of Non Redundant Load. Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Condition Plated	0.05	0.05	0.05	0.05	Redundant load lost is valued as 1/20th of Non Redundant Load. Satisfactory default established

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
					through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Condition Fire Start	0.05	0.05	0.05	0.05	Redundant load lost is valued as 1/20th of Non Redundant Load. Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Condition Bush Fire	0.05	0.05	0.05	0.05	Redundant load lost is valued as 1/20th of Non Redundant Load. Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Non-Condition Pole Break	0.05	0.05	0.05	0.05	Redundant load lost is valued as 1/20th of Non Redundant Load. Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Non-Condition Fire Start	0.05	0.05	0.05	0.05	Redundant load lost is valued as 1/20th of Non Redundant Load. Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Non-Condition Bush Fire	0.05	0.05	0.05	0.05	Redundant load lost is valued as 1/20th of Non Redundant Load. Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

6.2.3.1.5 *11kV/LV Constants*

Value of CML	CBD	Rural Long	Rural Short	Urban	Last Update By
Value of CI	15.99	0.68	0.73	0.74	Determined using STPIS Rates and customer numbers obtained from the Network Performance and Regulatory Manager. CML is defined as SAIDI / Number of customers. CBD: $77,432/4,799; Urban: $431,766/584,615; Rural Short: $79,115/110,021; Rural Long: $96,760/143,337
Avg. No. CIs Per Fault	1462	94	84	62	Determined using STPIS Rates and customer numbers obtained from the Network Performance and Regulatory Manager. CI is defined as SAFI Incentive Rate / total customers, where SAIFI rate is converted from 0.01 interruption to 1 interruption. CBD: $70,783*100/4799; Urban: $359,393*100/584615; Rural Short: $90,873*100/110021; Rural Long: $134,597*100/143337.
NP Avg Duration of Outage (mins): Condition Pole Break 11kV	1	1	1	1	By definition, each customer on a radial feeder is interrupted during a fault
NP Avg Duration of Outage (mins): Condition Replacement 11kV	75	240	135	75	This was determined from records stored in the HV database for the last 5 years
NP Avg Duration of Outage (mins): Condition Plated 11kV	0	0	0	0	Planned outage during this event. No STPIS consequence is imposed
NP Avg Duration of Outage (mins):	0	0	0	0	Planned outage during this event. No STPIS consequence is imposed

Value of CML	CBD	Rural Long	Rural Short	Urban	Last Update By
Condition Fire Start 11kV					
NP Avg Duration of Outage (mins): Condition Bush Fire 11kV	0	0	0	0	Planned outage during this event. No STPIS consequence is imposed
NP Avg Duration of Outage (mins): Non Condition Pole Break 11kV	0	0	0	0	Planned outage during this event. No STPIS consequence is imposed
NP Avg Duration of Outage (mins): Non Condition Fire Start 11kV	75	240	135	75	This was determined from records stored in the HV database for the last 5 years
NP Avg Duration of Outage (mins): Non Condition Bush Fire 11kV	0	0	0	0	A bushfire is a major event, this means that no STPIS consequence is imposed as the network requires rebuilding
NP Avg Duration of Outage (mins): Condition Pole Break LV	0	0	0	0	The network performance consequences of LV outages are minimal
NP Avg Duration of Outage (mins):	30	240	135	35	This was determined from records stored in the HV database for the last 5 years

Value of CML	CBD	Rural Long	Rural Short	Urban	Last Update By
Condition Replacement LV					
NP Avg Duration of Outage (mins): Condition Plated LV	0	0	0	0	Planned outage during this event. No STPIS consequence is imposed
NP Avg Duration of Outage (mins): Condition Fire Start LV	0	0	0	0	Planned outage during this event. No STPIS consequence is imposed
NP Avg Duration of Outage (mins): Condition Bush Fire LV	0	0	0	0	A bushfire is a major event, this means that no STPIS consequence is imposed as the network requires rebuilding
NP Avg Duration of Outage (mins): Non Condition Pole Break LV	0	0	0	0	The network performance consequences of LV outages are minimal
NP Avg Duration of Outage (mins): Non Condition Fire Start LV	30	240	135	35	This was determined from records stored in the HV database for the last 5 years
NP Avg Duration of Outage (mins): Non Condition Bush Fire LV	0	0	0	0	A bushfire is a major event, this means that no STPIS consequence is imposed as the network requires rebuilding

6.2.3.2 OPEX

Setting Item	11kV	33/66kV	LV	Justification
Opex Avg. Consequence: Condition Replacement	0	0	0	All pole replacement is CAPEX
Opex Avg. Consequence: Condition Pole Break	0	0	0	All pole replacement is CAPEX
Opex Avg. Consequence: Condition Fire Start	2000001	2000001	2000001	A minor bushfire costs the business $2M, this value was determined by the Manager Network Asset Management
Opex Avg. Consequence: Condition Bush Fire 2	250000001	250000001	250000001	A catastrophic bushfire costs the business $250M, this value was determined by the Manager Network Asset Management
Opex Avg. Consequence: Condition Plated	0	0	0	All pole replacement is CAPEX
Opex Avg. Consequence: Non-Condition Pole Break	0	0	0	All pole replacement is CAPEX
Opex Avg. Consequence: Non-Condition Fire Start	2000001	2000001	2000001	A minor bushfire costs the business $2M, this value was determined by the Manager Network Asset Management
Opex Avg. Consequence: Non-Condition Bush Fire	250000001	250000001	250000001	A catastrophic bushfire costs the business $250M, this value was determined by the Manager Network Asset Management

6.2.3.3 CAPEX

Setting Item	11kV	33/66kV	LV	Justification
Opex : Capex Ratio	1	1	1	Based on SA Power Networks' operational experience CAPEX and OPEX are valued equally
Capex Avg. Consequence: Condition Replacement	10000	14000	7600	Based on SAP DD records with SAP codes related to pole replacement which were created within the last 5 years
Capex Avg. Consequence: Condition Pole Break	10500	14500	8500	SAP FM data could not be used to determine the CAPEX, however in consultation with the Pole SME, it was determined that the CAPEX required to repair a broken pole is similar to replacing on condition, but with additional CAPEX required to replace the broken pole top equipment as well
Capex Avg. Consequence: Condition Fire Start	0	0	0	Not used
Capex Avg. Consequence: Condition Bush Fire 2	0	0	0	Not used
Capex Avg. Consequence: Condition Plated	800	1500	650	These costs were determined from SA Power Network's operating experience
Capex Avg. Consequence: Non-Condition Pole Break	10500	14500	8500	SAP FM data could not be used to determine the CAPEX, however in consultation with the Pole SME, it was determined that CAPEX to repair a broken pole is similar to replacing on condition, but with additional CAPEX required to replace the broken pole top equipment as well
Capex Avg. Consequence: Non-Condition Fire Start	0	0	0	Not used
Capex Avg. Consequence: Non-Condition Bush Fire	0	0	0	Not used

6.2.3.4 SAFETY

6.2.3.4.1 *Consequences*

The safety consequences are valued in monetary terms, and have been assessed by establishing a value of a safety event in terms of its adverse cost on society. CBRM uses the following consequences to determine safety risk:

- Minor – The event leads to an individual requiring medical treatment only;
- Major – The event incurs a lost time injury;
- Fatality – The event causes death or permanent disability.

EA Technology established the values for the three consequence types through collaboration with the Network Asset Management Group, the process that was used is outlined in Section 2 of Attachment A.

6.2.3.4.2 *Average Consequences*

The average safety consequences look at the frequency of all the events across all models, their determination is outlined in Section 3 of Attachment A.

6.2.3.5 Environment

6.2.3.5.1 *Consequences*

Five significant environmental consequences have been identified that could arise as a result of a network asset failure:

- Loss of oil;
- Emission of SF6 gas into the atmosphere;
- A significant fire with smoke pollution;
- The production of contaminated waste; and
- Major disturbance such as traffic congestion or noise.

CBRM assigns a monetary value to the environmental consequences based on trading values for carbon emissions. The overall process that was used to determine this is outlined in Section 2 of Attachment A.

6.2.3.5.2 *Failure Scenario Constants*

The average safety consequences look at the frequency of all the events across all models, their determination is outlined in Section 3 of Attachment A.

7. SUBSTATION CIRCUIT BREAKERS – DISTRIBUTION

7.1 HEALTH INDEX

7.1.1 Location Factor

The Location factor models how the installation environment affects the Circuit Breaker's condition over time. For example, outdoor Circuit Breakers are more susceptible to atmospheric corrosion than units located indoors.

7.1.1.1 Constants

Setting Item	Value	Justification
Pollution Factor Default	1	Used if the pollution factor cannot be determined, and is set to have no effect on HI
Corrosion Default Factor	1	Used if the corrosion factor cannot be determined, and is set to have no effect on HI
Location Factor Increment	0.05	Determined as satisfactory value in workshop with EA Technology CBRM Experts, Asset Strategy Engineers and Circuit Breaker SME
Situation Default Factor	1	Used if the situation factor cannot be determined, and is set to have no effect on HI
Minimum Location Factor	0.9	Determined as satisfactory value in workshop with EA Technology CBRM Experts, Asset Strategy Engineers and Circuit Breaker SME
Surge Arrestor Default Factor	1	If surge arrestor field is undefined, the most common instance is assigned, being no surge arrestors installed
Situation With Air Conditioning Flag	Indoor Air Conditioned	

7.1.1.2 Pollution Factor

Pollution zones are manually assigned to each Circuit Breaker, this takes into account any corrosion the Circuit Breaker may experience due to its external environment. Factors were determined in workshops with EA Technology CBRM Experts, Circuit Breaker SME, and Asset Strategy Engineers.

Pollution	Pollution Factor	Justification
1	0.95	Extremely clean environment
2	1	Low pollution

Pollution	Pollution Factor	Justification
3	1.05	Average - medium issues
4	1.1	Industrial pollution – requires regular washing

7.1.1.3 Surge Arrestor Factor

There is a marginal benefit for CBs with Surge Arrestors, the amount was determined by the Circuit Breaker SME.

Surge Arrestor	Surge Arrestor Factor
Yes	0.95
No	1

7.1.1.4 Corrosion Factor

The corrosion factor models the effect of corrosion the installation environment has on the Circuit Breaker, the factor is assigned based on the Circuit Breaker's corrosion zone.

Corrosion Zone	Corrosion Factor	Justification
1	0.95	Low corrosion zone
2	1	Severe corrosion zone
3	1.05	Very severe corrosion zone
4	1.1	Extreme corrosion environment

7.1.1.5 Situation Factor

Circuit Breakers are installed in various situations, including air conditioned rooms and partially enclosed sheds. Factors have been assigned to model the situation's effect on the asset's life, and were determined by the Circuit Breaker SME in consultation with EA Technology CBRM Experts.

Situation with Air Con	Situation Factor	Justification
Indoor Air Conditioned	0.25	Constant environmental control
Building	0.5	Changed to match Indoor
Indoor	0.5	Some shelter from the environment
Building - Restricted	0.9	Better than outdoor, worse than indoor/building
Outdoor	1	Standard outdoor installation
Outdoor Cubicle	2	Units installed in sheet metal enclosure are very susceptible to environment

7.1.2 Feeders

7.1.2.1 Constants

Setting Item	Value	Justification
Class of Asset Default	Feeder	Majority of distribution CBs operate at 11kV
Number of Transformers at Sub Default	2	Assigned when the number of step down Transformers cannot be determined, standard zone sub arrangement is two step down Transformers

7.1.2.2 Class of Asset

The class of asset settings are used to convert the asset function code to a generic functional description for HI calculation.

7.1.3 Duty Factor

Duty factor models how hard an asset has worked in its operational life. Workshops between EA Technology CBRM experts, Circuit Breaker SME, and Asset Strategy Engineers determined that the prime indicators of Circuit Breaker duty are the number of faults it experiences during its operational life, the fault level (magnitude of electrical fault current,) and number of normal operations undertaken.

7.1.3.1 Constants

Setting Item	Value	Justification
Duty Factor Multiplier	0.05	Determined as satisfactory value in workshop with EA Technology CBRM Experts, Asset Strategy Engineers and Circuit Breaker SME
Fault Rating Factor Default	1	If the fault rating cannot be determined, it is excluded from HI determination
Fault Operations Factor Default	0.8	Circuit Breakers that have no recorded fault operation in the last 5 years are in better condition than those recently experiencing faults
Normal Operations Factor Default	1	If the number of normal operations cannot be determined, it is not used as part of the HI determination
Maximum Operations Default	20	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Number of Normal Operations Default	20000	If the maximum number of normal operations for the Circuit Breaker unit cannot be determined, the maximum normal operations for Reyrolle LMVP vacuum bottle is used

7.1.3.2 Maximum Fault Operations

The maximum number of fault operations was determined by the Circuit Breaker SME in consultation with EA Technology CBRM experts, who was advised to use the average number of fault operations experienced by each function for the last 5 years.

Function	Maximum Fault Ops
VCN	0.7
SEC	0.9
GEN	1
HVB	1
LVB	1
PTF	1.1
HVL	3.5
LVL	7.1

7.1.3.3 Maximum Normal Operations

The maximum number of normal operations was determined in workshops with EA Technology CBRM Experts and the Circuit Breaker SME, which identified that the operations are to be assigned with the following classifications: Oil, LV Switchgear, Vacuum and Reyrolle units. The Reyrolle maximum normal operations were available from the manufacturer user manual.

Unit Classification	Maximum Normal Ops
Oil	1000
LV Switchgear	5000
Vacuum	10000
Reyrolle	20000

7.1.3.4 Fault Rating Factor

Fault Rating Factor values and bands were established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

> Fault Rating Percentage Minimum	<= Fault Rating Percentage Maximum	Fault Rating Factor	Justification
0	30	0.8	Very low fault level
30	50	0.9	Light Fault Duty
50	70	1	No Effect

> Fault Rating Percentage Minimum	<= Fault Rating Percentage Maximum	Fault Rating Factor	Justification
70	90	1.1	High fault duty
90	1,000.00	1.2	Nearing Circuit Breaker's rating

7.1.3.5 Fault Operations Factor

Fault Operations Factor values and bands were established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

> % Fault Ops Minimum	<= % Fault Ops Maximum	Fault Ops Factor	Justification
-1	100	0.9	100% indicates the average number of fault operations for a functional location
100	200	1.05	1 - 2 times average fault duty
200	400	1.1	2 - 4 times average fault duty
400	600	1.15	4 - 6 time average fault duty
600	2,000.00	1.2	More than 6 times average fault duty

7.1.3.6 Normal Operations Factor

Normal Operations Factor values and bands were established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

> % Normal Ops Minimum	<= % Normal Ops Maximum	Normal Ops Factor	Justification
-1	30	0.9	Negligible Mechanical Wear
30	60	0.95	Low Mechanical Wear
60	90	1	Average Mechanical Wear
90	150	1.1	Possible Significant Mechanical Wear
150	200,000.00	1	Based on Circuit Breaker counter reading at inspection - not all are reliable indications of total Circuit Breaker operations

7.1.4 Faults

The number of faults a Circuit Breaker has experienced can be used to determine its condition, for example a Circuit Breaker which has experienced many faults during its operational life can be considered problematic.

7.1.4.1 Constants

Setting Item	Value	Justification
Fault Factor Default	0.95	No FM recorded in the last 5 years, indicates the asset is in better condition than anticipated
Default Fault Score	1	Used for the case where the cumulative fault score cannot be determined, and sets an average 'norm' effect towards the HI

7.1.4.2 Fault Score

The Cumulative Fault Score is determined by identifying all SAP FM records created in the last 5 years which correspond to the Circuit Breaker. The individual fault scores are summed together, with appropriate weighting based on the FM's priority and problem code.

The Fault Scores were determined in workshops with EA Technology CBRM Experts and the Circuit Breaker SME, they're based on how each fault effects the condition of a Circuit Breaker.

Fault Problem code Text	Fault Priority	Fault Score
Vibration	4	0.5
Wear or Abrasion	4	0.5
Mechanical Overload	4	0.5
Internal Fault	4	0.5
Corrosion	4	0.5
Design - Unsuitable or Incorrect	4	0.5
Electrical Overload	4	0.5
Failed to Operate	4	0.5
Fault Current - Unknown	4	0.5
Faulty Workmanship	4	0.5
Gasket Failure	4	0.5
High Resistance Joint	4	0.5
Age	4	0.5
Mechanical Overload	3	0.5
Internal Fault	3	0.5
Age	3	0.5

Fault Problem code Text	Fault Priority	Fault Score
Vibration	3	0.5
Wear or Abrasion	3	0.5
Design - Unsuitable or Incorrect	3	0.5
Electrical Overload	3	0.5
Failed to Operate	3	0.5
Fault Current - Unknown	3	0.5
Faulty Workmanship	3	0.5
Gasket Failure	3	0.5
High Resistance Joint	3	0.5
Corrosion	3	0.5
Mechanical Overload	2	1
Internal Fault	2	1
Vibration	2	1
Wear or Abrasion	2	1
Design - Unsuitable or Incorrect	2	1
Electrical Overload	2	1
Failed to Operate	2	1
Fault Current - Unknown	2	1
Faulty Workmanship	2	1
Gasket Failure	2	1
High Resistance Joint	2	1
Corrosion	2	1
Age	2	1
Cable Insulation Breakdown	1	1
FLASHED OVER	1	1
DAMAGE	1	1

Fault Problem code Text	Fault Priority	Fault Score
SUPPLY INTERRUPTION - 5 - WIDESPREAD	1	1
LOW OIL LEVEL	1	1.5
Overheating	1	1.5
Safety Hazard Fire	1	1.5
Safety Hazard Isolation required for safety Fire	1	1.5
Spring not Charged	1	1.5
Vermin / Pests in ETSA Equipment	1	1.5
Vibrating	1	1.5
Worn	1	1.5
Burnt	1	1.5
Misaligned	1	1.5
Corroded	1	1.5
Does Not Operate	1	1.5
Internal Electrical Fault	1	1.5
Arcing	1	1.5
Broken	1	1.5
Age	1	1.5
Internal Fault	1	1.5
Corrosion	1	1.5
Design - Unsuitable or Incorrect	1	1.5
Electrical Overload	1	1.5
Failed to Operate	1	1.5
Fault Current - Unknown	1	1.5
Faulty Workmanship	1	1.5
Gasket Failure	1	1.5

Fault Problem code Text	Fault Priority	Fault Score
High Resistance Joint	1	1.5
Mechanical Overload	1	1.5
Vibration	1	1.5
Wear or Abrasion	1	1.5

7.1.4.3 Fault Factor
The Cumulative Fault score is matched to a fault factor, which is used to determine if the Circuit Breaker is problematic. Factors and bands are based on EA Technology's CBRM experience with over 30 electrical utilities in 10 countries worldwide.

> Sum of FMs Scores Minimum	<= Sum of FMs Scores Maximum	Fm Factor	Justification
-1	0	1	Some (not important) defects recorded
0	1	1	↓
1	5	1.05	↓
5	10	1.1	↓
10	1,000.00	1.15	Many small or some significant failures against asset, indicating that the Circuit Breaker is problematic

7.1.5 Defects
The number of defects assigned against the Circuit Breaker can be a good indicator of its condition, for example a Circuit Breaker with lots of defects found within a small timeframe could be a problematic unit.

7.1.5.1 Constants

Setting Item	Value	Justification
Defect Factor Default	0.95	If no defect has been recorded against the Circuit Breaker in the last 5 years, it is in better condition than anticipated
Default Defect Score	1	If the cumulative defect score cannot be determined, it is excluded from the HI determination

7.1.5.2 Defect Score
The Cumulative Defect Score is determined by identifying all SAP SD records created in the last 5 years which correspond to the Circuit Breaker. The individual defect scores are summed together, with appropriate weighting based on the SD's priority and problem code.

CBRM Justification

The Defect Score was determined in workshops with EA Technology CBRM Experts and the Circuit Breaker SME, and is based on how the defect affects the condition of a Circuit Breaker.

Defect Problem Code	Defect Priority	Defect Score
VERMIN	4	0.5
WORN / ABRADED	4	0.5
MAL OPERATION	4	0.5
MISALIGNMENT	4	0.5
MAL OPERATION	3	0.5
MISALIGNMENT	3	0.5
OVERHEATING	4	0.5
PITTED CONTACTS	4	0.5
POLLUTION	4	0.5
RESISTANCE HIGH	4	0.5
RESISTANCE LOW	4	0.5
SEIZED	4	0.5
TRACKING	4	0.5
TRIP FREE	4	0.5
INCORRECT OPERATION	4	0.5
LEAKING	4	0.5
LOW GAS PRESSURE	4	0.5
LOW OIL LEVEL	4	0.5
FAILURE	4	0.5
FIRE	4	0.5
FLASHED OVER	4	0.5
HIGH THERMAL IMAGE	4	0.5
FAILURE	3	0.5
FIRE	3	0.5
FLASHED OVER	3	0.5

Defect Problem Code	Defect Priority	Defect Score
HIGH THERMAL IMAGE	3	0.5
VERMIN	3	0.5
WORN / ABRADED	3	0.5
BROKEN	4	0.5
BURNT	4	0.5
CONTAMINATED OIL	4	0.5
CORRODED <50%	4	0.5
CORRODED >50%	4	0.5
CRACKED	4	0.5
DAMAGE	4	0.5
EXCESSIVE NOISE	4	0.5
OVERHEATING	3	0.5
PITTED CONTACTS	3	0.5
POLLUTION	3	0.5
RESISTANCE HIGH	3	0.5
RESISTANCE LOW	3	0.5
SEIZED	3	0.5
TRACKING	3	0.5
TRIP FREE	3	0.5
INCORRECT OPERATION	3	0.5
LEAKING	3	0.5
LOW GAS PRESSURE	3	0.5
LOW OIL LEVEL	3	0.5
BROKEN	3	0.5
BURNT	3	0.5
CONTAMINATED OIL	3	0.5

Defect Problem Code	Defect Priority	Defect Score
CORRODED <50%	3	0.5
CORRODED >50%	3	0.5
CRACKED	3	0.5
DAMAGE	3	0.5
EXCESSIVE NOISE	3	0.5
VERMIN	2	1
WORN / ABRADED	2	1
MAL OPERATION	2	1
MISALIGNMENT	2	1
FAILURE	2	1
FIRE	2	1
FLASHED OVER	2	1
HIGH THERMAL IMAGE	2	1
OVERHEATING	2	1
PITTED CONTACTS	2	1
POLLUTION	2	1
RESISTANCE HIGH	2	1
RESISTANCE LOW	2	1
SEIZED	2	1
TRACKING	2	1
TRIP FREE	2	1
INCORRECT OPERATION	2	1
LEAKING	2	1
LOW GAS PRESSURE	2	1
LOW OIL LEVEL	2	1
BROKEN	2	1

Defect Problem Code	Defect Priority	Defect Score
BURNT	2	1
CONTAMINATED OIL	2	1
CORRODED <50%	2	1
CORRODED >50%	2	1
CRACKED	2	1
DAMAGE	2	1
EXCESSIVE NOISE	2	1
VERMIN	1	1.5
WORN / ABRADED	1	1.5
MAL OPERATION	1	1.5
MISALIGNMENT	1	1.5
FAILURE	1	1.5
FIRE	1	1.5
FLASHED OVER	1	1.5
HIGH THERMAL IMAGE	1	1.5
OVERHEATING	1	1.5
PITTED CONTACTS	1	1.5
POLLUTION	1	1.5
RESISTANCE HIGH	1	1.5
RESISTANCE LOW	1	1.5
SEIZED	1	1.5
TRACKING	1	1.5
TRIP FREE	1	1.5
INCORRECT OPERATION	1	1.5
LEAKING	1	1.5
LOW GAS PRESSURE	1	1.5

Defect Problem Code	Defect Priority	Defect Score
LOW OIL LEVEL	1	1.5
BROKEN	1	1.5
BURNT	1	1.5
CONTAMINATED OIL	1	1.5
CORRODED <50%	1	1.5
CORRODED >50%	1	1.5
CRACKED	1	1.5
DAMAGE	1	1.5
EXCESSIVE NOISE	1	1.5
ERODED	1	1.5
Maloperation	1	1.5

7.1.5.3 Defect Factor

The Cumulative Defect Score is assigned a defect factor, which is used to determine if the Circuit Breaker is problematic. Factors and bands are based on EA Technology's CBRM experience with over 30 electrical utilities in 10 countries worldwide.

> Sum of Defect Scores Minimum	<= Sum of Defect Scores Maximum	SD Factor	Justification
-1	0	1	Some (not important) defects recorded
0	1	1.05	↓
1	5	1.1	
5	10	1.15	
10	1,000.00	1.2	Many small or some significant failures against asset, indicating the Circuit Breaker is problematic

7.1.6 Condition

7.1.6.1 Constants

Setting Item	Value	Justification
Condition Factor Multiplier	0.05	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
I2T Default Factor	1	If factor cannot be determined it has no effect on HI
DCR Default Factor	1	If factor cannot be determined it has no effect on HI
Timing Test Default factor	1	If factor cannot be determined it has no effect on HI
Insulation Resistance Default Factor	1	If factor cannot be determined it has no effect on HI
Maintenance 1 Default Factor	1	If factor cannot be determined it has no effect on HI
Maintenance 2 Default Factor	1	If factor cannot be determined it has no effect on HI
Maintenance 3 Default Factor	1	If factor cannot be determined it has no effect on HI
Maintenance 4 Default Factor	1	If factor cannot be determined it has no effect on HI
Visual Inspection 1 Default Factor	1	If factor cannot be determined it has no effect on HI
Visual Inspection 2 Default Factor	1	If factor cannot be determined it has no effect on HI
I2T Default Minimum HI	0.5	If the Minimum HI cannot determined, the result has no effect on HI
DCR Default Minimum HI	0.5	If the Minimum HI cannot determined, the result has no effect on HI
Timing Test Default Minimum HI	0.5	If the Minimum HI cannot determined, the result has no effect on HI
Insulation Resistance default Minimum HI	0.5	If the Minimum HI cannot determined, the result has no effect on HI
Maintenance 1 Default Minimum HI	0.5	If the Minimum HI cannot determined, the result has no effect on HI

Setting Item	Value	Justification
Maintenance 2 Default Minimum HI	0.5	If the Minimum HI cannot determined, the result has no effect on HI
Maintenance 3 Default Minimum HI	0.5	If the Minimum HI cannot determined, the result has no effect on HI
Maintenance 4 Default Minimum HI	0.5	If the Minimum HI cannot determined, the result has no effect on HI
Visual Inspection 1 Default Minimum HI	0.5	If the Minimum HI cannot determined, the result has no effect on HI

7.1.6.2 I2T Factor
SA Power Networks does not undertake I2T measurements, this feature will be used in the future.

7.1.6.3 DCR Factor
SA Power Networks does not undertake DCR measurements, this feature will be used in the future.

7.1.6.4 Timing Test Factor
SA Power Networks does not undertake Timing Test measurements, this feature will be used in the future.

7.1.6.5 Insulation Resistance Factor
SA Power Networks does not currently measure insulation resistance.

7.1.6.6 Maintenance 1 Factor
This feature is to be used for future condition measurements.

7.1.6.7 Maintenance 2 Factor
This feature is to be used for future condition measurements.

7.1.6.8 Maintenance 3 Factor
This feature is to be used for future condition measurements.

7.1.6.9 Maintenance 4 Factor
This feature is to be used for future condition measurements.

7.1.6.10 Visual Inspection 1 Factor
Visual measurements are recorded by inspectors into the PAT. The measurements are manually assigned a score between 1 and 4, which CBRM uses as part of determining HI.

Visual Inspection 1	Visual Inspection 1 Factor	Justification
1	0.9	No visual corrosion
2	1	Minor corrosion
3	1.1	Severe corrosion
4	1.2	Major corrosion

7.1.6.11 *Visual Inspection 2 Factor*
Visual measurements are recorded by inspectors into the PAT. The measurements are manually assigned a score between 1 and 4, which CBRM uses as part of determining HI.

Visual Inspection 2	Visual Inspection 2 Factor	Justification
1	0.9	No visual corrosion
2	1	Minor corrosion
3	1.1	Severe corrosion
4	1.2	Major corrosion

7.1.6.12 *I2T Minimum HI*
SA Power Networks does not undertake I2T measurements, this feature will be used in the future.

7.1.6.13 *DCR Minimum HI*
SA Power Networks does not undertake DCR measurements, this feature will be used in the future.

7.1.6.14 *Timing Test Minimum HI*
SA Power Networks does not undertake Timing Test measurements, this feature will be used in the future.

7.1.6.15 *Insulation Resistance Minimum HI*
SA Power Networks does not undertake Insulation Resistance measurements, this feature will be used in the future.

7.1.6.16 *Maintenance 1 Minimum HI*
This feature is to be used for future condition measurements.

7.1.6.17 *Maintenance 2 Minimum HI*
This feature is to be used for future condition measurements.

7.1.6.18 *Maintenance 3 Minimum HI*
This feature is to be used for future condition measurements.

7.1.6.19 *Maintenance 4 Minimum HI*
This feature is to be used for future condition measurements.

7.1.6.20 *Visual Inspection 1 Minimum HI*
This feature is to be used for future condition measurements.

7.1.6.21 *Visual Inspection 2 Minimum HI*
This feature is to be used for future condition measurements.

7.1.7 Overdue Maintenance
The HI of a Circuit Breaker degrades if it is not maintained within the specified interval. CBRM factors this by identifying if the last maintenance date exceeds maintenance requirements for the particular Circuit Breaker.

7.1.7.1 Constants

Setting Item	Value	Justification
Days Between Maintenance Default	1643	Maintenance manual specifies 4.5 year maintenance interval
Default Days Between Maintenance	0	If the last maintenance date cannot be determined, the conservative approach is used in which the unit is assigned to be the most recently maintained

7.1.7.2 Days Between Maintenance

In accordance with SA Power Networks' operational requirements, the maintenance interval for all CBs is set to 1643 days (i.e. 4.5 years).

7.1.7.3 Overdue Maintenance Factor

The overdue maintenance factor is assigned based the number of days maintenance is late. The value and bands were established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

> Days Overdue Minimum	<= Days Overdue Maximum	Overdue Maintenance factor	Justification
-1	183	1	No Effect
183	365	1.05	6 months - 1 year overdue
365	730	1.1	1 to 2 years overdue
730	100,000.00	1.15	More than 2 years overdue

7.1.8 Partial Discharge

7.1.8.1 Constants

Setting Item	Value	Justification
Offline Default	1	Used if offline testing results do not exist, has no effect on HI
Ultrasonic Factor	1	Used if ultrasonic factor cannot be determined, has no effect on HI
TEV Default Rating		Blank rating assigned if TEV rating cannot be determined
Default TEV Factor	1	Used if TEV factor cannot be determined, has no effect on HI

7.1.8.2 Ultrasonic Factor
The Ultrasonic Factor accounts for ultrasonic test results and modifies the Circuit Breaker's HI according to the Ultrasonic Activity. The factors were established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

Ultrasonic Activity	Ultrasonic Factor	Justification
Amber	1	Sporadic ultrasonic activity when tested over last 5 years
Green	0.9	No detected ultrasonic activity in last 5 years
Red	1.2	Regular Ultrasonic activity when tested

7.1.8.3 TEV Rating
The TEV rating is used to identify problematic units, it is determined from the TEV score. The score bands were established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

> Tev Score Minimum	<= Tev Score Maximum	TEV Rating
0	15	Green
15	30	Amber
30	1,000.00	Red

7.1.8.4 TEV Factor
The TEV factor modifies the Circuit Breaker's HI according to the TEV Rating. The factors were established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

TEV Rating	TEV Factor	Justification
Green	0.9	No activity or stable readings over last 5 years
Amber	1	No activity or fluctuating / inconclusive readings over last 5 years
Red	1.15	Regular activity when tested / trending upwards

7.1.8.5 Offline PD Factor
There are no offline PD test results.

7.1.9 HI1
HI1 is primarily age driven however it does take into account the duty and location factor. After CBRM determines HI1, it applies condition information to determine the overall HI the asset stands at today.

7.1.9.1 Constants

Setting Item	Value	Justification
Average Life Default	65	For all Circuit Breakers, the average life has been assigned the REPEX calibrated life of 65 years.
As New HI Default	0.5	HI of 0.5 indicates a brand new asset
HI1 Cap	5.5	HI of 5.5 indicates beginning of serious degradation. CBRM process caps the HI at this value if no condition information is available
Reliability Rating Default	1	Used if no reliability rating is available, and assigns the asset as having normal reliability
LogCalc	2.397895273	Model Constant set by EA Technology

7.1.9.2 Average Life
For all Circuit Breakers, the average life has been assigned the REPEX calibrated life of 65 years.

7.1.9.3 As New HI
All Circuit Breakers are assigned an as new HI of 0.5, which indicates they're brand new.

7.1.10 Factor Value
7.1.10.1 Constants

Setting Item	Value	Justification
Reliability Rating Default	1	If the Circuit Breaker has no reliability rating assigned to it, the unit is assumed to have no common problems
Reliability Factor Default	1	If a reliability factor cannot be assigned to the reliability rating, the unit is assumed to have no common problems
Defect Factor Default	0.95	Default where no SAP defect recorded in last 5 years, indicates the Circuit Breaker is in better condition than anticipated
Overall Defect/Fault Factor Multiplier	0.05	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

7.1.10.2 Reliability Factor
The Reliability Factor identifies Circuit Breaker models with inherent design faults. The factors were established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

CBRM Justification

Reliability Rating	Reliability Factor	Justification
1	0.9	Operation & maintenance requirements normal, no common problems of type
2	1	Minor/occasional corrective maintenance required in comparison to above models
3	1.15	Significant additional corrective maintenance required in comparison to score 1's; Type has a history of high priority/forced outages to fix; numerous planned outage extensions required to correct problems (discovery of problems during maintenance); failure in service attributable to design
4	1.3	Repeat forced outages/failures of type; significant mechanical problems; maintenance not cost effective; difficult to bring up to spec (timing/travel etc) during maintenance without major work

7.1.11 Failure Scenarios

Workshops undertaken with EA Technology CBRM Experts, The Circuit Breaker SME and Asset Strategy Engineers identified that distribution Circuit Breakers have the following failure scenarios:

- Minor: Substation inspections identify the Circuit Breaker requires minor repairs;
- Significant: The Circuit Breaker fails and requires major repairs for restoration;
- Major: The Circuit Breaker catastrophically fails and needs to be replaced;
- Replacement: The Circuit Breaker is replaced as it is in poor condition; and
- Fail to Trip: The Circuit Breaker fails to clear a fault resulting in an upstream protection trip.

7.1.11.1 Constants

Setting Item	Value	Justification
No. Failures: Condition Minor	42	Calculated from SAP - annual number of SAP SD Notifications created over last 5 years (excluding those closed (NOCO) without being issued to FS (ISFS) and notifications associated with other failure types.
No. Failures: Condition Significant	1.0	Any disruptive failure is considered Significant or Major (includes forced interruptions & 'simple fix' failures that cause protection to operate i.e. low oil trips). Statistics are gathered from records of in-service failures and (unplanned) condition replacement
No. Failures: Condition Major	1.4	Any disruptive failure is considered Significant or Major (includes forced interruptions & 'simple fix' failures that cause protection to operate i.e. low oil trips). Statistics are gathered from records of in-service failures and (unplanned) condition replacement
No. Failures: Condition	2.0	Average number of condition replacements completed over the last 5 years. Excludes historical 'targeted intervention' &

Setting Item	Value	Justification
Replacement		refurbishment program
No. Failures: Condition Failure To Trip	0.6	Statistics are gathered from records of in-service failures for the last 5 years. Failure to trip occurs when a breaker cannot clear a fault, causing upstream protection to activate
No. Failures: Non-Condition Minor	3	Calculated from SAP - annual number of SAP SD Notifications created over last 5 years (excluding those closed (NOCO) without being issued to FS (ISFS) and notifications associated with other failure types.
No. Failures: Non-Condition Significant	0.6	No data for last 5 years - Any disruptive failure is considered Significant or Major (includes forced interruptions & 'simple fix' failures that cause protection to operate i.e. low oil trips). Statistics are gathered from records of in-service failures and (unplanned) condition replacement
No. Failures: Non-Condition Major	0.1	Any disruptive failure is considered Significant or Major (includes forced interruptions & 'simple fix' failures that cause protection to operate i.e. low oil trips). Statistics are gathered from records of in-service failures and (unplanned) condition replacement
HI Lim: Condition Minor	4	Industry standard setting for HI where wear out PoF curve begins
HI Lim: Condition Significant	4	Industry standard setting for HI where wear out PoF curve begins
HI Lim: Condition Major	4	Industry standard setting for HI where wear out PoF curve begins
HI Lim: Condition Failure to Trip	4	Industry standard setting for HI where wear out PoF curve begins
HI Lim: Condition Replacement	4	Industry standard setting for HI where wear out PoF curve begins
HI Avg: Condition Minor	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HI Avg: Condition Significant	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HI Avg: Condition Major	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HI Avg: Condition Failure to Trip	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HI Avg: Condition	4	Standard CBRM setting to maintain constant PoF equivalent to

Setting Item	Value	Justification
Replacement		HI=4 for HI < HI Lim
Cval: Condition Minor	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4.
Cval: - Condition Significant	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4.
Cval: Condition Major	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4.
Cval: Condition Failure to Trip	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4.
C Value: Condition Replacement	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4.

7.1.12 Year 0 HI & PoF

7.1.12.1 Constants

Setting Item	Value	Justification
New Asset HI	0.5	Indicates a brand new asset
Minimum Health Index	0.5	Indicates a brand new asset
End of Life HI	7	CBRM process defines HI of 7 represents an asset at end of life
HI Category Default	No Result	Used if HI cannot be determined
Substation HI Category Default	No Result	Used if HI cannot be determined
Maximum Y0 HI	10	CBRM caps today’s HI to a value of 10
Grouping Multiplier Default	0	Used if HI cannot be determined

7.1.12.2 HI Category Y0

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

7.1.12.3 Weighted Health Index Y0

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

7.1.13 HI – Yn Health Index

HI – Yn represents the future forecasted condition of the asset at Year Yn.

7.1.13.1 Constants

Setting Item	Value	Justification
Yn	11	2014 to 2025
Minimum Health Index	0.5	Represents a brand new asset
Maximum Yn HI	15	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Ageing Reduction Factor Default	1	If an ageing reduction factor cannot be applied, its effect is excluded from the HI determination
HI Category Default	No Result	Used for the case where HI cannot be determined
Ageing Constant from Y0 HI Maximum increase(multiplier)	1.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Minimum Age for Recalculated B	10	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Ageing Constant Multiplier Cap	1.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

7.1.13.2 Age Reduction Factor

The age reduction factor models the increased life expectancy as CBs age. The factors and HI bands were provided by the CBRM Architect and have been developed from EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

Final Asset HI Y0 Minimum	Final Asset HI Y0 Maximum	Ageing Reduction Factor
0	0	1
0	2	1
2	5.5	1.5
5.5	10	1.5

7.1.13.3 Future HI Category

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

7.1.13.4 Weighted Health Index Yn

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

7.2 RISK

7.2.1 Interventions

7.2.1.1 Constants

Setting Item	Value	Justification
Yn	11	2014-2025
Percentage Replacement	0.35	Percentage of Circuit Breaker population to be replaced annually so that a constant risk profile is maintained
% Replacement Ranking Column	Delta Risk	Prioritises based on difference in risk between existing asset and new asset
Replacement Default Cost	550000	Based on replacement of 25 indoor Circuit Breaker panels (Tea Tree Gully x 7, Ingle Farm x 9, Campbelltown x 9)
Refurbishment Default Cost	25000	Has no effect on results as refurbishment is determined external to CBRM. Refer to Section 7.2.1.8
Average Life of New Asset	65	For all CBs, the average life has been assigned the REPEX calibrated life of 65 years.
As New Duty Factor	1	Normal duty factor is assigned to the replaced asset

7.2.1.2 Future Year % Replacement HI Category

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

7.2.1.3 Future Year Target Intervention HI Category

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

7.2.1.4 Percentage Replacement Weighted Health Index

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

7.2.1.5 Target Replacement Weighted Health Index

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

7.2.1.6 Percentage Replacement Cost of Replacement

SA Power Networks’ operational experience has found that HV distribution Circuit Breaker replacement costs do not vary with voltage, and therefore $550,000 has been assigned as the replacement cost for all distribution Circuit Breakers.

LV Circuit Breakers have been excluded from the model as their replacement cost, risk level and total population is small in comparison to HV units.

CBRM Justification

The replacement cost was determined using costing records from recent replacement projects in which 25 indoor Circuit Breaker panels (Tea Tree Gully x 7, Ingle Farm x 9, Campbelltown x 9) were replaced.

7.2.1.7 Targeted Intervention Replacement Cost

Targeted intervention has not been used to justify replacement CAPEX.

7.2.1.8 Targeted Intervention Refurbishment Cost

CBRM is used to determine Replacement CAPEX, refurbishment is determined external to CBRM and is justified within the Circuit Breaker Asset Management Plan.

7.2.1.9 New Asset

Setting Item	Value	Justification
New Asset HI	0.5	Represents a brand new asset

7.2.2 Criticality

Criticality is determined for each consequence category, it identifies the significance of a fault/failure, and is comprised of a number of weighting factors which represent relative severity.

7.2.2.1 Network Performance Criticality

Network Performance criticality represents significance of the penalty imposed on SA Power Networks when the asset causes an unplanned outage.

7.2.2.1.1 *Constants*

Setting Item	Value	Justification
Obsolescence Rating Default	2	Set to have no significance on risk if obsolescence rating cannot be determined
Spares/Obsolescence NP Factor Default	1	Set to have no significance on risk if obsolescence factor cannot be determined
Single Bus Section Factor	1	Conservative approach is to assume there are multiple bus sections
Major Customer Default Factor	1	If major customers cannot be determined, the conservative approach is used in which the feeder is assumed to only supply residential customers
SCADA Site Factor Default	1	Set to have no effect on risk if it cannot be determined that SCADA is installed in the substation
Number of Feeders Factor Default	1	No emphasis is placed on the number of feeder exists because customer numbers are used instead
NP Minimum Factor	0.5	Satisfactory default established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
NP Maximum Factor	10	Satisfactory default established through EA

Setting Item	Value	Justification
		Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

7.2.2.1.2 *Spares/Obsolescence*

Spares/Obsolescence places more Network Performance significance on the Circuit Breaker units that require spare parts which are difficult to source, and varies according to the unit's make and type.

Spares/Obsolescence	Justification
1	Manufacturers current product line, ready whole/component spares are in stock
2	Minimal spares but manufacturer/aftermarket parts are available. Catastrophic failure is covered by replacement with a modern equivalent.
3	Spares are only available through retirement of (aged) in service units (of average/uncertain condition).
4	Asset cannot easily be replaced with a modern equivalent, and no existing spares or vendor support is available.

7.2.2.1.3 *Spares/Obsolescence Factor*

The Spares/Obsolescence factor is assigned to the Spares/Obsolescence rating, it directly adjusts the Network Performance criticality. Factor values were established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

Spares/Obsolescence	Spares/Obsolescence NP Factor
1	0.5
2	1
3	1.5
4	2

7.2.2.1.4 *Single Bus Section Factor*

Substations with single bus section will result in a full substation outage, and are assigned more significance than those with multiple bus sections.

7.2.2.1.5 *Number of Feeders Factor*

No emphasis is placed on the number of feeder exists because customer numbers are used instead.

7.2.2.1.6 *Major Customer Factor*

Major Customer	Major Customer Factor	Justification
No	1	No effect
Yes	1.5	Reflects delays in restoration when coordinating switching with customer network

7.2.2.1.7 *SCADA Site Factor*

Substations with SCADA have faster restoration times because the location and occurrence of faults is immediately identified.

SCADA Site	SCADA Site Factor	Justification
Yes	0.5	Relative speed of dispatch and directed fault response due to SCADA monitoring
RTU	0.5	Relative speed of dispatch and directed fault response due to RTU monitoring
TDU	1.25	Very basic indication
Indicating	1.5	Basic indication only
None	2.5	Slow speed of dispatch and lack of directed fault response due to lack of SCADA monitoring
No	2.5	Slow speed of dispatch and lack of directed fault response due to lack of SCADA monitoring

7.2.2.1 OPEX Criticality

OPEX criticality represents the significance an event has on the Operational Expenditure required to remediate it.

7.2.2.1.1 *Constants*

Setting Item	Value	Justification
Medium Factor Default	1	If the medium of the Circuit Breaker cannot be determined, it is set to have no significance on risk
Opex Minimum Factor	0.5	Satisfactory default established through EA Technology’s CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Opex Maximum Factor	10	Satisfactory default established through EA Technology’s CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Spares/Obsolescence OPEX Factor Default	1	If the Spares/Obsolescence factor cannot be determined it is set to have no significance on risk

Setting Item	Value	Justification
Number of Feeders Factor Default	1	No emphasis is placed on the number of feeder exists because customer numbers are used
Substation Customer Type Factor (OPEX) Default	1	If the substation customer type cannot be determined the assumption is made that the unit supplies urban customers as this is the most common customer type.

7.2.2.1.2 ***Medium Factor***

The Medium factor emphasizes cleanup costs for spillages.

Medium	OPEX Medium Factor	Justification
Air	1	No clean up costs
Vacuum	1	No clean up costs
Small Bulk Oil	1.5	Additional work of oil handling/repair/cleanup
VACUUM/SF6	2	Additional work of repair/cleanup
Bulk Oil	3	Additional work of oil handling/repair/cleanup
SF6	3	Additional work of repair/cleanup

7.2.2.1.3 ***Spares/Obsolescence Factor***

Spares/Obsolescence places more OPEX significance on Circuit Breaker units requiring spare parts that are difficult to source.

Spares/Obsolescence	Spares/Obsolescence OPEX Factor	Justification
1	0.5	Modern Equipment - quicker restoration/repair
2	1	Average equipment/spares holdings
3	2	Reflects time spent looking/rebuilding spare parts
4	3	Reflects additional time spent looking/rebuilding spare parts

7.2.2.1.4 *Number of Feeders Factor*

OPEX does not depend on total feeder exits, and as such the settings have been assigned to have no effect on risk.

7.2.2.1.5 *Substation Customer Type Factor*

SCONRRR Category	Substation Customer Type Factor	Justification
Urban	1	Base standard
Rural Short	1.2	Additional travel times, LAFA, and remote allowances
Rural Long	1.5	Additional travel times, LAFA, and remote allowances
CBD	2	Movement, access, and switching requirements within CBD are difficult

7.2.2.2 CAPEX Criticality

CAPEX criticality represents the significance an event has on the Capital Expenditure required to remediate it.

7.2.2.2.1 *Constants*

Setting Item	Value	Justification
Voltage Factor (CAPEX) Default	1	If the voltage cannot be determined it is set to have no significance on risk
Substation Customer Type Factor (CAPEX) Default	1	If the customer type cannot be determined it is set to have no significance on risk
Capex Minimum Factor	0.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Capex Maximum Factor	10	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

7.2.2.2.2 *Voltage Factor*

SA Power Networks' operational experience has found that with the exception of LV Circuit Breakers, there is no voltage significance on CAPEX for HV Circuit Breakers.

7.2.2.2.3 *Substation Customer Type Factor*

SCONRRR Category	Substation Customer Type Factor (CAPEX)	Justification
Urban	1	Set to have no effect based on SA Power Networks experience
Rural Short	1	Set to have no effect based on SA Power Networks experience
Rural Long	1	Set to have no effect based on SA Power Networks experience
CBD	1.25	Additional cost of suitable equipment for CBD

7.2.2.3 Environment Criticality

Environmental criticality represents the significance the asset has on the environment when an event occurs.

7.2.2.3.1 *Constants*

Setting Item	Value	Justification
Pre-Oil Containment System Factor Default	1	If it cannot be determined if oil containment is installed, the significance on environment is ignored
Env Minimum Factor	0.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Env Maximum Factor	10	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Env Consequence: Default Medium Type	Oil	Most units are oil filled

7.2.2.3.2 *Environment Risk Assessment Factor*

The environmental risk assessment is made outside of CBRM and varies asset to asset, it is used to identify the level of impact failure of the Circuit Breaker will have on the environment.

Environmental Risk Assessment	Environment Risk Assessment Factor
Low	1
Medium	1.5
High	3

7.2.2.3.3 *Medium Type*
These calibration settings are used for reporting in the CBRM client, and have no significance on risk.

7.2.2.4 Safety Criticality
Safety criticality represents the significance the asset has on public and employee safety.

7.2.2.4.1 *Constants*

Setting Item	Value	Justification
Bushing Insulation Type Default	1	If the bushing insulation type cannot be determined, its significance on safety is ignored
Internal Arc Rated Safety Factor Default	2	Assumes no containment unless specified
Medium Factor Default	1	If the type of medium cannot be determined, its significance on safety is ignored
Situation Factor Default	1	If the installation situation cannot be determined, its significance on safety is ignored
Safety Minimum Factor	0.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Safety Maximum Factor	10	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

7.2.2.4.2 *Internal Arc Rated Factor*
Internal Arc Containment reduces a Circuit Breaker's significance on safety.

Internal Arcing	Internal Arc Rated Safety Factor	Justification
A-FLR/25kA/1s	1	The Circuit Breaker is fully fault contained
A-FL/15kA/1s	1	The Circuit Breaker is fully fault contained
Mixed	1.5	Some internal Fault containment installed
None	2	No internal Fault Containment installed

7.2.2.4.3 *Bushing Insulation Type Factor*
Bushing Insulation Type factor places more safety emphasis on porcelain insulators as they shard on failure.

7.2.2.4.4 *Medium Factor*

Medium	Safety Medium Factor	Justification
Air	1	Air medium has no safety impact
Vacuum	1	Vacuum medium has no safety impact
VACUUM/SF6	1.2	Toxic by-products are released on failure
SF6	1.5	Toxic by-products are released on failure
Small Bulk Oil	2	Fire risk if oil is ignited on failure
Bulk Oil	3	Fire risk if oil is ignited on failure

7.2.2.4.5 *Situation Factor*

Due to inaccessibility to the public as well as the safety of substation design, the installation situation has no significance on safety.

7.2.3 Average Cost of a Fault

7.2.3.1 Network Performance

Network Performance consequences are the penalties imposed on SA Power Networks whenever an outage occurs. Distribution Circuit Breakers are arranged in radial configuration and are therefore non redundant.

If the Circuit Breaker fails, all of the feeders it protects will experience an outage, this means that the Network Performance consequences can be determined in accordance with the STPIS.

7.2.3.1.1 *Constants by Customer Group*

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
Value of CML	13.51	0.62	0.59	0.66	STPIS Rates as of 9 Sept 2013. Determined as SAIDI Rate / # Customers in SCONRRR
Value of CI	1235	86	67	55	STPIS Rates as of 9 Sept 2013. Determined as SAIFI Rate / # Customers in SCONRRR
Avg. No. CIs Per Fault	1	1	1	1	All customers on the feeder experience an outage if a fault occurs
NP Avg Duration of Outage (mins): Condition Minor	0	0	0	0	A minor failure does not result in an outage is it is essentially a small defect
NP Avg Duration of Outage (mins): Condition	124	337	191	159	Determined using records stored in the HV

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
Significant					database
NP Avg Duration of Outage (mins): Condition Major	124	337	191	159	Determined using records stored in the HV database
NP Avg Duration of Outage (mins): Condition Replacement	0	0	0	0	A condition replacement is a planned outage, which does not result in STPIS penalties
NP Avg Duration of Outage (mins): Condition Failure to Trip	124	337	191	159	Determined using records stored in the HV database
NP Avg Duration of Outage (mins): Non-Condition Minor	0	0	0	0	Minor failure is essentially a small defect, the Circuit Breaker continues to operate in this circumstance so no outage will occur
NP Avg Duration of Outage (mins): Non-Condition Significant	124	337	191	159	Determined using records stored in the HV database
NP Avg Duration of Outage (mins): Non-Condition Major	124	337	191	159	Determined using records stored in the HV database

7.2.3.1.2 *Number of Customers Default*

It is rare that default customer numbers need to be assigned, as most of the feeder customer numbers are known. The default values were determined in workshops with EA Technology CBRM experts, Circuit Breaker SME and Asset Strategy Engineers by categorising the customer numbers in region and voltage.

Type of Site Used	Number of Customers Used	Justification
CBD	500	Assumes 500 Customers associated per bus section in an average CBD substation
Rural Long	700	Assumes 1400 Customers associated with an average 2 section Rural Long substation
Rural Short	1350	Assumes 2700 Customers associated with an average 2 section Rural Short substation
Urban	2500	Assumes 5000 Customers associated with an

Type of Site Used	Number of Customers Used	Justification
		average Urban substation (2 sections)

7.2.3.2 OPEX

OPEX consequences are the Operational Expenditure required in response to an event.

7.2.3.2.1 *Situation Constants*

Setting Item	Indoor	Outdoor	Justification
Opex Avg. Consequences: Minor Failure	2260	2260	Average SAP SD Notification OPEX Orders for the last 5 years
Opex Avg. Consequences: Significant Failure	15000	10000	Average of Significant SAP FM Notification OPEX Orders recorded against Distribution Circuit Breakers for the last 5 years
Opex Avg. Consequences: Major Failure	50000	14000	Average of Major SAP FM Notification OPEX Orders recorded against Distribution Circuit Breakers for the last 5 years
Opex Avg. Consequences: Failure to Trip Non-Condition Failure	15000	15000	Based on Parafield Gardens Fail To Trip event
Opex Avg. Consequence: Condition Replacement	12000	12000	Cost based on Compton St as an average operational cost of inspection/diagnostic testing to determine need for condition replacement.
Opex Avg. Consequences: Minor Non-Condition Failure	2260	2260	Average SAP SD Notification OPEX Orders for the last 5 years
Opex Avg. Consequences: Significant Non-Condition Failure	15000	10000	Average of Significant SAP FM Notification OPEX Orders recorded against Distribution Circuit Breakers for the last 5 years
Opex Avg. Consequences: Major Non-Condition Failure	50000	14000	Average of Major SAP FM Notification OPEX Orders recorded against Distribution Circuit Breakers for the last 5 years

7.2.3.2.2 *Situation for Cost of Failure*

These settings are used for reporting in the CBRM front end, and have no effect on results.

7.2.3.3 CAPEX

CAPEX consequences are the Capital Expenditure required in response to an event.

7.2.3.3.1 *Situation Based Constants*

Setting Item	Indoor	Outdoor	Justification
Capex Avg. Consequence: Minor Failure	0	0	Minor repairs required, mainly maintenance involved
Capex Avg. Consequence: Significant Failure	0	0	Minor repairs required, mainly maintenance involved
Capex Avg. Consequence: Major Failure	240000	350000	Determined using historical costs.
Capex Avg. Consequence: Failure to Trip	0	0	Minor repairs required, mainly maintenance involved
Capex Avg. Consequence: Condition Replacement	485000	350000	Average cost of 11kV Circuit Breaker failure & replacement based on SA Power Networks' Operational Experience
Capex Avg. Consequence: Minor Non-Condition Failure	0	0	Minor repairs involved, this is classed as OPEX
Capex Avg. Consequence: Significant Non-Condition Failure	0	0	Significant repairs are involved, this is classed as OPEX
Capex Avg. Consequence: Major Non-Condition Failure	240000	350000	Determined using historical costs.

7.2.3.3.2 *Situation Based Cost of Failure*

These settings are used for reporting in the CBRM front end, and have no effect on results.

7.2.3.4 Safety

7.2.3.4.1 *Consequences*

The safety consequences are valued in monetary terms, and have been assessed by establishing a value of a safety event in terms of its adverse cost on society. CBRM uses the following consequences to determine safety risk:

- Minor – The event leads to an individual requiring medical treatment only;
- Major – The event incurs a lost time injury;
- Fatality – The event causes death or permanent disability.

EA Technology established the values for the three consequence types through collaboration with the Network Asset Management Group from SA Power Networks, the process that was used is outlined in Section 2 of Attachment A.

7.2.3.4.2 *Average Consequences*

The average safety consequences look at the frequency of all the events across all models, their determination is outlined in Section 3 of Attachment A.

7.2.3.5 Environment

7.2.3.5.1 *Consequences*

Five significant environmental consequences have been identified that could arise as a result of a network asset failure:

- Loss of oil;
- Emission of SF6 gas into the atmosphere;
- A significant fire with smoke pollution;
- The production of contaminated waste; and
- Major disturbance such as traffic congestion or noise.

CBRM assigns a monetary value to the environmental consequences based on trading values for carbon emissions. The overall process that was used to determine this is outlined in Section 2 of Attachment A.

7.2.3.5.2 *Failure Scenario Constants*

The average safety consequences look at the frequency of all the events across all models, their determination is outlined in Section 3 of Attachment A.

8. SUBSTATION CIRCUIT BREAKERS – SUBTRANSMISSION

8.1 HEALTH INDEX

8.1.1 Location Factor

The Location factor models how the installation environment affects the Circuit Breaker's condition over time. For example, outdoor circuit breakers are more susceptible to atmospheric corrosion than those located indoors.

8.1.1.1 Constants

Setting Item	Value	Justification
Pollution Factor Default	1	Used if the pollution factor cannot be determined, and is set to have no effect on HI
Corrosion Default Factor	1	Used if the corrosion factor cannot be determined, and is set to have no effect on HI
Location Factor Increment	0.05	Determined as satisfactory value in workshop with EA Technology CBRM Experts, Asset Strategy Engineers and Conductor SME
Situation Default Factor	1	Used if the situation factor cannot be determined, and is set to have no effect on HI
Minimum Location Factor	0.9	Determined as satisfactory value in workshop with EA Technology CBRM Experts, Asset Strategy Engineers and Conductor SME
Surge Arrestor Default Factor	1	To be assigned if surge arrestors are not installed. Determined as satisfactory value in workshop with EA Technology CBRM Experts, Asset Strategy Engineers and Conductor SME
Situation With Air Conditioning Flag	Indoor Air Conditioned	

8.1.1.2 Pollution Factor

Pollution zones are manually assigned to each Circuit Breaker, this takes into account any corrosion the Circuit Breaker may experience due to its external environment. Factors were determined in workshops with EA Technology CBRM Experts, Circuit Breaker SME, and Asset Strategy Engineers.

Pollution	Pollution Factor	Justification
1	0.9	Extremely clean environment
2	1	Low pollution
3	1.05	Average - medium issues
4	1.1	Industrial pollution - requires regular washing

8.1.1.3 Surge Arrestor Factor

There is a marginal benefit for Circuit Breakers with Surge Arrestors, the level of benefit was determined by the Circuit Breaker SME.

Surge Arrestor	Surge Arrestor Factor
Yes	0.95
No	1

8.1.1.4 Corrosion Factor

The corrosion factor models the effect that atmospheric corrosion has on the Circuit Breaker, it is assigned based on the Circuit Breaker's corrosion zone. Atmospheric corrosion is more severe for subtransmission Circuit Breaker units because they are located outdoors without an enclosure.

Corrosion Zone	Corrosion Factor	Justification
1	0.95	Low corrosion zone
2	1	Severe corrosion zone
3	1.1	Very severe corrosion zone
4	1.2	Extreme corrosion environment

8.1.1.5 Situation Factor

CBs are installed in various situations, including air conditioned rooms and sheds. Factors have been assigned to model the situation's effect on the asset's life, and were determined by the Circuit Breaker SME in consultation with EA Technology CBRM Experts.

Situation with Air Con	Situation Factor	Justification
Outdoor Cubicle	2	Installed in sheet metal enclosure are very susceptible to environment
Outdoor	1	Standard installation
Indoor Air Conditioned	0.25	Constant environmental control
Indoor	0.5	Some shelter from the environment
Building - Restricted	0.9	Better than outdoor, worse than indoor/building
Building	0.5	Changed to match indoor

8.1.2 Duty Factor

Duty factor models how hard an asset has worked in its operational life. Workshops between EA Technology CBRM experts, Circuit Breaker SME, and Asset Strategy Engineers determined that the prime indicators of Circuit Breaker duty are the number of faults it has experienced, the fault level (magnitude of electrical fault current,) and number of normal operations it has completed.

8.1.2.1 Constants

Setting Item	Value	Justification
Duty Factor Multiplier	0.05	Determined as satisfactory value from EA Technology's past CBRM experience with over 30 electrical utilities in 10 countries worldwide
Fault Rating Factor Default	1	If the fault rating cannot be determined, it is excluded from the HI determination
Fault Operations Factor Default	0.8	Circuit Breakers that have no recorded fault operation in the last 5 years are in better condition than anticipated
Normal Operations Factor Default	1	If the number of normal operations cannot be determined, it is excluded from the HI determination
Maximum Operations Default	20	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Number of Normal Operations Default	2000	If the maximum number of normal operations for the Circuit Breaker unit cannot be determined, the maximum normal operations for a Cap Bank Circuit Breaker is used

8.1.2.2 Maximum Fault Operations

The maximum number of fault operations was determined by the Circuit Breaker SME in consultation with EA Technology CBRM experts, in which it was advised to use the average number of fault operations experienced by each function for the last 5 years.

Function	Maximum Fault Ops
GEN	1
HVB	1.1
PTF	1.1
VCN	1.3
SEC	2.3
LVB	3.3
HVL	3.5
LVL	6.1

8.1.2.3 Maximum Normal Operations

For most of the units, the maximum number of normal operations was determined in workshops with EA Technology CBRM Experts and the Circuit Breaker SME. Conservative limits are used based on oil and non-oil filled capacitor bank breakers.

Unit Classification	Maximum Normal Ops
Oil Filled	1000
All Other Mediums	2000

8.1.2.4 Fault Rating Factor

Fault Rating Factor values and bands were established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

> Fault Rating Percentage Minimum	<= Fault Rating Percentage Maximum	Fault Rating Factor	Justification
0	40	0.9	Very low fault level
40	60	0.95	Light Fault Duty
60	75	1	No Effect
75	90	1.1	High fault duty
90	1,000.00	1.25	Nearing Circuit Breaker's rating

8.1.2.5 Fault Operations Factor

Fault Operations Factor values and bands were established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

> % Fault Ops Minimum	<= % Fault Ops Maximum	Fault Ops Factor	Justification
-1	100	0.9	100% is average number of fault ops for a functional location
100	200	1	1 - 2 times average fault duty
200	400	1.1	2 - 4 times average fault duty
400	600	1.15	4 - 6 time average fault duty
600	2,000.00	1.2	More than 6 times average fault duty

8.1.2.6 Normal Operations Factor
Normal Operations Factor values and bands were established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

> % Normal Ops Minimum	<= % Normal Ops Maximum	Normal Ops Factor	Justification
-1	30	0.9	Negligible Mechanical Wear
30	60	0.95	Low Mechanical Wear
60	90	1	Average Mechanical Wear
90	150	1.1	Possible Significant Mechanical Wear
150	200,000.00	1	Based on Circuit Breaker counter reading at inspection - not all are reliable indications of total Circuit Breaker operations

8.1.3 Faults
The number of faults a Circuit Breaker has experienced can be used to determine its condition, for example a Circuit Breaker which has experienced many faults during its operational life can be considered problematic.

8.1.3.1 Constants

Setting Item	Value	Justification
Fault Factor Default	0.95	No FM recorded in the last 5 years, indicates the asset is in better condition than anticipated
Default Fault Score	1	Used for the case where the cumulative fault score cannot be determined, and sets an average 'norm' effect towards the HI

8.1.3.2 Fault Score
The Cumulative Fault Score is determined by identifying all SAP FM records created in the last 5 years which correspond to the Circuit Breaker. The individual fault scores are summed together, with appropriate weighting based on the FM's priority and problem code.

The Fault Score was determined in workshops with EA Technology CBRM Experts and the Circuit Breaker SME, and is based on how the fault affects the condition of a Circuit Breaker.

Fault Problem code Text	Fault Priority	Fault Score
Fell Out	1	0.5
Vibration	4	0.5
Wear or Abrasion	4	0.5
Mechanical Overload	4	0.5

Fault Problem code Text	Fault Priority	Fault Score
Internal Fault	4	0.5
Corrosion	4	0.5
Design - Unsuitable or Incorrect	4	0.5
Electrical Overload	4	0.5
Failed to Operate	4	0.5
Fault Current - Unknown	4	0.5
Faulty Workmanship	4	0.5
Gasket Failure	4	0.5
High Resistance Joint	4	0.5
Age	4	0.5
Mechanical Overload	3	0.5
Internal Fault	3	0.5
Age	3	0.5
Vibration	3	0.5
Wear or Abrasion	3	0.5
Design - Unsuitable or Incorrect	3	0.5
Electrical Overload	3	0.5
Failed to Operate	3	0.5
Fault Current - Unknown	3	0.5
Faulty Workmanship	3	0.5
Gasket Failure	3	0.5
High Resistance Joint	3	0.5
Corrosion	3	0.5
Mechanical Overload	2	1
Internal Fault	2	1
Vibration	2	1

Fault Problem code Text	Fault Priority	Fault Score
Wear or Abrasion	2	1
Design - Unsuitable or Incorrect	2	1
Electrical Overload	2	1
Failed to Operate	2	1
Fault Current - Unknown	2	1
Faulty Workmanship	2	1
Gasket Failure	2	1
High Resistance Joint	2	1
Corrosion	2	1
Age	2	1
Cable Insulation Breakdown	1	1
	1	1
Clearance Inadequate	1	1
Customer Protection Equipment Operated	1	1
INADEQUATE	1	1
FAILURE	1	1
Missing	1	1
Vandalism	1	1
Worn	1	1.5
Overheating	1	1.5
Oil - Low & or Leaking	1	1.5
Misaligned	1	1.5
Loose	1	1.5
LOW GAS PRESSURE	1	1.5
Internal Electrical Fault	1	1.5
Arcing	1	1.5

Fault Problem code Text	Fault Priority	Fault Score
Broken	1	1.5
Burnt	1	1.5
Corroded	1	1.5
Does Not Operate	1	1.5
Age	1	1.5
Internal Fault	1	1.5
Corrosion	1	1.5
Design - Unsuitable or Incorrect	1	1.5
Electrical Overload	1	1.5
Failed to Operate	1	1.5
Fault Current - Unknown	1	1.5
Faulty Workmanship	1	1.5
Gasket Failure	1	1.5
High Resistance Joint	1	1.5
Mechanical Overload	1	1.5
Vibration	1	1.5

8.1.3.3 Fault Factor

The Cumulative Fault score is matched to a fault factor, which is used to determine if the Circuit Breaker is problematic. Factors are based on EA Technology's CBRM experience with over 30 electrical utilities in 10 countries worldwide.

> Sum of FMs Scores Minimum	<= Sum of FMs Scores Maximum	Fm Factor	Justification
-1	0	1	Some (not important) defects recorded
0	1	1.05	
1	5	1	
5	10	1.15	
10	1,000.00	1.2	Many small or some significant failures against asset, indicating that the Circuit Breaker is

> Sum of FMs Scores Minimum	<= Sum of FMs Scores Maximum	Fm Factor	Justification
			problematic

8.1.4 Defects

The number of defects assigned against the Circuit Breaker can be a good indicator of its condition, for example a Circuit Breaker with lots of defects found within a small timeframe could be a problematic unit.

8.1.4.1 Constants

Setting Item	Value	Justification
Defect Factor Default	0.95	If no defect has been recorded against the Circuit Breaker in the last 5 years, it is in better condition than anticipated
Default Defect Score	1	If the cumulative defect score cannot be determined, the factor is set to the 'norm' so it has no effect on the HI

8.1.4.2 Defect Score

The Cumulative Defect Score is determined by identifying all SAP SD records created in the last 5 years which correspond to the Circuit Breaker. The individual defect scores are summed together, with appropriate weighting based on the SD's priority and problem code.

The Defect Score was determined in workshops with EA Technology CBRM Experts and the Circuit Breaker SME, and is based on how the defect affects the condition of a Circuit Breaker.

Defect Problem Code	Defect Priority	Defect Score
VERMIN	4	0.5
WORN / ABRADED	4	0.5
MAL OPERATION	4	0.5
MISALIGNMENT	4	0.5
MAL OPERATION	3	0.5
MISALIGNMENT	3	0.5
OVERHEATING	4	0.5
PITTED CONTACTS	4	0.5
POLLUTION	4	0.5
RESISTANCE HIGH	4	0.5
RESISTANCE LOW	4	0.5

Defect Problem Code	Defect Priority	Defect Score
SEIZED	4	0.5
TRACKING	4	0.5
TRIP FREE	4	0.5
LEAKING	4	0.5
LOW GAS PRESSURE	4	0.5
LOW OIL LEVEL	4	0.5
FAILURE	4	0.5
FIRE	4	0.5
FLASHED OVER	4	0.5
HIGH THERMAL IMAGE	4	0.5
FAILURE	3	0.5
FIRE	3	0.5
FLASHED OVER	3	0.5
HIGH THERMAL IMAGE	3	0.5
VERMIN	3	0.5
WORN / ABRADED	3	0.5
BROKEN	4	0.5
BURNT	4	0.5
CONTAMINATED OIL	4	0.5
CORRODED <50%	4	0.5
CORRODED >50%	4	0.5
CRACKED	4	0.5
DAMAGE	4	0.5
EXCESSIVE NOISE	4	0.5
OVERHEATING	3	0.5
PITTED CONTACTS	3	0.5

Defect Problem Code	Defect Priority	Defect Score
POLLUTION	3	0.5
RESISTANCE HIGH	3	0.5
RESISTANCE LOW	3	0.5
SEIZED	3	0.5
TRACKING	3	0.5
TRIP FREE	3	0.5
LEAKING	3	0.5
LOW GAS PRESSURE	3	0.5
LOW OIL LEVEL	3	0.5
BROKEN	3	0.5
BURNT	3	0.5
CONTAMINATED OIL	3	0.5
CORRODED <50%	3	0.5
CORRODED >50%	3	0.5
CRACKED	3	0.5
DAMAGE	3	0.5
EXCESSIVE NOISE	3	0.5
VERMIN	2	1
WORN / ABRADED	2	1
MAL OPERATION	2	1
MISALIGNMENT	2	1
FAILURE	2	1
FIRE	2	1
FLASHED OVER	2	1
HIGH THERMAL IMAGE	2	1
OVERHEATING	2	1

Defect Problem Code	Defect Priority	Defect Score
PITTED CONTACTS	2	1
POLLUTION	2	1
RESISTANCE HIGH	2	1
RESISTANCE LOW	2	1
SEIZED	2	1
TRACKING	2	1
TRIP FREE	2	1
LEAKING	2	1
LOW GAS PRESSURE	2	1
LOW OIL LEVEL	2	1
BROKEN	2	1
BURNT	2	1
CONTAMINATED OIL	2	1
CORRODED <50%	2	1
CORRODED >50%	2	1
CRACKED	2	1
DAMAGE	2	1
EXCESSIVE NOISE	2	1
VERMIN	1	1.5
WORN / ABRADED	1	1.5
MAL OPERATION	1	1.5
MISALIGNMENT	1	1.5
FAILURE	1	1.5
FIRE	1	1.5
FLASHED OVER	1	1.5
HIGH THERMAL IMAGE	1	1.5

Defect Problem Code	Defect Priority	Defect Score
OVERHEATING	1	1.5
PITTED CONTACTS	1	1.5
POLLUTION	1	1.5
RESISTANCE HIGH	1	1.5
RESISTANCE LOW	1	1.5
SEIZED	1	1.5
TRACKING	1	1.5
TRIP FREE	1	1.5
LEAKING	1	1.5
LOW GAS PRESSURE	1	1.5
LOW OIL LEVEL	1	1.5
BROKEN	1	1.5
BURNT	1	1.5
CONTAMINATED OIL	1	1.5
CORRODED <50%	1	1.5
CORRODED >50%	1	1.5
CRACKED	1	1.5
DAMAGE	1	1.5
EXCESSIVE NOISE	1	1.5
Maloperation	1	1.5

8.1.4.3 Defect Factor

The Cumulative Defect Score is assigned a defect factor, which is used to determine if the Circuit Breaker is problematic. Factors are based on EA Technology's CBRM experience with over 30 electrical utilities in 10 countries worldwide.

> Sum of Defect Scores Minimum	<= Sum of Defect Scores Maximum	SD Factor	Justification
-1	0	1	Some (not important) defects recorded
0	1	1.05	
1	5	1.1	
5	10	1.15	
10	1,000.00	1.2	Many small or some significant failures against asset, indicating the Circuit Breaker is problematic

8.1.5 Condition

8.1.5.1 Constants

Setting Item	Value	Justification
Condition Factor Multiplier	0.05	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
I2T Default Factor	1	If factor cannot be determined it has no effect on HI
DCR Default Factor	1	If factor cannot be determined it has no effect on HI
Timing Test Default factor	1	If factor cannot be determined it has no effect on HI
Insulation Resistance Default Factor	1	If factor cannot be determined it has no effect on HI
Maintenance 1 Default Factor	1	If factor cannot be determined it has no effect on HI
Maintenance 2 Default Factor	1	If factor cannot be determined it has no effect on HI
Maintenance 3 Default Factor	1	If factor cannot be determined it has no effect on HI
Maintenance 4 Default Factor	1	If factor cannot be determined it has no effect on HI
Visual Inspection 1 Default Factor	1	If factor cannot be determined it has no effect on HI

Setting Item	Value	Justification
Visual Inspection 2 Default Factor	1	If factor cannot be determined it has no effect on HI
I2T Default Minimum HI	0.5	If the Minimum HI cannot determined, the result has no effect on HI
DCR Default Minimum HI	0.5	If the Minimum HI cannot determined, the result has no effect on HI
Insulation Resistance default Minimum HI	0.5	If the Minimum HI cannot determined, the result has no effect on HI
Maintenance 1 Default Minimum HI	0.5	If the Minimum HI cannot determined, the result has no effect on HI
Maintenance 2 Default Minimum HI	0.5	If the Minimum HI cannot determined, the result has no effect on HI
Maintenance 3 Default Minimum HI	0.5	If the Minimum HI cannot determined, the result has no effect on HI
Maintenance 4 Default Minimum HI	0.5	If the Minimum HI cannot determined, the result has no effect on HI
Visual Inspection 1 Default Minimum HI	0.5	If the Minimum HI cannot determined, the result has no effect on HI
Visual Inspection 2 Default Minimum HI	0.5	If the Minimum HI cannot determined, the result has no effect on HI
Timing Test Default Minimum HI	0.5	If the Minimum HI cannot determined, the result has no effect on HI

8.1.5.2 I2T Factor
SA Power Networks does not undertake I2T measurements, this feature will be used in the future.

8.1.5.3 DCR Factor
SA Power Networks does not undertake DCR measurements, this feature will be used in the future.

8.1.5.4 Timing Test Factor
SA Power Networks does not undertake Timing Test measurements, this feature will be used in the future.

8.1.5.5 Insulation Resistance Factor
SA Power Networks does not currently measure insulation resistance.

8.1.5.6 Maintenance 1 Factor
This feature is to be used for future condition measurements.

8.1.5.7 Maintenance 2 Factor
This feature is to be used for future condition measurements.

8.1.5.8 Maintenance 3 Factor
This feature is to be used for future condition measurements.

8.1.5.9 Maintenance 4 Factor
This feature is to be used for future condition measurements.

8.1.5.10 Visual Inspection 1 Factor
Visual measurements are recorded by inspectors into the PAT. The measurements are manually assigned a score between 1 and 4, which CBRM uses as part of determining HI.

Visual Inspection 1	Visual Inspection 1 Factor	Justification
1	0.9	No visual corrosion
2	1	minor corrosion
3	1.1	severe corrosion
4	1.2	major corrosion

8.1.5.11 Visual Inspection 2 Factor
Visual measurements are recorded by inspectors into the PAT. The measurements are manually assigned a score between 1 and 4 which CBRM uses as part of determining the HI.

Visual Inspection 2	Visual Inspection 2 Factor	Justification
1	0.9	No visual corrosion
2	1	Minor corrosion
3	1.1	Severe corrosion
4	1.2	Major corrosion

8.1.5.12 I2T Minimum HI
SA Power Networks does not undertake I2T measurements, this feature will be used in the future.

8.1.5.13 DCR Minimum HI
SA Power Networks does not undertake DCR measurements, this feature will be used in the future.

8.1.5.14 Timing Test Minimum HI
SA Power Networks does not undertake Timing Test measurements, this feature will be used in the future.

8.1.5.15 Insulation Resistance Minimum HI
SA Power Networks does not undertake Insulation Resistance measurements, this feature will be used in the future.

8.1.5.16 Maintenance 1 Minimum HI
This feature is to be used for future condition measurements.

8.1.5.17 Maintenance 2 Minimum HI
This feature is to be used for future condition measurements.

8.1.5.18 Maintenance 3 Minimum HI
This feature is to be used for future condition measurements.

8.1.5.19 Maintenance 4 Minimum HI
This feature is to be used for future condition measurements.

8.1.5.20 Visual Inspection 1 Minimum HI
This feature is to be used for future condition measurements.

8.1.5.21 Visual Inspection 2 Minimum HI
This feature is to be used for future condition measurements.

8.1.6 Overdue Maintenance
The HI of a Circuit Breaker degrades if it is not maintained within the specified interval. CBRM factors this by identifying if the last maintenance date exceeds maintenance requirements for the particular Circuit Breaker.

8.1.6.1 Constants

Setting Item	Value	Justification
Days Between Maintenance Default	1643	Maintenance manual specifies 4.5 year maintenance interval
Default Days Between Maintenance	0	If the last maintenance date cannot be determined, the conservative approach is used in which the unit is assigned to be the most recently maintained

8.1.6.2 Days Between Maintenance
In accordance with SA Power Networks' operational requirements, the maintenance interval for all Circuit Breakers is set to 1643 days (i.e. 4.5 years).

8.1.6.3 Overdue Maintenance Factor
The overdue maintenance factor depends on then number of days maintenance is late. The value and bands were established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

> Days Overdue Minimum	<= Days Overdue Maximum	Overdue Maintenance factor	Justification
-1	183	1	No Effect
183	365	1.05	6 months - 1 year overdue

> Days Overdue Minimum	<= Days Overdue Maximum	Overdue Maintenance factor	Justification
365	730	1.1	1 to 2 years overdue
730	100,000.00	1.15	More than 2 years overdue

8.1.7 Partial Discharge

8.1.7.1 Constants

Setting Item	Value	Justification
Offline Default	1	Used if offline testing results do not exist, has no effect on HI
Ultrasonic Factor	1	Used if ultrasonic factor cannot be determined, has no effect on HI
TEV Default Rating		Blank rating assigned if TEV rating cannot be determined
Default TEV Factor	1	Used if TEV factor cannot be determined, has no effect on HI

8.1.7.2 Ultrasonic Factor

The Ultrasonic Factor accounts for ultrasonic test results, it modifies the Circuit Breaker’s HI according to the Ultrasonic Activity. The factors were established through EA Technology’s CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

Ultrasonic Activity	Ultrasonic Factor	Justification
Amber	1	Sporadic ultrasonic activity when tested over last 5 years
Green	0.9	No detected ultrasonic activity in last 5 years
Red	1.2	Regular Ultrasonic activity when tested

8.1.7.3 TEV Rating

The TEV rating is used to identify problematic units, it is determined from the TEV score. The score bands were established through EA Technology’s CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

> Tev Score Minimum	<= Tev Score Maximum	TEV Rating
0	15	Green
15	30	Amber
30	1,000.00	Red

8.1.7.4 TEV Factor

The TEV factor modifies the Circuit Breaker's HI according to the TEV Rating. The factors were established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

TEV Rating	TEV Factor	Justification
Green	0.9	No activity or stable readings over last 5 years
Amber	1	No activity or fluctuating / inconclusive readings over last 5 years
Red	1.15	Regular activity when tested / trending upwards

8.1.7.5 Offline PD Factor

There are no offline PD test results.

8.1.8 HI1

HI1 is primarily age driven however it does take into account the duty and location factor. After CBRM determines HI1, it applies condition information to determine the overall HI the asset stands at today.

8.1.8.1 Constants

Setting Item	Value	Justification
Average Life Default	65	For all Circuit Breakers, the average life has been assigned the REPEX calibrated life of 65 years.
As New HI Default	0.5	HI of 0.5 indicates a brand new asset
HI1 Cap	5.5	HI of 5.5 indicates beginning of serious degradation. CBRM process caps the HI at this value if no condition information is available
Reliability Rating Default	1	Used if no reliability cannot be determined, and assigns the asset as having normal reliability
LogCalc	2.397895	Model Constant set by EA Technology

8.1.8.2 Average Life

For all Circuit Breakers, the average life has been assigned with the REPEX calibrated life of 65 years.

8.1.8.3 As New HI

All Circuit Breakers are assigned an as new HI of 0.5, indicating that they're brand new.

8.1.9 Factor Value

8.1.9.1 Constants

Setting Item	Value	Justification
Reliability Rating Default	1	Used for the case where no reliability rating is assigned to the asset, and therefore assigns the asset with average reliability
Reliability Factor Default	1	Used for the case where the reliability rating cannot be mapped to a factor, and therefore assigns the asset with average reliability
Defect Factor Default	0.95	Default where no SAP defect recorded in last 5 years, indicates the Circuit Breaker is in better condition than anticipated
Overall Defect/Fault Factor Multiplier	0.05	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

8.1.9.2 Reliability Factor

The Reliability Factor identifies Circuit Breaker models with inherent design faults. The factors were established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

Reliability Rating	Reliability Factor	Justification
1	0.9	Operation & maintenance requirements normal, no common problems of type.
2	1	Minor/occasional corrective maintenance required in comparison to above models.
3	1.15	Significant additional corrective maintenance required in comparison to score 1's; Type has a history of high priority/forced outages to fix; numerous planned outage extensions required to correct problems (discovery of problems during maintenance); failure in service attributable to design.
4	1.3	Repeat forced outages/failures of type; significant mechanical problems; maintenance not cost effective; difficult to bring up to spec (timing/travel etc) during maintenance without major work.

8.1.10 Failure Scenarios

Workshops undertaken with EA Technology CBRM Experts, The Circuit Breaker SME and Asset Strategy Engineers identified that distribution Circuit Breakers have the following failure scenarios:

- Minor: Substation inspections identify the Circuit Breaker requires minor repairs;
- Significant: The Circuit Breaker fails and requires major repairs for restoration;
- Major: The Circuit Breaker catastrophically fails and needs to be replaced;

- Replacement: The Circuit Breaker is replaced as it is in poor condition; and
- Fail to Trip: The Circuit Breaker fails to clear a fault resulting in an upstream protection trip.

Setting Item	Value	Justification
No. Failures: Condition Minor	92	Annual number of SAP SD Notifications created over last 5 years (excluding those closed (NOCO) without being issued to FS (ISFS) and notifications associated with other failure types.
No. Failures: Condition Significant	0.3	Any disruptive failure is considered Significant or Major (includes forced interruptions & 'simple fix' failures that cause protection to operate i.e. low oil trips). Statistics are gathered from records of in-service failures and (unplanned) condition replacement
No. Failures: Condition Major	0.2	Any disruptive failure is considered Significant or Major (includes forced interruptions & 'simple fix' failures that cause protection to operate i.e. low oil trips). Statistics are gathered from records of in-service failures and (unplanned) condition replacement
No. Failures: Condition Failure To Trip	0.2	Statistics are gathered from records of in-service failures within the last 5 years. Failure to trip occurs when an the breaker cannot clear a fault, causing upstream protection to activate
No. Failures: Condition Replacement	1.4	Based on average number of condition replacements completed for the last 5 years, excluding historical 'targeted intervention' & refurbishment program
No. Failures: Non-Condition Minor	5	Annual number of SD Notifications created over last 5 years (excluding those closed (NOCO) without being issued to FS (ISFS) and notifications associated with other failure types.
No. Failures: Non-Condition Significant	0.1	No data for last 5 years - Any disruptive failure is considered Significant or Major (includes forced interruptions & 'simple fix' failures that cause protection to operate i.e. low oil trips). Statistics are gathered from records of in-service failures and (unplanned) condition replacement
No. Failures: Non-Condition Major	0.3	Any disruptive failure is considered Significant or Major (includes forced interruptions & 'simple fix' failures that cause protection to operate i.e. low oil trips). Statistics are gathered from records of in-service failures and (unplanned)

Setting Item	Value	Justification
		condition replacement
HILim: Condition Minor	4	Industry standard setting for HI where wear out begins
HILim: Condition Significant	4	Industry standard setting for HI where wear out begins
HILim: Condition Major	4	Industry standard setting for HI where wear out begins
HILim: Condition Failure to Trip	4	Industry standard setting for HI where wear out begins
HI Lim: Condition Replacement	4	Industry standard setting for HI where wear out begins
HIAvg: Condition Minor	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HIAvg: Condition Significant	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HIAvg: Condition Major	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HIAvg: Condition Failure to Trip	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HI Avg: Condition Replacement	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
Cval: Condition Minor	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4.
Cval: - Condition Significant	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4.
Cval: Condition Major	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4.
Cval: Condition Failure to Trip	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4.
C Value: Condition Replacement	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4.

8.1.11 Year 0 HI & PoF

8.1.11.1 Constants

Setting Item	Value	Justification
New Asset HI	0.5	Indicates a brand new asset
Minimum Health Index	0.5	Indicates a brand new asset
End of Life HI	7	CBRM process defines HI of 7 represents an asset at end of life
HI Category Default	No Result	Used if HI cannot be determined
Substation HI Category Default	No Result	Used if HI cannot be determined
Maximum Y0 HI	10	CBRM caps today's HI to a value of 10
Grouping Multiplier Default	0	Used if HI cannot be determined

8.1.11.2 HI Category Y0

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

8.1.11.3 Weighted Health Index Y0

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

8.1.12 HI – Yn Health Index

HI – Yn represents the future forecasted condition of the asset at Year Yn.

8.1.12.1 Constants

Setting Item	Value	Justification
Yn	11	2014 to 2025
Minimum Health Index	0.5	Represents a brand new asset
Maximum Yn HI	15	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Ageing Reduction Factor Default	1	If an ageing reduction factor cannot be applied, it is excluded from the determination of the HI
HI Category Default	No Result	Used for the case where HI cannot be determined
Ageing Constant from Y0 HI Maximum increase(multiplier)	1.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

Setting Item	Value	Justification
Minimum Age for Recalculated B	10	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Ageing Constant Multiplier Cap	1.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

8.1.12.2 Ageing Reduction Factor

The age reduction factor models the increased life expectancy as Circuit Breakers age. The factors and HI bands were provided by the CBRM Architect and have been developed from EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

Final Asset HI Y0 Minimum	Final Asset HI Y0 Maximum	Ageing Reduction Factor
0	0	1
0	2	1
2	5.5	1.5
5.5	10	1.5

8.1.12.3 Future HI Category

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

8.1.12.4 Weighted Health Index Yn

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

8.2 RISK

8.2.1 Interventions

8.2.1.1 Constants

Setting Item	Value	Justification
Yn	11	2014-2025
Percentage Replacement	0	No intervention
% Replacement Ranking Column	Delta Risk	Prioritises based on difference in risk between existing asset and new asset
Replacement Default Cost	500000	If the replacement cost cannot be determined, the conservative approach is to use 33kV costs.
Refurbishment Default Cost	500000	Refurbishment program for subtransmission Circuit Breakers is determined external to CBRM, and is

Setting Item	Value	Justification
		documented in the Circuit Breaker Asset Management Plan
Average Life of New Asset	65	For all Circuit Breakers, the average life has been assigned the REPEX calibrated life of 65 years.
As New Duty Factor	1	Normal duty factor is assigned to the replaced asset

8.2.1.2 Yn Percentage Replacement HI Category
The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

8.2.1.3 Yn Target Intervention Category
The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

8.2.1.4 Percentage Replacement Group Multiplier
The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

8.2.1.5 Percentage Replacement Cost of Replacement

Primary Voltage	% Replacement Program Costs	Justification
33000	500000	This is the average replacement cost of all 33kV Circuit Breaker & disconnect replacements (average of 3 disconnects per Circuit Breaker), within the last 5 years
6600	550000	Refer to Section 7.2.1.6
7600	550000	Refer to Section 7.2.1.6
11000	550000	Refer to Section 7.2.1.6
66000	600000	This is the average replacement cost of all 66kV Circuit Breaker & disconnect replacements (average of 1.8 disconnects per Circuit Breaker), for the last 5 years
132000	750000	Assumed to be 125% of the unit cost of a 66kV Circuit Breaker replacement. It is important to note that there is only one 132kV Circuit Breaker in service

8.2.1.6 Targeted Intervention Replacement Cost

Primary Voltage	Target Intervention Replacement Costs	Justification
33000	500000	This is the average replacement cost of all 33kV Circuit Breaker & disconnect replacements (average of 3 disconnects per Circuit Breaker), for the last 5 years
6600	550000	Refer to Section 7.2.1.6
7600	550000	Refer to Section 7.2.1.6
11000	550000	Refer to Section 7.2.1.6
66000	600000	This is the average replacement cost of all 66kV Circuit Breaker & disconnect replacements (average of 1.8 disconnects per Circuit Breaker), for the years last 5 years
132000	750000	Assumed to be 125% of the unit cost of a 66kV Circuit Breaker replacement. It is important to note that there is only one 132kV Circuit Breaker in service

8.2.1.7 Targeted Intervention Refurbishment Cost

SA Power Networks determines its refurbishment program external to CBRM, and has documented this in the Circuit Breaker Asset Management Plan.

8.2.2 Criticality

Criticality is determined for each consequence category, it identifies the significance of a fault/failure, and is comprised of a number of weighting factors which represent relative severity.

8.2.2.1 Network Performance

Network Performance criticality represents significance of the penalty imposed on SA Power Networks when the asset causes an unplanned outage.

8.2.2.1.1 *Constants*

Setting Item	Value	Justification
Obsolescence Rating Default	2	Set to have no significance on risk if obsolescence rating cannot be determined
Spares/Obsolescence NP Factor Default	1	Set to have no significance on risk if obsolescence factor cannot be determined
Single Bus Section Factor	1	Conservative approach is to assume there are multiple bus sections
Major Customer Default Factor	1	If major customers cannot be determined, the conservative approach is used in which the feeder is assumed to supply no major customers

Setting Item	Value	Justification
SCADA Site Factor Default	1	Set to have no effect on risk if it cannot be determined that SCADA is installed in the substation
NP Function Factor Default	1	No emphasis is placed on the number of feeder exists because customer numbers are used instead
NP Minimum Factor	0.1	Satisfactory default established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
NP Maximum Factor	10	Satisfactory default established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

8.2.2.1.2 *Spares/Obsolescence*

Spares/Obsolescence places more Network Performance significance on the Circuit Breaker units that require spare parts which are difficult to source, and varies in accordance with the unit's make and type.

Spares/Obsolescence	Justification
1	Manufacturers current product line, ready whole/component spares are in stock
2	Minimal spares but manufacturer/aftermarket parts are available. Catastrophic failure is covered by replacement with a modern equivalent.
3	Spares are only available through retirement of (aged) in service units (of average/uncertain condition).
4	Asset cannot easily be replaced with a modern equivalent, and no existing spares or vendor support is available.

8.2.2.1.3 *Spares/Obsolescence Factor*

The Spares/Obsolescence factor is assigned to the Spares/Obsolescence rating, the factor directly adjusts the Network Performance criticality. Factor values were established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

Spares/Obsolescence	Spares/Obsolescence NP Factor
1	0.5
2	1
3	1.5
4	2

8.2.2.1.4 *Single Bus Section Factor*

Substations with a single bus section will result in a full substation outage, and are assigned more significance than those with multiple bus sections.

8.2.2.1.5 *Major Customer Factor*

Major Customer	Major Customer Factor	Justification
No	1	No major customers impacts, set to have no effect
Yes	1.5	Reflects delays in restoration when coordinating switching with customer network

8.2.2.1.6 *No. TX Factor*

Substations with more entry Transformers have more inherent redundancy, this allows for more fault bypass options, which means that all assets on the site have less network performance significance. The factors were determined by EA Technology through their experience with implementing CBRM with over 30 electrical utilities in 10 countries worldwide.

Number of TXs	No. Transformers NP Factor	Justification
6	0.7	More redundancy on site
5	0.75	More redundancy on site
4	0.8	More redundancy on site
3	0.9	More redundancy on site
2	1	Average redundancy on site
1	1.5	likely no simple bypass
0	1.25	Ease of restoration given number of other transformers at site

8.2.2.1.7 *Load at Risk Factor*

Load at risk is used to directly calculate the Network Performance Consequence, and therefore no extra significance to risk is used here.

8.2.2.1.8 *SCADA Site Factor*

Substations with SCADA installed have faster restoration times because the location and occurrence of faults is immediately identified.

SCADA Site	SCADA Site Factor	Justification
Yes	0.5	Relative speed of dispatch and directed fault response due to SCADA monitoring
RTU	0.5	Relative speed of dispatch and directed fault response due to RTU monitoring
TDU	1.25	Very basic indication
Indicating	1.5	Basic indication only
None	2.5	Slow speed of dispatch and lack of directed fault response due to lack of SCADA monitoring
No	2.5	Slow speed of dispatch and lack of directed fault response due to lack of SCADA monitoring

8.2.2.1.9 *Function Factor*

Section and Capacitor Circuit Breakers can be isolated without load transfers, and therefore have been set to have less significance on Network Performance Risk. The remaining Circuit Breaker functions have no significance on Network Performance Risk.

8.2.2.2 OPEX

OPEX criticality represents the significance an event has on the Operational Expenditure required to remediate it.

8.2.2.2.1 *Constants*

Setting Item	Value	Justification
Medium Factor Default	1	If the medium of the Circuit Breaker cannot be determined, it is set to have no significance on risk
Spares/Obsolescence OPEX Factor Default	1	If the Spares/Obsolescence factor cannot be determined it is set to have no significance on risk
OPEX Function Factor Default	1	If the function of the Circuit Breaker cannot be determined, it is set to have no significance on risk
Substation Customer Type Factor (OPEX) Default	1	If the substation customer type cannot be determined the assumption is made that the unit supplies urban customers as this is the most common customer type.
OPEX Major Customer Factor Default	1	If Major customers cannot be allocated to the

Setting Item	Value	Justification
		Circuit Breaker, then the assumption is made that the unit does not supply major customers
Opex Minimum Factor	0.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Opex Maximum Factor	10	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

8.2.2.2.2 *Medium Factor*

The Medium factor emphasizes cleanup costs for spillages.

Medium	OPEX Medium Factor	Justification
Air	1	No clean up costs
Vacuum	1	No clean up costs
MIN OIL	1.5	Additional work of oil handling/repair/cleanup
Small Bulk Oil	1.5	Additional work of oil handling/repair/cleanup
VACUUM/SF6	2	Additional work of repair/cleanup
Bulk Oil	3	Additional work of repair/cleanup
SF6	3	Additional work of repair/cleanup
GIS	6	Additional work of repair/cleanup

8.2.2.2.3 *Spares/Obsolescence Factor*

Spares/Obsolescence places more OPEX significance on Circuit Breaker units requiring spare parts which are difficult to source.

Spares/Obsolescence	Spares/Obsolescence OPEX Factor	Justification
1	0.5	Modern Equipment - quicker restoration/repair
2	1	Average equipment/spares holdings
3	2	Reflects time spent looking/rebuilding spare parts
4	3	Reflects additional time spent looking/rebuilding spare parts

8.2.2.2.4 *Substation Customer Type Factor*

Type of Site Used	Substation Customer Type Factor	Justification
Urban	1	Base standard
Rural Short	1.2	Additional travel times, LAFA, and remote allowances
Rural Long	1.5	Additional travel times, LAFA, and remote allowances
CBD	2	Movement, access, and switching requirements within CBD is difficult

8.2.2.3 CAPEX

CAPEX criticality represents the significance an event has on the Capital Expenditure required to remediate it.

8.2.2.3.1 *Constants*

Setting Item	Value	Justification
Voltage Factor (CAPEX) Default	1	If the voltage cannot be determined it is set to have no significance on risk
Substation Customer Type Factor (CAPEX) Default	1	If the customer type cannot be determined, URBAN is assigned as the majority of customers are located in this SCONRRR
Capex Minimum Factor	0.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Capex Maximum Factor	10	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

8.2.2.3.2 *Voltage Factor*

SA Power Networks' operational experience has found that there is a voltage significance on CAPEX for Subtransmission Circuit Breakers. The level of significance was determined in workshops with EA Technology CBRM experts and the Circuit Breaker SME.

Primary Voltage	Voltage Factor (CAPEX)
33000	1
66000	1.25
132000	1.5

8.2.2.3.3 *Substation Customer Type Factor*

Type of Site Used	Substation Customer Type Factor (CAPEX)	Justification
Rural Long	1	Set to have no effect based on SA Power Networks experience
Urban	1	Set to have no effect based on SA Power Networks experience
Rural Short	1	Set to have no effect based on SA Power Networks experience
CBD	1.25	Additional cost of suitable equipment in CBD

8.2.2.4 Environment

Environmental criticality represents the significance the asset has on the environment when an event occurs.

8.2.2.4.1 *Constants*

Setting Item	Value	Justification
Pre-Oil Containment System Factor Default	1	If it cannot be determined if oil containment is installed, the significance on environment is ignored
Env Minimum Factor	0.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Env Maximum Factor	10	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Env Consequence: Default Medium Type	Oil	Most units are oil filled

8.2.2.4.2 *Environmental Risk Assessment Factor*

The environmental risk assessment is made outside of CBRM and varies asset to asset, it is used to identify the environmental impact if the Circuit Breaker fails.

Environmental Risk Assessment	Environment Risk Assessment Factor
Low	1
Medium	1.5
High	3

8.2.2.4.3 *Medium Type*

These calibration settings are used for reporting in the CBRM client, and have no significance on risk.

8.2.2.5 Safety

Safety criticality represents the significance the asset has on public and employee safety.

8.2.2.5.1 *Constants*

Setting Item	Value	Justification
Bushing Insulation Type Default	1	If the bushing insulation type cannot be determined, its significance on safety is ignored
Internal Arc Rated Safety Factor Default	1	Refer to Section 8.2.2.5.2
Medium Factor Default	1	If the medium type cannot be determined, it is conservatively assigned as air
Situation Factor Default	1	Refer to Section 8.2.2.5.5
Safety Minimum Factor	0.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Safety Maximum Factor	10	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

8.2.2.5.2 *Internal Arc Rated Factor*

Subtransmission CBs are self contained units, and as such do not require the installation of Internal Arc Containment. These settings have been assigned to have no significance on Safety Risk.

8.2.2.5.3 *Bushing Insulation Type Factor*

Bushing Insulation Type factor places more safety emphasis on porcelain insulators as they shard on failure.

8.2.2.5.4 *Medium Factor*

Medium	Safety Medium Factor	Justification
Air	1	Air medium has no safety impact
Vacuum	1	Vacuum medium has no safety impact
VACUUM/SF6	1.2	Toxic by-products are released on failure
SF6	1.5	Toxic by-products are released on failure
Small Bulk Oil	2	Fire risk if oil is ignited on failure

Medium	Safety Medium Factor	Justification
MIN OIL	2	Fire risk if oil is ignited on failure
GIS	3	Hazardous decomposition products released on failure
Bulk Oil	3	Fire risk if oil is ignited on failure

8.2.2.5.5 *Situation Factor*
Due to inaccessibility to the public as well as the inherent safety of substation design, the installation situation has no significance on safety.

8.2.3 Average Cost of a Fault
8.2.3.1 Network Performance
Network Performance consequences are the penalties imposed on SA Power Networks whenever an outage occurs. It is important to note the majority of subtransmission Circuit Breakers protect redundant lines, which means that a failure does not typically result in an outage. If a section of redundant line fails, its load is no longer redundant and is classed as load put at additional risk. CBRM uses a direct calculation of the load put at additional risk and converts it to a dollar value using VCR.

A LAFF is then applied to the load at additional risk. The LAFF is a factor which uses a cubic relationship to quantify the additional risk when the load is above firm capacity of the network, it is calibrated to offset the Risk Factor (described in Section 8.2.3.1.4) with a value representing 1 for fully redundant and 20 for non redundant.

Network Performance consequences for radial (non redundant) subtransmission Circuit Breakers is determined using VCR because the outage will have SAIDI exceeding the Major Event threshold therefore having no STPIS penalty imposed.

8.2.3.1.1 *Constants*

Setting Item	Value	Justification
Section Addition	1	Section breaker adds an extra section to the bus it protects
Section Tag	SEC	All Bus Circuit Breakers are assigned as Section Breakers
Function Default	Feeder	If the function of the Circuit Breaker cannot be determined, it is assumed to be Feeder Exit, as this is common the network
Default Asset Redundancy	Redundant	If it cannot be determined that the Circuit Breaker protects radial or redundant lines, redundancy is assumed as the consequences are more conservative.
KVALNP	1	Gives a 20:1 relationship between LAFF and % load above firm capacity

CBRM Justification

Setting Item	Value	Justification
CVALNP	0.037	Gives a 20:1 relationship between LAFF and % load above firm capacity.
Load Lost/Add. Risk Default	5	Sets a default value of 5MVA of load lost where actual load at additional risk is unknown. This value was determined in workshops with EA Technology CBRM Experts, Asset Strategy Engineers, and Substation Planning
LAFF Value Default for Non-Redundant Assets	1	Conservative approach is used in which assets with unknown LAFF are assumed to be fully redundant
Type of Site Default	Rural Short	If the type of substation cannot be determined, rural short is assumed. This accounts for both the majority of urban feeders as well as rural feeders supplying high loads to urban areas

8.2.3.1.2 *VCR Constants*

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
VCR ($) Redundant Assets	99243	49711	49711	49711	As Per AER STPIS Report
Power Factor Redundant Assets	0.9	0.9	0.9	0.9	Recommended by the Manager Network Planning
Load Factor Redundant Assets	0.4	0.4	0.4	0.4	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
VCR ($) Non Redundant Assets	99243	49711	49711	49711	As Per AER STPIS Report
Load Factor Non Redundant Assets	0.4	0.4	0.4	0.4	Satisfactory default established through EA Technology's CBRM experience

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
					with over 30 Electrical Utilities in 10 countries worldwide
Power Factor Non Redundant Assets	0.9	0.9	0.9	0.9	Recommended by the Manager Network Planning

8.2.3.1.3 *Non Redundant Constants*

The duration of non redundant outages has been derived using records in the HV database. Since outages of subtransmission lines typically result in SAIDI above the Major Event threshold there are cases where no reliable records exist, and therefore the following assumptions needed to be made:

- Assume condition and non-condition failures are restored in the same timeframe;
- Assume significant and major failures are restored in the same timeframe.

The assumptions were determined in workshops with EA Technology CBRM experts, Circuit Breaker SME, and Asset Strategy Engineers.

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
NP Avg. Restoration Time (hrs): Non Redundant Condition Minor	0	0	0	0	No outage occurs here as this is a defect which is repaired while the unit is still in service
NP Avg. Restoration Time (hrs): Non Redundant Condition Significant	1.6	6.6	2.5	2	Determined from records stored in the HV database
NP Avg. Restoration Time (hrs): Non Redundant Condition Major	1.6	6.6	2.5	2	Determined from records stored in the HV database
NP Avg. Restoration Time (hrs): Non Redundant Condition Failure to Trip	1.6	6.6	2.5	2	Determined from records stored in the HV database
NP Avg. Restoration Time (hrs): Non Redundant Condition Replacement	0	0	0	0	This is a planned outage, and as such does not result in a STPIS penalty
NP Avg. Restoration Time (hrs): Non Redundant Non-Condition Minor	0	0	0	0	No outage occurs here as this is a defect which is repaired while the unit is still in service
NP Avg. Restoration Time (hrs): Non Redundant Non-Condition Significant	1.6	6.6	2.5	2	Determined from records stored in the HV database

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
NP Avg. Restoration Time (hrs): Non Redundant Non-Condition Major	1.6	6.6	2.5	2	Determined from records stored in the HV database
NP Avg. Repair/Replace Time Factor: Non Redundant Condition Minor	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Condition Significant	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Condition Major	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Condition Failure to Trip	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Condition Replacement	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Non-Condition Minor	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Non-Condition Significant	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Non-Condition Major	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Risk Factor: Non Redundant Condition Minor	1	1	1	1	100% of load is lost when a fault occurs on a non redundant line
NP Avg. Risk Factor: Non Redundant Condition Significant	1	1	1	1	100% of load is lost when a fault occurs on a non redundant line
NP Avg. Risk Factor: Non Redundant Condition Major	1	1	1	1	100% of load is lost when a fault occurs on a non redundant line
NP Avg. Risk Factor: Non Redundant Condition Failure to Trip	1	1	1	1	100% of load is lost when a fault occurs on a non

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
					redundant line
NP Avg. Risk Factor: Non Redundant Condition Replacement	1	1	1	1	100% of load is lost when a fault occurs on a non redundant line
NP Avg. Risk Factor: Non Redundant Non-Condition Minor	1	1	1	1	100% of load is lost when a fault occurs on a non redundant line
NP Avg. Risk Factor: Non Redundant Non-Condition Significant	1	1	1	1	100% of load is lost when a fault occurs on a non redundant line
NP Avg. Risk Factor: Non Redundant Non-Condition Major	1	1	1	1	100% of load is lost when a fault occurs on a non redundant line

8.2.3.1.4 *Redundant Constants*

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
NP Avg. Restoration Time (hrs): Redundant Condition Minor	0	0	0	0	No outage occurs here as this is a defect which is repaired while the unit is still in service
NP Avg. Restoration Time (hrs): Redundant Condition Significant	1.6	6.6	2.5	2	Determined from records stored in the HV database
NP Avg. Restoration Time (hrs): Redundant Condition Major	1.6	6.6	2.5	2	Determined from records stored in the HV database
NP Avg. Restoration Time (hrs): Redundant Condition Failure to Trip	1.6	6.6	2.5	2	Determined from records stored in the HV database
NP Avg. Restoration Time (hrs): Redundant Condition Replacement	1.6	6.6	2.5	2	Determined from records stored in the HV database
NP Avg. Restoration Time (hrs): Redundant Non-Condition Minor	0	0	0	0	No outage occurs here as this is a defect which is repaired while the unit is still in service
NP Avg. Restoration Time (hrs): Redundant Non-Condition Significant	1.25	4	3.5	2	Determined from records stored in the HV database

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
NP Avg. Restoration Time (hrs): Redundant Non-Condition Major	1.25	4	3.5	2	Determined from records stored in the HV database
NP Avg. Repair/Replace Time Factor: Redundant Condition Minor	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Condition Significant	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Condition Major	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Condition Failure to Trip	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Condition Replacement	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Non-Condition Minor	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Non-Condition Significant	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Non-Condition Major	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Risk Factor: Redundant Condition Minor	0.05	0.05	0.05	0.05	For redundant assets (load at risk = 1/20th load lost). This is based on EA Technology's CBRM Experience with 30 electrical utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Condition Significant	0.05	0.05	0.05	0.05	For redundant assets (load at risk = 1/20th load lost). This is based on EA Technology's CBRM Experience with 30 electrical utilities in 10 countries worldwide

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
NP Avg. Risk Factor: Redundant Condition Major	0.05	0.05	0.05	0.05	For redundant assets (load at risk = 1/20th load lost). This is based on EA Technology's CBRM Experience with 30 electrical utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Condition Failure to Trip	0.05	0.05	0.05	0.05	For redundant assets (load at risk = 1/20th load lost). This is based on EA Technology's CBRM Experience with 30 electrical utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Condition Replacement	0.05	0.05	0.05	0.05	For redundant assets (load at risk = 1/20th load lost). This is based on EA Technology's CBRM Experience with 30 electrical utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Non-Condition Minor	0.05	0.05	0.05	0.05	For redundant assets (load at risk = 1/20th load lost). This is based on EA Technology's CBRM Experience with 30 electrical utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Non-Condition Significant	0.05	0.05	0.05	0.05	For redundant assets (load at risk = 1/20th load lost). This is based on EA Technology's CBRM Experience with 30 electrical utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Non-Condition Major	0.05	0.05	0.05	0.05	For redundant assets (load at risk = 1/20th load lost). This is based on EA Technology's CBRM Experience with 30 electrical utilities in 10 countries worldwide

8.2.3.2 OPEX

OPEX consequences are the Operational Expenditure required in response to an event.

8.2.3.2.1 *Situation Constants*

Setting Item	Indoor	Outdoor	Justification
Opex Avg. Consequences: Minor Failure	2590	2590	Average SAP SD Notification OPEX Orders created for the last 5 years
Opex Avg. Consequences: Significant Failure	35000	15000	Average of Significant Failure SAP FM Notification OPEX Orders recorded against Subtransmission Circuit Breakers for the last 5 years
Opex Avg. Consequences: Major Failure	60000	60000	Average of Major Failure SAP FM Notification OPEX Orders recorded against Subtransmission Circuit Breakers for the last 5 years
Opex Avg. Consequences: Failure to Trip Non-Condition Failure	12000	12000	Average cost of Willunga ($11k) & Pt Stanvac ($13k) Fail To Trip events
Opex Avg. Consequence: Condition Replacement	15000	20000	Cost assumed similar to indoor distribution Circuit Breakers, based on similar failure modes & CM techniques. Additional amount represents greater CM testing to confirm condition
Opex Avg. Consequences: Minor Non-Condition Failure	2590	2590	Average SAP SD Notification OPEX Orders for the last 5 years
Opex Avg. Consequences: Significant Non-Condition Failure	35000	15000	Average of Significant SAP FM Notification OPEX Orders recorded against Subtransmission Circuit Breakers created within the last 5 years
Opex Avg. Consequences: Major Non-Condition Failure	60000	60000	Average of Major SAP FM Notification OPEX Orders recorded against Subtransmission Circuit Breakers created within the last 5 years

8.2.3.2.2 *Situation for Cost of Failure*

These settings are used for reporting in the CBRM front end, and have no effect on results.

8.2.3.3 CAPEX

CAPEX consequences are the Capital Expenditure required in response to an event.

8.2.3.3.1 *Situation Based Constants*

Setting Item	Indoor	Outdoor	Justification
Capex Avg. Consequence: Minor Failure	0	0	Minor repairs involved, this is classed as OPEX
Capex Avg. Consequence: Failure to Trip	0	0	Minor repairs involved, this is classed as OPEX
Capex Avg. Consequence: Minor Non-Condition Failure	0	0	All costs are OPEX
Capex Avg. Consequence: Major Failure	310000	235000	Determined using historical costs.
Capex Avg. Consequence: Condition Replacement	615000	235000	Determined using historical costs.
Capex Avg. Consequence: Major Non-Condition Failure	615000	235000	Determined using historical costs.
Capex Avg. Consequence: Significant Failure	0	0	Significant repairs are involved, this is classed as OPEX
Capex Avg. Consequence: Significant Non-Condition Failure	0	0	Significant repairs are involved, this is classed as OPEX

8.2.3.3.2 *Situation For Cost of Failure*

These settings are used for reporting in the CBRM front end, and have no effect on results.

8.2.3.4 SAFETY

8.2.3.4.1 *Consequences*

The safety consequences are valued in monetary terms, and have been assessed by establishing a value of a safety event in terms of its adverse cost on society. CBRM uses the following consequences to determine safety risk:

- Minor – The event leads to an individual requiring medical treatment only;
- Major – The event incurs a lost time injury;
- Fatality – The event causes death or permanent disability.

EA Technology established the values for the three consequence types through collaboration with the Network Asset Management Group from SA Power Networks, the process that was used is outlined in Section 2 of Attachment A.

8.2.3.4.2 *Average Consequences*

The average safety consequences look at the frequency of all the events across all models, their determination is outlined in Section 3 of Attachment A.

8.2.3.5 Environment

8.2.3.5.1 *Consequences*

Five significant environmental consequences have been identified that could arise as a result of a network asset failure:

- Loss of oil;
- Emission of SF6 gas into the atmosphere;
- A significant fire with smoke pollution;
- The production of contaminated waste; and
- Major disturbance such as traffic congestion or noise.

CBRM assigns a monetary value to the environmental consequences based on trading values for carbon emissions. The overall process that was used to determine this is outlined in Section 2 of Attachment A.

8.2.3.5.2 *Failure Scenario Constants*

The average safety consequences look at the frequency of all the events across all models, their determination is outlined in Section 3 of Attachment A.

9. SUBSTATION TRANSFORMERS

9.1 HEALTH INDEX

There are Substation Transformers which use a Tap Changer. The Tap Changer contains oil which can contaminate the main Transformer tank, leading to spurious condition monitoring results. Contrary to this statement, the condition of the Tap Changer can also be a good indicator of the Transformer HI. CBRM determines the HI of both the Tap Changer and Transformer, and combines both HIs to give an overall determination of the entire unit's HI.

9.1.1 Tap Changer

9.1.1.1 Defect Factor

The number of defects identified on the Tap Changer is a good indicator of its condition. The Defect Factor is determined from a cumulative score of SAP SD notifications assigned to the corresponding Tap Changer over the last 5 years.

9.1.1.1.1 *Constants*

Setting Item	Value	Justification
Defect Factor Default	0.95	If no defects have been identified in the last 5 years, the Tap Changer is in better condition than anticipated
Overall Defect/Fault Factor Multiplier	0.05	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

9.1.1.1.2 *Defect Factor*

The defect factor and bands were established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

> Sum of Tapchanger Defects Scores Minimum	<= Sum of Tapchanger Defects Scores Maximum	Tapchanger Defect Factor	Justification
-1	0	1	Shows small amount of insignificant defects, no effect on HI
0	2	1.05	More insignificant defects
2	7	1.1	Significant amount of defects
7	15	1.15	Major defects
15	100	1.25	Many major defects recorded against the Tap Changer, indicating the it is problematic

9.1.1.2 Fault Factor

The number of faults experienced by the Tap Changer is a good indicator of its condition, and is therefore used to determine its HI. The Fault Factor is determined from a cumulative score of SAP FM notifications assigned to the corresponding Tap Changer over the last 5 years.

9.1.1.2.1 *Constants*

Setting Item	Value	Justification
Fault Factor Default	1	No fault recorded in last 5 years, set to have no effect on HI
Overall Defect/Fault Factor Multiplier	0.05	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

9.1.1.2.2 *Fault Factor*

The Fault Factor and bands were established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

> Sum of Tapchanger Faults Minimum	<= Sum of Tapchanger Faults Maximum	Tapchanger Fault Factor	Justification
-1	0	1	Shows small amount of insignificant breakdowns
0	1	1	More insignificant breakdowns
1	5	1.05	Significant amount of breakdowns
5	10	1.1	Major breakdowns
10	100	1.15	Many major breakdowns, as the Tap Changer is problematic

9.1.1.3 Condition

9.1.1.3.1 *Constants*

Setting Item	Value	Justification
Condition Factor Multiplier	0.05	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
TC Maintenance 1 Default Factor	1	Sets Maintenance Factor to 1 for no overall effect on HI when no factor can be calculated
TC Maintenance 2 Default Factor	1	Sets Maintenance Factor to 1 for no overall effect on HI when no factor can be calculated
TC Maintenance 3 Default Factor	1	Sets Maintenance Factor to 1 for no overall effect on HI when no factor can be calculated
TC Maintenance 4 Default Factor	1	Sets Maintenance Factor to 1 for no overall effect on HI when no factor can be calculated
TC Visual Inspection 1 Default Factor	1	Sets Visual Inspection Factor to 1 for no overall

Setting Item	Value	Justification
		effect on HI when no factor can be calculated
TC Visual Inspection 2 Default Factor	1	Sets Visual Inspection Factor to 1 for no overall effect on HI when no factor can be calculated
TC Maintenance 1 Default Minimum	0.5	Sets minimum calculated Maintenance Factor to 0.5, if no value is assigned
TC Maintenance 2 Default Minimum	0.5	Sets minimum calculated Maintenance Factor to 0.5, if no value is assigned
TC Maintenance 3 Default Minimum	0.5	Sets minimum calculated Maintenance Factor to 0.5, if no value is assigned
TC Maintenance 4 Default Minimum	0.5	Sets minimum calculated Maintenance Factor to 0.5, if no value is assigned
TC Visual Inspection 1 Default Minimum	0.5	Sets minimum calculated Visual Inspection Factor to 0.5, if no value is assigned
TC Visual Inspection 2 Default Minimum	0.5	Sets minimum calculated Visual Inspection Factor to 0.5, if no value is assigned

9.1.1.3.2 *Maintenance 1*
This feature is to be used for future condition measurements.

9.1.1.3.3 *Maintenance 2*
This feature is to be used for future condition measurements.

9.1.1.3.4 *Maintenance 3*
This feature is to be used for future condition measurements.

9.1.1.3.5 *Maintenance 4*
This feature is to be used for future condition measurements.

9.1.1.3.6 *Visual Inspection 1*
Not used, as for most cases the Tap Changer is enclosed within the Transformer.

9.1.1.3.7 *Visual Inspection 2*
Not used, as for most cases the Tap Changer is enclosed within the Transformer.

9.1.1.3.8 *TC Maintenance 1 Minimum HI*
This feature is to be used for future condition measurements.

9.1.1.3.9 *TC Maintenance 2 Minimum HI*
This feature is to be used for future condition measurements.

9.1.1.3.10 *TC Maintenance 3 Minimum HI*
This feature is to be used for future condition measurements.

9.1.1.3.11 *TC Maintenance 4 Minimum HI*
This feature is to be used for future condition measurements.

9.1.1.3.12 *TC Visual Inspection 1 Minimum HI*
Not used, as for most cases the Tap Changer is enclosed within the Transformer.

9.1.1.3.13 *TC Visual Inspection 2 Minimum HI*
Not used, as for most cases the Tap Changer is enclosed within the Transformer.

9.1.1.4 Duty
Duty factor models how hard an asset has worked in its operational life. Workshops between EA Technology CBRM experts, Transformer SME, and Asset Strategy Engineers determined that the prime indicator of Tap Changer duty is the number of operations it has completed.

9.1.1.4.1 *Constants*

Setting Item	Value	Justification
Tapchanger Duty Factor Default	1	Sets Factor to 1 (ie average number of operations) if the duty factor cannot be determined

9.1.1.4.2 *Tapchanger Tap Duty Factor*
The duty factor and operation bands were established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

> TC Taps Per Year Minimum	<= TC Taps Per Year Maximum	Tapchanger Duty Factor	Justification
0	1,000.00	0.9	Infrequent operation
1,000.00	3,000.00	1	Average number of operations
3,000.00	6,000.00	1.15	Moderate number of operations
6,000.00	10,000.00	1.25	High Number of operations
10,000.00	10,000,000.00	1	Possible incorrect measurement. Default to Average

9.1.1.5 Ops Since Last Maintenance
The HI of a Tap Changer degrades if it is not maintained within the manufacturer specified number of operations. CBRM factors this by identifying if the number of operations since last maintenance exceeds the amount recommended by the manufacturer.

9.1.1.5.1 *Constants*

Setting Item	Value	Justification
Ops Between Maintenance Default	50000	If the recommended number of operations between maintenance cannot be determined, the Reinhausen manufacturer recommendation is used
Ops Since Maintenance Factor Default	1	Sets factor to 1 for no overall effect on HI when the duty factor cannot be calculated

9.1.1.5.2 *Operations Between Maintenance*

The number of operations between maintenance has been assigned for each make and type, and is identical to those used by SA Power Networks.

9.1.1.5.3 *Ops Since Maintenance Factor*

The ops since maintenance factor and bands were established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

> Ops Since Last Maintenance % Minimum	<= Ops Since Last Maintenance % Maximum	Ops Since Last Maintenance Factor
0	90	0.5
90	100	3
100	10,000.00	7

9.1.1.6 End of Life Ops

9.1.1.6.1 *Constants*

Setting Item	Value	Justification
Max. Number of Operations Default	300000	Refer to Section 9.1.1.6.2
Ops End of Life Min HI Default	0.5	Refer to Section 9.1.1.6.2

9.1.1.6.2 *Max Number of Operations*

The proportion of maximum number of operations experienced by the Tap Changer can be used to determine the 'at best' HI. Based on SA Power Networks' operational experience and advice from the Transformer SME it was decided not to use this feature.

9.1.1.7 Overdue Maintenance

Apart from exceeding the maximum allowed operations between maintenance, time scheduled maintenance can also degrade the Tap Changer HI.

9.1.1.7.1 *Constants*

Setting Item	Value	Justification
Days Between Maintenance Default	2190	6 years nominal in accordance with the maintenance manual
Default Days Between Maintenance	0	Default to recently maintained Tap Changer
Overdue Maintenance Factor Default	1	Exclude from HI determination if the date when Tap Changer was last maintained is unknown

9.1.1.7.2 *Days Between Maintenance*

For each make and type, the days between maintenance has been set to 2190 (ie 6 years) as this is in accordance with the maintenance manual as well as SA Power Networks' current practice.

9.1.1.7.3 *Overdue Maintenance Factor*

The overdue maintenance factor and bands were established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

> Days Overdue Minimum	<= Days Overdue Maximum	Overdue Maintenance factor	Justification
-1	0	1	Maintenance is completed within the set interval
0	30	1.05	6 months - 1 year overdue
30	90	1.1	1 to 2 years overdue
90	100,000.00	1.3	More than 2 years overdue

9.1.1.8 HI1

HI1 is primarily age driven however it does take into account the duty and location factor. After CBRM determines HI1, it applies condition information to determine the overall HI the asset stands at today.

9.1.1.8.1 *Constants*

Setting Item	Value	Justification
HI1 Cap	5.5	HI of 5.5 indicates beginning of serious degradation. CBRM process caps the HI at this value if no condition information is available
Tapchanger Average Life Default	65	The average life has been assigned the REPEX calibrated life of 65 years
Tapchanger As New Age Default	0.5	HI of 0.5 indicates a brand new asset

Setting Item	Value	Justification
LogCalc	2.397895273	Model Constant set by EA Technology

9.1.1.8.2 *Tapchanger Average Life*

All Tap Changers have been assigned the REPEX calibrated life of 65 years.

9.1.1.8.3 *Tapchanger As New HI*

All Tap Changers are assigned an as new HI of 0.5, as this indicates that they're brand new.

9.1.1.9 Factor Value

The Factor Value is a HI modifier which uses results obtained from TASA tests, and known inherent design faults.

9.1.1.9.1 *Constants*

Setting Item	Value	Justification
Reliability Rating Default	2	If no reliability rating is assigned to the Tap Changer, average reliability is assumed
TASA Factor Default	1	If no TASA results have been recorded, it is excluded from HI determination

9.1.1.9.2 *Tapchanger Reliability Rating*

The Reliability Rating identifies Tap Changer models with inherent design flaws, and is assigned to each unit on a scale between 1 and 4, in accordance with SA Power Networks' operational experience.

9.1.1.9.3 *Tapchanger Reliability Factor*

The factors were established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide. They convert the Reliability Rating to a HI modifier.

Tapchanger Reliability Rating	Tapchanger Reliability Factor
1	0.9
2	1
3	1.1
4	1.3

9.1.1.9.4 *TASA Factor*
The factors were established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide. They convert the TASA score to a HI modifier.

Latest TASA Score	TASA Factor
1	0.9
2	1
3	1.2
4	1.5
Potential 4*	1.5
4*	2

9.1.1.10 Health Index
The Tap Changer HI is a combination of its age, location, duty, reliability, and condition measurements.

9.1.1.10.1 *Constants*

Setting Item	Value	Justification
Factor Value Multiplier	0.05	Established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide. They convert the TASA score to a HI modifier.
Tapchanger Maximum HI	10	Established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide. They convert the TASA score to a HI modifier.

9.1.1.10.2 *Minimum Health Index*
The Transformer SME decided not to use this feature as an unreliable Tap Changer is not necessarily in poor condition.

9.1.2 Transformer
The Transformer HI is determined from the following interim HIs:

- HI2 – Determined by HI1 with the following condition based measurements:
    - Tank Reliability: Captures operator knowledge with respect to Transformer reliability;
    - Bushing Reliability: Captures operator knowledge with respect to bushing types;
    - Overall Defect Fault Factor: Captures operational history of the Transformer by combining separate weighted sums of the defects and faults recorded against the Transformer in SAP;
    - Fault Damage: Allows for the Transformer to be tagged as having experienced above average fault events, and is only used when no other fault data is available;
    - Future Maintenance/Visual Inspection Placeholders.

- HI2a – Determined from Dissolved Gas Analysis (DGA) test results. CBRM finds the most recent result, and combines this with a history factor representing the trend from previous results. The trend is used to estimate if DGA is accelerating, stable or falling. CBRM also uses a flag to indicate likely contamination between the Transformer and Tap Changer so that HI2a is capped if the flag is set.
- HI2b – Determined using oil condition information. Ideal information used to determine this HI is the moisture content, acidity and breakdown strength.
- HI2c – Determined from FFA value. FFA represents the mechanical strength of the paper used to insulate the windings within the transformer. CBRM uses an empirical mathematical relationship to determine this HI, which is calibrated to give a value of 7 for a FFA value of 5ppm indicating that the paper has very little remaining strength and is at risk of failure during operation.

Year 0 HI is determined by combining the highest interim HI with a modifying factor. Further details on how the modifying factor is determined are documented in Sections 9.1.2.10.4, 9.1.2.10.5, and 9.1.2.10.6.

9.1.2.1 Defect Factor

The number of defects identified on the Transformer is a good indicator of its condition. CBRM counts the number of defects assigned over the last 5 years, and converts it to a factor which modifies the HI accordingly.

9.1.2.1.1 *Constants*

Setting Item	Value	Justification
Defect Factor Default	1	If no defects have been identified in the last 5 years, they have no effect on HI determination
Overall Defect/Fault Factor Multiplier	0.05	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

9.1.2.1.2 *Defect Factor*

The Defect Factor is determined from a cumulative score of SAP SD notifications assigned to the corresponding Transformer over the last 5 years.

> Sum of Defect Scores Minimum	<= Sum of Defect Scores Maximum	SD Factor	Justification
-1	0	1.00	Shows small amount of insignificant defects, no effect on HI
0	2	1.05	more insignificant defects
2	7	1.10	significant amount of defects
7	15	1.15	major defects
15	100	1.20	Many major defects recorded against, indicating the unit is problematic

9.1.2.2 Fault Factor

The number of faults experienced by the Transformer is a good indicator of its condition. The Fault Factor is determined from a cumulative score of SAP FM notifications assigned to the corresponding Transformer over the last 5 years, and modifies the HI accordingly.

9.1.2.2.1 *Constants*

Setting Item	Value	Justification
Fault Factor Default	1	No fault recorded in last 5 years, set to have no effect on HI
Overall Defect/Fault Factor Multiplier	0.05	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

9.1.2.2.2 *Fault Factor*

The fault factor and bands were established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

> Sum of FMs Scores Minimum	<= Sum of FMs Scores Maximum	Fm Factor	Justification
-1	0	1	Shows small amount of insignificant breakdowns
0	1	1	More insignificant breakdowns
1	5	1.05	Significant amount of breakdowns
5	10	1.1	Major breakdowns
10	100	1.15	Many major breakdowns, as the TC is problematic

9.1.2.3 Oil Test

Oil test results are a good indicator of Transformer condition, and are used to determine the interim HI2b.

9.1.2.3.1 *Constants*

Setting Item	Value	Justification
Moisture Default	0	Ignores measurement point if no condition data is available
Breakdown Strength Default	0	Ignores measurement point if no condition data is available
Acidity Default	0	Ignores measurement point if no condition data is available
Moisture Condition Index Multiplier	80	Relative weighting multiplier established through past CBRM / analytical experience with over 30 electrical utilities in 10 countries worldwide

Setting Item	Value	Justification
BD Strength Condition Index Multiplier	80	Relative weighting multiplier established through past CBRM / analytical experience with over 30 electrical utilities in 10 countries worldwide
Acidity Condition Index Multiplier	125	Relative weighting multiplier established through past CBRM / analytical experience with over 30 electrical utilities in 10 countries worldwide
Oil Condition Classification Default	1	Relative weighting multiplier established through past CBRM / analytical experience with over 30 electrical utilities in 10 countries worldwide

9.1.2.3.2 *Temperature Band*
Temperature band depends on the minimum and maximum recorded operating temperatures of the Transformer within the last 5 years. The banding ranges have been established from EA Technology's Experience with over 30 electrical utilities in 10 countries worldwide.

9.1.2.3.3 *Moisture Condition State*
The Moisture Condition State depends on moisture measurements from oil samples taken over the last 5 years. The banding ranges have been established from EA Technology's Experience with over 30 electrical utilities in 10 countries worldwide.

9.1.2.3.4 *BD Strength Condition State*
The Breakdown Strength Condition State depends on tests undertaken from oil samples taken over the last 5 years. The banding ranges have been established from EA Technology's Experience with over 30 electrical utilities in 10 countries worldwide.

9.1.2.3.5 *Acidity Condition State*
The Acidity Condition State depends on acidity measurements from oil samples taken over the last 5 years. The banding ranges have been established from EA Technology's Experience with over 30 electrical utilities in 10 countries worldwide.

9.1.2.3.6 *Oil Condition Classification*
The Oil Condition Classification depends on the overall test score assigned to measurements from oil samples taken over the last 5 years. The banding ranges have been established from EA Technology's Experience with over30 electrical utilities in 10 countries worldwide.

9.1.2.4 DGA Test
Dissolved Gasses within Transformer oil are a good indicator of Transformer condition, and are used to determine the interim HI2a.

9.1.2.4.1 *Constants*

Setting Item	Value	Justification
Hydrogen Default	0	Ignores measurement point if no condition data is available
Methane Default	0	Ignores measurement point if no condition data is available
Ethylene Default	0	Ignores measurement point if no condition data is available
Ethane Default	0	Ignores measurement point if no condition data is available
Acetylene Default	0	Ignores measurement point if no condition data is available
Hydrogen Condition Index Multiplier	50	Relative weighting multiplier established through past CBRM / analytical experience with over 30 electrical utilities in 10 countries worldwide
Methane Condition Index Multiplier	30	Relative weighting multiplier established through past CBRM / analytical experience with over 30 electrical utilities in 10 countries worldwide
Ethylene Condition Index Multiplier	30	Relative weighting multiplier established through past CBRM / analytical experience with over 30 electrical utilities in 10 countries worldwide
Ethane Condition Index Multiplier	30	Relative weighting multiplier established through past CBRM / analytical experience with over 30 electrical utilities in 10 countries worldwide
Acetylene Condition Index Multiplier	120	Relative weighting multiplier established through past CBRM / analytical experience with over 30 electrical utilities in 10 countries worldwide
Include Based on Sample Point Default	Yes	Set to include results in calculations where sample point description is not recorded
DGA Test Yrs Valid	10	Recommendation by EA Technology CBRM Experts
DGA Test Period in Days	365	Recommendation by EA Technology CBRM Experts

9.1.2.4.2 *Hydrogen Condition State*
The Hydrogen Condition State depends on the minimum and maximum recorded hydrogen gas levels in the Transformer oil for the last 5 years. The banding ranges have been established from EA Technology's Experience with over 30 electrical utilities in 10 countries worldwide.

9.1.2.4.3 *Methane Condition State*
The Methane Condition State depends on the minimum and maximum recorded methane gas levels in the Transformer oil for the last 5 years. The banding ranges have been established from EA Technology's Experience with over 30 electrical utilities in 10 countries worldwide.

9.1.2.4.4 *Ethylene Condition State*

The Ethylene Condition State depends on the minimum and maximum recorded ethylene gas levels in the Transformer oil for the last 5 years. The banding ranges have been established from EA Technology's Experience with over 30 electrical utilities in 10 countries worldwide.

9.1.2.4.5 *Ethane Condition State*

The Ethane Condition State depends on the minimum and maximum recorded ethane gas levels in the Transformer oil for the last 5 years. The banding ranges have been established from EA Technology's Experience with over 30 electrical utilities in 10 countries worldwide.

9.1.2.4.6 *Acetylene Condition State*

The Acetylene Condition State depends on the minimum and maximum recorded acetylene gas levels in the Transformer oil for the last 5 years. The banding ranges have been established from EA Technology's Experience with over 30 electrical utilities in 10 countries worldwide.

9.1.2.4.7 *Sample Point Inclusion*

Sample Point Inclusions are flag settings used to set the sample points which are routine diagnostics.

9.1.2.5 Oil Test Results

9.1.2.5.1 *Constants*

Setting Item	Value	Justification
DGA Divider	220	Relative weighting divider from CBRM expert system for DGA analysis
DGA Diagnostic Limit	3	Appropriate limit established through CBRM expert system for DGA analysis
DGA History Factor Default	1	Sets history factor multiplier for no effect where history factors cannot be calculated
Maximum DGA HI(a)	10	Appropriate limit established through CBRM expert system for DGA analysis
DGA Min HI	0	Appropriate limit established through CBRM expert system for DGA analysis
History Factor HI Limit	3	Appropriate limit established through CBRM expert system for DGA analysis
Oil Condition Divider	275	Relative weighting divider from CBRM expert system for DGA analysis
Oil Condition HI Minimum	0	Appropriate limit established from CBRM expert system for DGA analysis
Oil Condition HI Maximum	3	Appropriate limit established from CBRM expert system for DGA analysis
FFA HI Maximum	10	Appropriate limit established from CBRM expert system for DGA analysis

Setting Item	Value	Justification
FFA HI Minimum	0	Appropriate limit established from CBRM expert system for DGA analysis
PD Limit	10	Appropriate limit established from CBRM expert system for DGA analysis
Tapchanger Contamination Limit	2	Appropriate limit established from CBRM expert system for DGA analysis
Diagnostic Detection Flag	Y	Set to enable display of diagnostic flags based on CIGRE WG 15.01 DGA interpretation publication
Thermal Limit	1	Appropriate limit established from CBRM expert system for DGA analysis
Acetylene Limit	30	Appropriate limit established from CBRM expert system for DGA analysis
Arcing Limit	1	Appropriate limit established from CBRM expert system for DGA analysis
Minimum Health Index	0.5	Represents HI of a brand new Transformer

9.1.2.5.2 *Rate of DGA Change*

The CBRM Rate of DGA Change is used to smooth HI results so that a trend in condition can be determined. The banding ranges and factors have been established from EA Technology's Experience with over 30 electrical utilities in 10 countries worldwide.

9.1.2.5.3 *DGA History Factor*

The DGA History factor puts hysteresis into the DGA measurements so that the HI results can be smoothed. The banding ranges and factors have been established from EA Technology's Experience with over 30 electrical utilities in 10 countries worldwide.

9.1.2.6 Condition

9.1.2.6.1 *Constants*

Setting Item	Value	Justification
Condition Factor Multiplier	0.05	Satisfactory default established from EA Technology's CBRM experience with over 30 electrical utilities in 10 countries worldwide
TX Maintenance 1 Default Factor	1	Sets Maintenance Factor to 1 for no overall effect on HI when no factor can be calculated
TX Maintenance 2 Default Factor	1	Sets Maintenance Factor to 1 for no overall effect on HI when no factor can be calculated
TX Maintenance 3	1	Sets Maintenance Factor to 1 for no overall effect on HI when no

Setting Item	Value	Justification
Default Factor		factor can be calculated
TX Maintenance 4 Default Factor	1	Sets Maintenance Factor to 1 for no overall effect on HI when no factor can be calculated
TX Visual Inspection 1 Default Factor	1	Sets Maintenance Factor to 1 for no overall effect on HI when no factor can be calculated
TX Visual Inspection 2 Default Factor	1	Sets Maintenance Factor to 1 for no overall effect on HI when no factor can be calculated
TX Maintenance 1 Default Minimum	0.5	Sets minimum HI to 0.5, if no value is assigned
TX Maintenance 2 Default Minimum	0.5	Sets minimum HI to 0.5, if no value is assigned
TX Maintenance 3 Default Minimum	0.5	Sets minimum HI to 0.5, if no value is assigned
TX Maintenance 4 Default Minimum	0.5	Sets minimum HI to 0.5, if no value is assigned
TX Visual Inspection 1 Default Minimum	0.5	Sets minimum HI to 0.5, if no value is assigned
TX Visual Inspection 2 Default Minimum	0.5	Sets minimum HI to 0.5, if no value is assigned

9.1.2.6.2 *Maintenance 1*
This feature is to be used for future condition measurements.

9.1.2.6.3 *Maintenance 2*
This feature is to be used for future condition measurements.

9.1.2.6.4 *Maintenance 3*
This feature is to be used for future condition measurements.

9.1.2.6.5 *Maintenance 4*
This feature is to be used for future condition measurements.

9.1.2.6.6 *Visual Inspection 1*
Visual measurements are recorded by inspectors into the PAT. The measurements are manually assigned a score between 1 and 4, which CBRM uses as part of determining HI.

Visual Inspection 1	Visual Inspection 1 Factor	Justification
1	0.9	No visual corrosion
2	1	minor corrosion
3	1.1	severe corrosion
4	1.2	major corrosion

9.1.2.6.7 *Visual Inspection 2*

Visual measurements are recorded by inspectors into the PAT. The measurements are manually assigned a score between 1 and 4, which CBRM uses as part of determining HI.

Visual Inspection 1	Visual Inspection 1 Factor	Justification
1	0.9	No visual corrosion
2	1	minor corrosion
3	1.1	severe corrosion
4	1.2	major corrosion

9.1.2.6.8 *TX Maintenance 1 Minimum HI*

This feature is to be used for future condition measurements.

9.1.2.6.9 *TX Maintenance 2 Minimum HI*

This feature is to be used for future condition measurements.

9.1.2.6.10 *TX Maintenance 3 Minimum HI*

This feature is to be used for future condition measurements.

9.1.2.6.11 *TX Maintenance 4 Minimum HI*

This feature is to be used for future condition measurements.

9.1.2.6.12 *TX Visual Inspection 1 Minimum HI*

This feature is to be used for future condition measurements.

9.1.2.6.13 *TX Visual Inspection 2 Minimum HI*

This feature is to be used for future condition measurements.

9.1.2.7 Duty

Duty factor models how hard an asset has worked in its operational life. Workshops between EA Technology CBRM experts, Transformer SME, and Asset Strategy Engineers determined that the prime indicator of Transformer duty is the level of electrical loading in both annual peak and normal conditions.

9.1.2.7.1 *Constants*

Setting Item	Value	Justification
MVA Divisor	1000	Factor to convert kVA data as supplied to MVA for calculation purposes
Size of Asset Default	Medium	Sets default asset size to Medium for calculation purposes where this cannot be determined from available data
Percentage Load Factor Default	1	Sets factor default to 1 for no effect on HI where this cannot be determined from available data
Load Ratio Factor Default	1	Sets factor default to 1 for no effect on HI where this cannot be determined from available data
Situation Duty Factor Default	1	Sets factor default to 1 for no effect on HI where this cannot be determined from available data

9.1.2.7.2 *Size of Asset*

The Size of Asset categorises each Transformer within the following bands: Small, Medium and Large. The bands are aligned to SA Power Networks' Transformer Classification based on MVA.

9.1.2.7.3 *Percent Load Factor*

The percentage load factor is determined based on the Transformer loading relative to its nameplate rating. The bands and factors are satisfactory defaults based on EA Technology's CBRM experience with over 30 utilities in 10 countries worldwide.

> % Loading Minimum	<= % Loading Maximum	Percentage Load Factor
0	25.00	0.9
25	50.00	0.95
50	75.00	1
75	100.00	1.05
100	130.00	1.1
130	100,000.00	1

9.1.2.7.4 *Load Ratio Factor*

CBRM identifies the load ratio of the Transformer's substation and assigns an appropriate factor based on satisfactory defaults identified from EA Technology's experience with over 30 electrical utilities in 10 countries worldwide.

CBRM Justification

> Load Ratio Minimum	<= Load Ratio Maximum	Load Ratio Factor	Justification
0	0.30	0.9	Lightly loaded (lower 30% of subs)
0.3	0.40	1	0.35 is average substation (middle 50% of subs)
0.4	0.45	1.05	Moderately loaded
0.45	10.00	1.1	Heavy/constant load (top 10%)

9.1.2.7.5 *Situation Factor*

The Transformer SME identified that the installation location has no effect on the Transformer duty, and therefore this functionality is not used.

9.1.2.8 HI1

HI1 is primarily age driven, however it takes into account the duty and location factor. After CBRM determines HI1, it applies condition information to determine the overall HI the asset stands at today.

9.1.2.8.1 *Constants*

Setting Item	Value	Justification
Average Life Default	65	Typical average life of a power transformer based on SA Power Networks' operating experience
As New HI Default	0.5	Represents the HI of a brand new Transformer
HI1 Cap	5.5	Satisfactory default based on EA Technology's CBRM experience with 30 electrical utilities in 10 countries worldwide
LogCalc	2.397895273	Model Constant set by EA Technology

9.1.2.8.2 *Average Life*

The average life of the majority of Transformers has been aligned to SA Power Networks' operating experience of 65 years, with the exception of the following units that have thin radiator fins welded onto their main tank causing premature corrosion.

TX Manufacturer	TX Spec	Average Life
ABB	E1164	50
ABB	QT757	50
ABB	E1164a	50
ABB	QT299	50
WILSON	QT670	50

9.1.2.8.3 *As New HI*

The as new HI for every Transformer Make and Manufacturer is set to 0.5 to indicate the unit is brand new.

9.1.2.9 Factor Value

The Factor Value is a HI modifier which accounts for inherent design flaws, and operational temperature.

9.1.2.9.1 *Constants*

Setting Item	Value	Justification
Reliability Factor Default	1	If the Transformer reliability cannot be determined it is assigned with average reliability
Bushing Reliability Factor Default	1	If the bushing reliability cannot be determined it is assigned with average reliability
Max. Winding Temp Factor Default	1	If the maximum winding temperature cannot be determined it is excluded from the HI determination
Fault Damage Factor Default	1	Fault damage not used
Factor Value Multiplier	0.05	Satisfactory default established through EA Technology's past CBRM experience with 30 electrical utilities in 10 countries worldwide

9.1.2.9.2 *TX Reliability Rating*

The following units have known design flaws which are factored into their reliability rating.

TX Manufacturer	TX Spec	Reliability Rating	Justification
TYREE	E288a	3	Weak winding clamping that makes the units more likely to fail during through faults
ABB	E1164a	3	Weak winding clamping that makes the units more likely to fail during through faults
TYREE	E465a	4	Generic winding design weakness
ENGLISH ELECTRIC	E391a	4	SRBP bushings prone to catastrophic failure
ENGLISH ELECTRIC	E129a	4	SRBP bushings prone to catastrophic failure
ENGLISH ELECTRIC	E158a	4	SRBP bushings prone to catastrophic failure
ENGLISH ELECTRIC	318a	4	SRBP bushings prone to catastrophic failure
TYREE	QT1332	4	Poorly manufactured unit

9.1.2.9.3 *TX Reliability Factor*

The reliability factor is assigned based on the units reliability rating, it has been determined from EA Technology's satisfactory experience with over 30 electric utilities in 10 countries worldwide.

Reliability Rating	Reliability Factor	Justification
1	0.95	No Issues
2	1	Some Issues
3	1.15	Regular Issues
4	1.25	Significant Issues

9.1.2.9.4 *Bushing Reliability Rating*

This feature is not used as bushings are not populated in SAP.

9.1.2.9.5 *Bushing Reliability Factor*

This feature is not used as bushings are not populated in SAP.

9.1.2.9.6 *Max Winding Temp Factor*

The maximum winding temperature is a good indicator of the Transformer's loading during summer peak conditions. The banding and factors have been determined from EA Technology's past CBRM experience with 30 over electrical utilities in 10 countries worldwide.

> Maximum Winding Temperature Minimum	<= Maximum Winding Temperature Maximum	Winding Temperature Factor	Justification
0	80.00	0.9	Low loading on Transformer
80	110.00	0.95	WTI temp in normal range to alarm
110	130.00	1	WTI in alarm range
130	150.00	1.15	Active monitoring to Trip
150	100,000.00	1	Reading accuracy questionable over 150 deg C

9.1.2.9.7 *Fault Damage Factor*

This functionality is not used because the Transformer SME advised that the protection schemas prevent the unit from experiencing high fault currents.

9.1.2.10 Health Index

9.1.2.10.1 *Constants*

Setting Item	Value	Justification

Setting Item	Value	Justification
Tap Contamination Default	No	In most cases the Transformer and Tap Changer do not contaminate
Use Tapchanger Contaminations	Cap	DGA is used for contaminated transformers, HI is capped
Contaminated DGA HI(2a) Cap	4	HI cap for contaminated Transformer set to 4, as contamination gives artificially high DGA HI
2nd Value % Default	1	If the second HI value cannot be determined it is excluded from the HI determination
Max of Populated HI2a, HI2b,HI2c default	1	The Transformer SME decided not to use a combination factor for the maximum of HI2a, HI2b, HI2c
Number of populated HI's default	0	Sets default number of populated HIs to zero for calculation purposes when HI2a, HI2b, HI2c all cannot be calculated
Maximum Combined HI	10	Satisfactory default established by EA Technology's past CBRM experience with over 30 electrical utilities in 10 countries worldwide
Minimum Health Index	0.5	Satisfactory default established by EA Technology's past CBRM experience with over 30 electrical utilities in 10 countries worldwide

9.1.2.10.2 *TC Manufacturer/Type Contamination*

Contamination of oils within the Tap Changer and Transformer affects the DGA and oil test results, for example if the Tap Changer oil indicates that the Tap Changer is in poor condition and has contaminated the Transformer oil, the Transformer oil can also indicate the Transformer is in poor condition even though this may not be the actual case. Based on SA Power Networks' operational experience, the following Tap Changers are prone to contaminate with the Transformer.

Tapchanger Manufacturer	Tapchanger Type
ELIN	SRKO
FULLER	F313.33/200
FULLER	F317.33/200
REINHAUSEN	C111200
REINHAUSEN	D111400
ASSOCIATED TAP CHANGER LTD	F317.33/300

9.1.2.10.3 *TX Manufacturer/Type Contamination*

Contamination of oils within the Transformer and Tap Changer affects the DGA and oil test results, for example if the Transformer oil indicates that the Transformer is in poor condition and has contaminated the Tap Changer oil, the Tap Changer oil can also indicate the Tap Changer is in poor condition even though this may not be the actual case. Based on SA Power Networks' operational experience, the following Transformer are prone to contaminate with the Tap Changer

TX Manufacturer	TX Spec
WILSON	E163
TYREE	E297
TYREE	E360
TYREE	E465
ELIN	E65
TYREE	E99
TYREE	E465a
ABB	E1163a

9.1.2.10.4 *Factor for Other Values < 1.0*

These are settings used to determine the modifying factor when the interim HIs (a, b, and c) are less than 1 and less than HI2, they have been assigned based on EA Technology's past CBRM experience with over 30 electrical utilities in 10 countries worldwide. Further details on the interim HIs can be found in Section 9.1.2.

9.1.2.10.5 *2nd Value Factor*

These are settings used to determine the modifying factor when one or more interim HIs (a, b, and c) are greater than HI2, they have been assigned based on EA Technology's past CBRM experience with over 30 electrical utilities in 10 countries worldwide. Further details on the interim HIs can be found in Section 9.1.2.

9.1.2.10.6 *Factor for Other Values > 1.0*

These are settings used to determine the modifying factor when the interim HIs (a, b, and c) are greater than 1 and less than HI2, they have been assigned based on EA Technology's past CBRM experience with over 30 electrical utilities in 10 countries worldwide. Further details on the interim HIs can be found in Section 9.1.2.

9.1.3 Location Factor

9.1.3.1 Constants

Setting Item	Value	Justification
Surge Arrestor Default Factor	1	Conservative assumption that surge arrestors are installed
Pollution Factor Default	1	If the pollution factor cannot be determined it is excluded from the HI
Corrosion Default Factor	1	If the corrosion factor cannot be determined it is excluded from the HI

Setting Item	Value	Justification
Situation Default Factor	1	If the situation factor cannot be determined it is excluded from the HI
Minimum Location Factor	0.9	Satisfactory default established from EA Technology's past experience with over 30 utilities in 10 countries worldwide
Location Factor Increment	0.05	Satisfactory default established from EA Technology's past experience with over 30 utilities in 10 countries worldwide

9.1.3.2 Surge Arrestor Factor

A Transformer is more likely to be in better condition if a Surge Arrestor is present, settings have been assigned to reflect this.

9.1.3.3 Pollution Factor

The pollution factor models the effect industrial pollution has on Transformers, the values have been determined based on EA Technology's past experience with over 30 utilities in 10 countries worldwide.

Pollution	Pollution Factor	Justification
1	0.9	Extremely clean environment
2	1	Low pollution
3	1.05	Average - medium issues
4	1.1	industrial pollution - requires insulator washing etc

9.1.3.4 Corrosion Factor

The corrosion factor models the effect atmospheric corrosion has on Transformers, the values have been determined based on EA Technology's past experience with over 30 utilities in 10 countries worldwide.

Corrosion Zone	Corrosion Factor	Justification
1	0.9	Low corrosion zone
2	1	Severe corrosion zone
3	1.1	Very severe corrosion zone
4	1.2	Extreme corrosion area

9.1.3.5 Situation Factor

The Transformer's installation environment can affect its expected operating life, for example those located indoors last significantly longer than those located outdoors. The factors have been determined based on SA Power Network's operational experience by the Transformer SME in consultation with EA Technology CBRM experts.

Installation Environment	Situation Factor	Justification
Indoor	0.5	Out of the environment, covered, adequate cooling etc - expect better physical condition
Indoor 1	0.5	Out of the environment, covered, adequate cooling etc - expect better physical condition
Building	0.5	Out of the environment, covered, adequate cooling etc - expect better physical condition
Padmount	0.8	Outdoor, compact, partially enclosed
Building - Restricted	0.9	Less efficient cooling, more pollution build-up than ideal indoor environment
Partially Enclosed	0.95	Less efficient cooling, more pollution build-up
Pole Top	1	Same as outdoor
Outdoor	1	Base standard installation
Outdoor Cubicle	1	Not relevant to Transformers

9.1.4 Defect Data

The number of defects assigned against the Transformer can be a good indicator of its condition, for example a Transformer with lots of defects found within a small timeframe could be a problematic unit.

9.1.4.1 Constants

Setting Item	Value	Justification
Defect Score Default	1	If the defect score cannot be determined it is excluded from the HI

9.1.4.2 Defect Score

The Cumulative Defect Score is determined by identifying all SAP SD records created in the last 5 years which correspond to the Transformer. The individual defect scores are summed together, with appropriate weighting based on the SAP SD's priority and problem code. The overall score is converted to a HI modifying factor by matching it to the bands outlined in Section 9.1.2.1.2.

The Defect Score was determined in workshops with EA Technology CBRM Experts and the Transformer SME, and is based on how the defect affects the condition of a Transformer.

Defect Problem Code	Defect Priority	Defect Score
WORN / ABRADED	4	0.5
TRACKING	4	0.5
RESISTANCE LOW	4	0.5
SEIZED	4	0.5
OUT OF STEP	4	0.5
POLLUTION	4	0.5
OPEN CIRCUIT	4	0.5
INCORRECT OPERATION	4	0.5
LEAKING	4	0.5
LOW FLUID LEVEL	4	0.5
LOW OIL LEVEL	4	0.5
LOW VOLTS	4	0.5
MAL OPERATION	4	0.5
HIGH THERMAL IMAGE	4	0.5
TRACKING	3	0.5
FAILURE	4	0.5
FLASHED OVER	4	0.5
GASING	4	0.5
EARTH LEAKAGE	4	0.5
ERODED	4	0.5
EXCESSIVE NOISE	4	0.5
RESISTANCE LOW	3	0.5
SEIZED	3	0.5
OUT OF STEP	3	0.5
POLLUTION	3	0.5
WORN / ABRADED	3	0.5

Defect Problem Code	Defect Priority	Defect Score
BROKEN	4	0.5
CONTAMINATED OIL	4	0.5
CORRODED <50%	4	0.5
CORRODED >50%	4	0.5
CRACKED	4	0.5
DAMAGE	4	0.5
OPEN CIRCUIT	3	0.5
HIGH THERMAL IMAGE	3	0.5
INCORRECT OPERATION	3	0.5
LEAKING	3	0.5
LOW FLUID LEVEL	3	0.5
LOW OIL LEVEL	3	0.5
LOW VOLTS	3	0.5
MAL OPERATION	3	0.5
EARTH LEAKAGE	3	0.5
ERODED	3	0.5
EXCESSIVE NOISE	3	0.5
FAILED CHECK LIST INSPECTION	3	0.5
FAILURE	3	0.5
FLASHED OVER	3	0.5
GASING	3	0.5
BROKEN	3	0.5
CONTAMINATED OIL	3	0.5
CORRODED <50%	3	0.5
CORRODED >50%	3	0.5
CRACKED	3	0.5

Defect Problem Code	Defect Priority	Defect Score
DAMAGE	3	0.5
FAILED CHECK LIST INSPECTION	2	0.5
CONTAMINATED OIL	2	0.5
CONTAMINATED OIL	1	0.5
FAILED CHECK LIST INSPECTION	1	1
CORRODED <50%	2	1
CORRODED >50%	2	1
CRACKED	2	1
DAMAGE	2	1
BROKEN	2	1
FAILURE	2	1
FLASHED OVER	2	1
GASING	2	1
EARTH LEAKAGE	2	1
ERODED	2	1
EXCESSIVE NOISE	2	1
OUT OF STEP	2	1
POLLUTION	2	1
HIGH THERMAL IMAGE	2	1
OPEN CIRCUIT	2	1
INCORRECT OPERATION	2	1
LEAKING	2	1
LOW FLUID LEVEL	2	1
LOW OIL LEVEL	2	1
LOW VOLTS	2	1
MAL OPERATION	2	1

Defect Problem Code	Defect Priority	Defect Score
TRACKING	2	1
RESISTANCE LOW	2	1
SEIZED	2	1
WORN / ABRADED	2	1
VEGETATION	2	1
VERMIN	1	1.5
Does not maintain correct voltage	1	1.5
BROKEN	1	1.5
WORN / ABRADED	1	1.5
FAILURE	1	1.5
FLASHED OVER	1	1.5
GASING	1	1.5
OPEN CIRCUIT	1	1.5
TRACKING	1	1.5
RESISTANCE LOW	1	1.5
SEIZED	1	1.5
OUT OF STEP	1	1.5
POLLUTION	1	1.5
HIGH THERMAL IMAGE	1	1.5
CORRODED <50%	1	1.5
CORRODED >50%	1	1.5
CRACKED	1	1.5
DAMAGE	1	1.5
EARTH LEAKAGE	1	1.5
ERODED	1	1.5
EXCESSIVE NOISE	1	1.5

Defect Problem Code	Defect Priority	Defect Score
INCORRECT OPERATION	1	1.5
LEAKING	1	1.5
LOW FLUID LEVEL	1	1.5
LOW OIL LEVEL	1	1.5
LOW VOLTS	1	1.5
MAL OPERATION	1	1.5
FAILURE	Z	2

9.1.5 Fault Data
The number of faults a Transformer has experienced can be used to determine its condition, for example a Transformer which has experienced many faults during its operational life can be considered problematic.

9.1.5.1 Constants

Setting Item	Value	Justification
Fault Score Default	1	If the fault score cannot be determined, it is discounted

9.1.5.2 Fault Score
The Cumulative Fault Score is determined by identifying all SAP FM records created in the last 5 years which correspond to the Transformer. The individual fault scores are summed together, with appropriate weighting based on the SAP FM's priority and problem code. The overall score is converted into a HI modifying factor by matching it to the bands outlined in Section 9.1.2.2.2.

The Fault Scores were determined in workshops with EA Technology CBRM Experts and the Transformer SME, they're based on how each fault effects the condition of a Transformer.

Fault Cause Code	Fault Priority	Fault Score
Water in Oil	4	0.5
WTI Alarm	4	0.5
Oil Pump Failure	4	0.5
OLTC Faulty	4	0.5
OLTC not Tapping	4	0.5
OLTC tripping	4	0.5
OPEN CIRCUIT	4	0.5

Fault Cause Code	Fault Priority	Fault Score
TF failure	4	0.5
TF Faulty	4	0.5
TF Isolated	4	0.5
TF Replacement	4	0.5
Gassing	4	0.5
High Load	4	0.5
High Load Alarm	4	0.5
Investigation	4	0.5
leaking	4	0.5
LOW OIL LEVEL	4	0.5
Water in Oil	3	0.5
WTI Alarm	3	0.5
Arcing	4	0.5
Buchholz Alarm	4	0.5
Cooler Failure	4	0.5
Current High Alarm	4	0.5
Damaged Bushings	4	0.5
Earthing	4	0.5
Earthing Replaced	4	0.5
Fan Failure	4	0.5
TF failure	3	0.5
TF Faulty	3	0.5
TF Isolated	3	0.5
TF Replacement	3	0.5
Oil Pump Failure	3	0.5
OLTC Faulty	3	0.5

Fault Cause Code	Fault Priority	Fault Score
OLTC not Tapping	3	0.5
OLTC tripping	3	0.5
OPEN CIRCUIT	3	0.5
Gassing	3	0.5
High Load	3	0.5
High Load Alarm	3	0.5
Investigation	3	0.5
leaking	3	0.5
LOW OIL LEVEL	3	0.5
Arcing	3	0.5
Buchholz Alarm	3	0.5
Cooler Failure	3	0.5
Current High Alarm	3	0.5
Damaged Bushings	3	0.5
Earthing	3	0.5
Earthing Replaced	3	0.5
Fan Failure	3	0.5
Water in Oil	2	1
WTI Alarm	2	1
Oil Pump Failure	2	1
OLTC Faulty	2	1
OLTC not Tapping	2	1
OLTC tripping	2	1
OPEN CIRCUIT	2	1
TF failure	2	1
TF Faulty	2	1

Fault Cause Code	Fault Priority	Fault Score
TF Isolated	2	1
TF Replacement	2	1
Gassing	2	1
High Load	2	1
High Load Alarm	2	1
Investigation	2	1
leaking	2	1
LOW OIL LEVEL	2	1
Arcing	2	1
Buchholz Alarm	2	1
Cooler Failure	2	1
Current High Alarm	2	1
Damaged Bushings	2	1
Earthing	2	1
Earthing Replaced	2	1
Fan Failure	2	1
	1	1
MAL OPERATION	2	1
NO AC SUPPLY	1	1
Annealing	1	1
DC Supply failure	1	1
CONTAMINATED OIL	1	1
FLASHED OVER	1	1
Misaligned	1	1
INCORRECT OPERATION	1	1
Insulation Breakdown - Cable	1	1

Fault Cause Code	Fault Priority	Fault Score
FAILURE	1	1
DAMAGE	1	1
Leaning	1	1
Insulation Flashover	1	1
Loose	1	1
SUPPLY INTERRUPTION - 5 - WIDESPREAD	1	1
Vermin / Pests in ETSA Equipment	1	1
OPERATION AT SUBSTATION	1	1
Gas - Low & or Leaking	1	1
Isolate Customers equipment	1	1
Seized	1	2
Oil - Contaminated	1	2
Oil - Low & or Leaking	1	2
Overheating	1	2
Internal Electrical Fault	1	2
Fluid Level High	1	2
Footing / Trench Erosion	1	2
High Resistance Joint	1	2
Broken	1	2
Burnt	1	2
Clashing	1	2
Corroded	1	2
Does Not Operate	1	2
TF failure	1	2
TF Faulty	1	2

Fault Cause Code	Fault Priority	Fault Score
TF Isolated	1	2
TF Replacement	1	2
Oil Pump Failure	1	2
OLTC Faulty	1	2
OLTC not Tapping	1	2
OLTC tripping	1	2
OPEN CIRCUIT	1	2
Gassing	1	2
High Load	1	2
High Load Alarm	1	2
Investigation	1	2
leaking	1	2
LOW OIL LEVEL	1	2
Arcing	1	2
Buchholz Alarm	1	2
Cooler Failure	1	2
Current High Alarm	1	2
Damaged Bushings	1	2
Earthing	1	2
Earthing Replaced	1	2
Fan Failure	1	2
Water in Oil	1	2
WTI Alarm	1	2

9.1.6 Condition Connection Factor

The connection type can affect the Transformer condition, for example oil boxes can leak causing oil to seep into the main unit leading to deterioration.

9.1.6.1 Constants

Setting Item	Value	Justification
Primary Connection Condition Rating Default	2	If no primary condition rating is available, it is excluded from HI determination
Secondary Connection Condition Rating Default	2	If no secondary condition rating is available, it is excluded from HI determination
Primary Factor Condition Default	1	If the primary condition factor cannot be determined, it is excluded from HI determination
Secondary Factor Condition Default	1	If the secondary condition factor cannot be determined, it is excluded from HI determination
Connection Factor Multiplier	0.05	Satisfactory default established through past CBRM experience with 30 electrical utilities in 10 countries worldwide

9.1.6.2 Primary Connection Rating

Primary Connection A	Condition Primary Connection A Rating	Justification
Open Bushing	1	No issues
Compound Box	1	No issues
Oil box/plug connection	2	Oil leaks can seep into and deteriorate DBE connection
Plug	2	Oil leaks can seep into and deteriorate DBE connection
Air box	3	Leak, Moisture ingress, oil leaks into compound, difficult to work on.
Compound / Oil Box	3	Leak, Moisture ingress, oil leaks into compound, difficult to work on.

9.1.6.3 Secondary Connection Rating

Secondary Connection	Condition Secondary Connection Rating	Justification
Open Bushing	1	No issues
Air box	1	No issues
Oil box/plug connection	2	Oil leaks can seep into and deteriorate DBE connection
Plug	2	Oil leaks can seep into and deteriorate DBE

Secondary Connection	Condition Secondary Connection Rating	Justification
		connection
Compound Box	3	Leak, Moisture ingress, oil leaks into compound, difficult to work on.
Compound / Oil Box	3	Leak, Moisture ingress, oil leaks into compound, difficult to work on.

9.1.6.4 Primary Connection Factor

The primary connection factors assign a HI modifier to the primary connection rating, they are satisfactory defaults established from EA Technology's past CBRM experience with over 30 electrical utilities in 10 countries worldwide.

9.1.6.5 Secondary Connection Factor

The secondary connections factor assign a HI modifier to the secondary connection rating, they are satisfactory defaults established from EA Technology's past CBRM experience with over 30 electrical utilities in 10 countries worldwide.

9.1.7 Non-Condition Connection Factor

The non condition connection factor models connection types that attract wildlife who can cause faults through the Transformer.

9.1.7.1 Constants

Setting Item	Value	Justification
Primary Connection Non-Condition Rating Default	1	If no primary condition rating is available, it is excluded from the HI determination
Secondary Connection Non-Condition Rating Default	1	If no secondary condition rating is available, it is excluded from the HI determination
Primary Factor Non-Condition Default	1	If the primary condition factor cannot be determined, it is excluded from the HI determination
Secondary Factor Non-Condition Default	1	If the secondary condition factor cannot be determined, it is excluded from the HI determination
Connection Factor Multiplier	0.05	Satisfactory default established through past CBRM experience with over 30 electrical utilities in 10 countries worldwide

9.1.7.2 Primary Connection Rating

Transformer using open bushings on the primary connection can be in poorer condition as they attract wildlife. The primary connection rating is assigned to reflect this.

9.1.7.3 Secondary Connection Rating

Transformer using open bushings on the secondary connection can be in poorer condition as they attract wildlife. The secondary connection rating is assigned to reflect this.

9.1.7.4 Primary Connection Factor

The primary connection factors assign a HI modifier to the connection rating, they are satisfactory defaults established from EA Technology's past CBRM experience with over 30 electrical utilities in 10 countries worldwide.

9.1.7.5 Secondary Connection Factor

The primary connection factors assign a HI modifier to the connection rating, they are satisfactory defaults established from EA Technology's past CBRM experience with over 30 electrical utilities in 10 countries worldwide.

9.1.8 Year0 HI and PoF

9.1.8.1 Constants

Setting Item	Value	Justification
New Asset HI	0.5	HI of 0.5 indicates a brand new asset
Minimum Health Index	0.5	HI of 0.5 indicates a brand new asset
End of Life HI	7	CBRM process defines HI of 7 represents an asset at end of life
HI Category Default	No Result	Assigned if the HI cannot be determined

9.1.8.2 TX/TC Combined Value Factor

These settings are used for the combination of the Transformer and Tap Changer HIs. The final HI is determined as the maximum of the Transformer and Tap Changer HIs adjusted by the combined value factor. The combined value factors and bands are based on EA Technology's past CBRM experience with 30 electrical utilities in 10 countries worldwide.

> TX/TC Comp HI Percentage Minimum	<= TX/TC Comp HI Percentage Maximum	TX/TC Comp Value Factor
0	49.99	1
49.99	69.99	1
69.99	84.99	1.05
84.99	100	1.1

9.1.8.3 HI Category Y0

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

9.1.8.4 HI Category Y0 Multiplier

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

9.1.9 Future Health Index

9.1.9.1 Constants

Setting Item	Value	Justification
Yn	11	2014-2025
Ageing Constant from Y0 HI Maximum increase(multiplier)	2	Satisfactory default established from past CBRM Experience with 30 electrical utilities in 10 countries worldwide
Minimum Health Index	0.5	CBRM process defines HI of 0.5 represents a brand new asset.
Maximum Yn HI	15	Satisfactory default established from past CBRM Experience with 30 electrical utilities in 10 countries worldwide
Ageing Reduction Factor Default	1	If the ageing reduction factor cannot be determined, it is excluded from the HI
HI Category Default	No Result	Used if HI cannot be determined
Ageing Constant Multiplier Cap	1.2	Satisfactory default established from past CBRM Experience with over 30 electrical utilities in 10 countries worldwide fault established through past CBRM experience
Minimum age for recalculated B	10	Satisfactory default established from past CBRM Experience over with over 30 electrical utilities in 10 countries worldwide fault established through past CBRM experience

9.1.9.2 Ageing Reduction Factor

The age reduction factor models the increased life expectancy as Transformers age. The factors and HI bands were provided by the CBRM Architect and have been developed from EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide.

Final Asset HI Y0 Minimum	Final Asset HI Y0 Maximum	Ageing Reduction Factor
0	0	1
0	2	1
2	5.5	1.5
5.5	10	1.5

9.1.9.3 Future HI Category

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

9.1.9.4 Future HI Category Multiplier

The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

9.1.9.5 Transformer Size PoF Factor

Transformer PoF does not depend on its size, settings are assigned to have no effect on the result.

9.1.10 Failure Scenarios

9.1.10.1 Constants

Workshops undertaken with EA Technology CBRM Experts, The Transformer SME and Asset Strategy Engineers identified that distribution CBs have the following failure scenarios:

- Minor: Substation inspections identify the Transformer requires minor repairs;
- Significant: The Transformer fails and requires major repairs for restoration;
- Major: The Transformer catastrophically fails and needs to be replaced; and
- Replacement: The Transformer is replaced as it is in poor condition.

Setting Item	Value	Justification
No. Failures: Condition Minor	346	SAP SD notifications recorded within the last 5 years. Statistics are gathered from records of in-service failures, and are allocated based on consequence of failure not nature of plant failure
No. Failures: Condition Significant	3.7	Statistics are gathered from records of in-service failures, and are allocated based on consequence of failure not nature of plant failure. Transformer is repaired on site
No. Failures: Condition Major	2	Statistics are gathered from records of in-service failures, and are allocated based on consequence of failure not nature of plant failure. Transformer needs to be replaced
No. Failures: Condition Replacement	2.8	Statistics are gathered from records of in-service failures excluding historical targeted programs
No. Failures: Non-Condition Minor	39	SAP SD notifications recorded within the last 5 years. Statistics are gathered from records of in-service failures, and are allocated based on consequence of failure not nature of plant failure
No. Failures: Non-Condition Significant	1.7	Statistics are gathered from records of in-service failures, and are allocated based on consequence of failure not nature of plant failure. Transformer is repaired on site
No. Failures: Non-Condition Major	0.3	Statistics are gathered from records of in-service failures, and are allocated based on consequence of failure not nature of plant failure. Transformer needs to be replaced

CBRM Justification

Setting Item	Value	Justification
HILim: Condition Minor	4	Industry standard setting for HI where wear out phase begins
HILim: Condition Significant	4	Industry standard setting for HI where wear out phase begins
HILim: Condition Major	4	Industry standard setting for HI where wear out phase begins
HI Lim: Condition Replacement	4	Industry standard setting for HI where wear out phase begins
HIAvg: Condition Minor	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HIAvg: Condition Significant	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HIAvg: Condition Major	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
HI Avg: Condition Replacement	4	Standard CBRM setting to maintain constant PoF equivalent to HI=4 for HI < HI Lim
Cval: Condition Minor	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4.
Cval: - Condition Significant	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4.
Cval: Condition Major	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4.
C Value: Condition Replacement	1.335	Standard CBRM setting to set PoF at HI = 10 to be 10x greater than PoF at HI = 4.

9.2 RISK

9.2.1 Interventions

9.2.1.1 Constants

Setting Item	Value	Justification
Yn	11	2014-2025
Percentage Replacement	0	Targeted Intervention is used as unplanned replacements skew the risk profile
% Replacement Ranking Column	Delta Risk	Prioritises based on difference in risk between existing asset and new asset

CBRM Justification

Setting Item	Value	Justification
Replacement Default Cost	1170000	Weighted average of 12.5MVA Transformer replacement cost for the last 5 years
Refurbishment Default Cost	1170000	Refurbishments are modelled external to CBRM based on condition assessment, and are documented in the Substation Transformers Asset Management Plan
Average Life of New Asset	65	The average life has been assigned the REPEX calibrated life of 65 years
As New Duty Factor	1	Normal duty factor is assigned to the replaced asset

9.2.1.2 Yn Percentage Replacement HI Category
The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

9.2.1.3 Yn Target Intervention HI Category
The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

9.2.1.4 Yn Percentage Replacement HI Category Multiplier
The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

9.2.1.5 Yn Target Intervention HI Category Multiplier
The settings are used for reporting within CBRM, they are default values assigned by EA Technology, and have no effect on results.

9.2.1.6 Percentage Replacement Cost of Replacement

Size of Asset Copy	% Replacement Program Costs	Justification
Small	260000	This is the average replacement cost of all small Transformers for the last 5 years
Medium	1170000	Weighted average of 12.5MVA Transformer replacement cost for the last 5 years
Large	1640000	This is the average replacement cost of all large Transformers for the last 5 years

9.2.1.7 Targeted Intervention Replacement Cost
Targeted intervention replacement costs are identical those listed in Section 9.2.1.6. Targeted intervention has been used to develop a replacement program that maintains the risk profile rather than the percentage replacement program because the program needs to include units replaced on poor condition.

9.2.1.8 Targeted Intervention Refurbishment Cost

Refurbishments are modelled external to CBRM based on condition assessment, and are documented in the Substation Transformers Asset Management Plan.

9.2.1.9 New Asset

9.2.1.9.1 *Constants*

Setting Item	Value	Justification
New Asset HI	0.5	HI of 0.5 indicates a brand new asset

9.2.2 Criticality

Criticality is determined for each consequence category, it identifies the significance of a fault/failure, and is comprised of a number of weighting factors which represent relative severity.

9.2.2.1 Network Performance

Network Performance criticality represents significance of the penalty imposed on SA Power Networks when the asset causes an unplanned outage.

9.2.2.1.1 *Constants*

Setting Item	Value	Justification
NP Obsolescence Factor Default	2	If the Spares/Obsolescence factor cannot be determined it is set to have no significance on risk
Customer Type NP Factor	1	Network Performance by SCONRRR category captured by average restoration times
NP Situation Default	1	If it cannot be determined that the Transformer is indoor/outdoor, outdoor is used as it represents most situations
Secondary Voltage NP Default Factor	1	For the case where the secondary voltage is not defined, the most common case is used
No. TXs NP Default Factor	1	If the number of Transformers on site cannot be determined, a single unit is assumed
NP Minimum Factor	0.5	Satisfactory default established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
NP Maximum Factor	5	Set to give average importance on Network Performance
Tapchanger Spares and Obs. Default	1	Satisfactory default established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
NP TX Obsolescence Default	2	Refer to Section 0

9.2.2.1.2 *Transformer Obsolescence*
This feature is not used because the transformer tanks are non consumable parts.

9.2.2.1.3 *Tapchanger Obsolescence*
For each make and type, an obsolescence rating has been assigned by matching the following criteria with SA Power Networks' operational experience.

TC Obsolescence	Justification
1	Manufacturer's current product line. SAPN stocks of ready whole/component spares
2	Some issues (but spares generally available)
3	Spares only available through retirement of (aged) in service units (of average/uncertain condition).
4	Assets can not easily be replaced with modern equivalent & no existing spares or vendor support.

9.2.2.1.4 *Obsolescence Factor*
The obsolescence factor is assigned to the Tap Changer obsolescence, it places more network performance significance on Tap Changers which are difficult to replace (ie a modern unit may need to be installed on failure). The factors were assigned in workshops with EA Technology CBRM experts, Transformer SME and Asset Strategy Engineers.

TC Obsolescence	NP Obsolescence Factor
1	0.5
2	1
3	1.5
4	2

9.2.2.1.5 *Customer Type Factor*
The Transformer SME decided that this feature is not to be used because Network Performance by SCONRRR category is captured by average restoration times.

9.2.2.1.6 *Situation Factor*
The situation factor places twice as much significance on restoring indoor Transformers, as they are approximately twice more difficult to restore than outdoor units.

9.2.2.1.7 *Secondary Voltage Factor*
The secondary voltage factor places more significance on less common Transformer configurations, as they take longer to restore.

Secondary Voltage	NP Secondary Voltage Factor	Justification
11000	1	No Effect
240	1	No Effect
433	1	No Effect
3300	1	No Effect
33000	1	No Effect
66000	1	No Effect
33000/11000	2	Transformer with dual secondary voltages (in service tertiary) - restoration required at each voltage level
33000/7600	2	Transformer with dual secondary voltages (in service tertiary) - restoration required at each voltage level
7600	2	Non-standard distribution voltage/network
6600	3	Dedicated distribution substation

9.2.2.1.8 *No. Transformers Factor*

Substations with multiple Transformers take longer to restore than those with a single unit, and therefore have more significance to network performance risk. The levels of significance were determined in workshops with EA Technology CBRM experts, and the Transformer SME.

Number of TXs	No. Transformers NP Factor	Justification
5	0.5	Substations with 5 Transformers
6	0.5	Substations with 6 Transformers
4	0.6	Substations with 4 Transformers
3	0.8	Greater load redundancy - less switching/restoration efforts required
2	0.9	Possible Transformer redundancy (for part of the year)
1	1	Single Transformer Site restoration considered reference - more Transformers = easier to restore from Transformer failure than single unit
0	1	Ease of restoration given number of other Transformers at site

9.2.2.2 *OPEX*

OPEX criticality represents the significance an event has on the Operational Expenditure required to remediate it.

9.2.2.2.1 *Constants*

Setting Item	Value	Justification
Obsolescence Opex Default Factor	1	If the Spares/Obsolescence factor cannot be determined it is set to have no significance on risk
Customer Type Opex Default Factor	1	If the customer type cannot be determined, urban is assigned as it is more common
Opex Minimum Factor	0.5	Satisfactory default established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Opex Maximum Factor	5	Satisfactory default established through EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

9.2.2.2.2 *Obsolescence Factor*

The Obsolescence Factor reflects additional time spent looking/rebuilding spare parts, the levels of significance were determined in workshops with EA Technology CBRM experts and the Transformer SME. As previously mentioned in Section 9.2.2.1.3 Transformer obsolescence is not used, and therefore this criticality is only dependent on Tap Changer obsolescence, which is outlined in Section 9.2.2.1.3

TC Obsolescence	Opex Obsolescence Factor
1	0.5
2	1
3	2
4	3

9.2.2.2.3 *Customer Type Factor*

SCONRRR Category	Customer Type OPEX Factor	Justification
Urban	1	Set to have no effect based on SA Power Networks experience
Rural Short	1.2	Additional travel times, LAFA, and remote allowances

SCONRRR Category	Customer Type OPEX Factor	Justification
Rural Long	1.5	Additional travel times, LAFA, and remote allowances
CBD	2	Movement, access, and switching requirements within CBD are difficult

9.2.2.3 CAPEX

CAPEX criticality represents the significance an event has on the Capital Expenditure required to remediate it.

9.2.2.3.1 *Constants*

Setting Item	Value	Justification
Situation Capex Default Factor	1	If the situation cannot be determined, indoor is assigned as it is more common
Capex Minimum Factor	0.5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Capex Maximum Factor	5	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide

9.2.2.3.2 *Situation Factor*

Based on SA Power Networks' operational experience, indoor equipment requires 20% more CAPEX, and is therefore given 20% more significance.

9.2.2.4 Environment

Environmental criticality is used to factor adverse effects Transformer failure has on the environment.

9.2.2.4.1 *Constants*

Setting Item	Value	Justification
Asset Size Environment Default Factor	1	If the asset size cannot be determined, it is set to have no significance on the environment
Pre Oil Containment Environment Default Factor	1	If the presence of pre oil containment cannot be determined it is set to have no significance on the environment
Environment Medium Default Factor	1	If the medium cannot be determined, oil is assigned as it is the most common type
Bushing Construction Type Factor Default	1	If the bushing type cannot be determined, it is set to have no effect on the environment

Setting Item	Value	Justification
Env Minimum Factor	1	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Env Maximum Factor	10	Set to give environment a high relative importance

9.2.2.4.2 ***Environmental Risk Assessment Factor***

The environmental risk assessment is made outside of CBRM and varies asset to asset, it is used to identify the environmental impact if the Transformer fails.

Environmental Risk Assessment	Environmental Risk Assessment Factor
Low	0.5
Medium	1
High	2

9.2.2.4.3 ***Pre-Oil Containment Factor***

This factor is used to give 3x more environmental significance if no oil containment system is installed, as determined in workshops undertaken with EA Technology CBRM experts and the Transformer SME.

9.2.2.4.4 ***Medium Factor***

Medium	Environment Medium Factor	Justification
DRY	0.75	Dry Medium Transformers will not damage the environment, their significance is set below the norm because most Transformers are oil filled
OIL	1	More likely to damage environment

9.2.2.4.5 ***Size of Transformer Factor***

Larger Transformers spill/leak more of their insulation medium into the environment, and are therefore more expensive to clean up.

Size of Asset Copy	Size of Asset Environment Factor	Justification
Small	1	Low oil volume
Medium	2	Moderate oil volume
Large	3	High oil volume

9.2.2.4.6 ***Bushing Construction Type Factor***

CBRM Justification

Transformers that use oil filled bushings have been set to have more significance on environmental risk as failure will require oil cleanup.

9.2.2.5 Safety

Safety criticality represents the significance the asset has on public and employee safety.

9.2.2.5.1 *Constants*

Setting Item	Value	Justification
Situation Safety Default Factor	1	If the situation cannot be determined, outdoor is assigned as it is more common
Customer Type Safety Default Factor	1	If the customer type cannot be determined, it is set to have no effect on safety risk
Medium Safety Default Factor	1	If the medium cannot be determined oil is used as it is more common
Safety Minimum Factor	1	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Safety Maximum Factor	10	Set to give safety a high relative importance

9.2.2.5.2 *Situation Factor*

Indoor Transformers have been assigned to have more significance on safety because of the risk of uncontained fire/explosion.

9.2.2.5.3 *Customer Type Factor*

SCONRRR Category	Customer Type Safety Factor	Justification
Rural Long	0.5	Based on site location, remote sites have a lower probability of public exposure
Rural Short	1	Based on EA Technology's past CBRM experience with over 30 Electrical Utilities in 10 countries worldwide, Rural Short is assigned to have normal safety consequences
Urban	1.5	More likely to have an event in a built up area
CBD	2	Most likely to have an event in a heavily built up area

9.2.2.5.4 *Medium Factor*

Dry medium Transformers have been assigned below average safety significance because their medium is not flammable.

9.2.3 Average Cost of a Fault

9.2.3.1 Network Performance

CBRM Justification

Network Performance consequences are the penalties imposed on SA Power Networks whenever an outage occurs. It is important to note that SA Power Networks' operational experience has found that most Transformer failures incur a SAIDI that exceeds Major Event threshold, and as such there is no STPIS penalty. The only possible method for modelling Network Performance risk is to identify the adverse affect the failure has on the state economy, which is achieved by directly calculating the load put at additional risk and converting it to a dollar value using VCR.

A LAFF is then applied to the load at additional risk. The LAFF is a factor which uses a cubic relationship to quantify the additional risk when the load is above firm capacity of the network, it is calibrated to offset the Risk Factor (described in Section 9.2.3.1.4) with a value representing 1 for fully redundant and 20 for non redundant.

9.2.3.1.1 *Constants*

Setting Item	Value	Justification
CVALNP	0.037	Gives a 20:1 relationship between LAFF and % load above firm capacity.
KVALNP	1	Gives a 20:1 relationship between LAFF and % load above firm capacity.
Urban Lookup	Rural Short	If the type of substation cannot be determined, rural short is assumed. This accounts for both the majority of urban feeders as well as rural feeders supplying high loads to urban areas
Default Asset Redundancy	Redundant	If it cannot be determined that the Transformer supplies radial or redundant lines, redundancy is assumed as the consequences are more conservative
LAFF Value Default for Non-Redundant Assets	1	Conservative approach is to assume full redundancy if LAFF cannot be determined for non-redundant asset

9.2.3.1.2 *VCR Constants*

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
VCR ($) Redundant Assets	99243	49711	49711	49711	As Per AER STPIS Report
Power Factor Redundant Assets	0.9	0.9	0.9	0.9	Recommended by the Manager Network Planning
Load Factor Redundant Assets	0.4	0.4	0.4	0.4	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
VCR ($) Non Redundant Assets	99243	49711	49711	49711	As per AER STPIS Report

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
Load Factor Non Redundant Assets	0.4	0.4	0.4	0.4	Satisfactory default established through EA Technology's CBRM experience with over 30 Electrical Utilities in 10 countries worldwide
Power Factor Non Redundant Assets	0.9	0.9	0.9	0.9	Recommended by the Manager Network Planning

9.2.3.1.3 *Non-Redundant Constants*

The duration of non redundant outages has been derived using records in the HV database. Since outages of subtransmission transformers typically result in SAIDI above the major event threshold there are cases where no reliable records exist, and therefore the following assumptions needed to be made:

- Assume condition and non-condition failures are restored in the same timeframe;
- Assume significant and major failures are restored in the same timeframe.

The assumptions were determined in workshops with EA Technology CBRM experts, Transformer SME, and Asset Strategy Engineers.

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
NP Avg. Restoration Time (hrs): Non Redundant Condition Minor	0	0	0	0	No outage occurs here as this is a defect which is repaired while the unit is still in service
NP Avg. Restoration Time (hrs): Non Redundant Condition Significant	2.3	5	4	2.6	Determined from records stored in the HV database
NP Avg. Restoration Time (hrs): Non Redundant Condition Major	2.3	5	4	2.6	Determined from records stored in the HV database
NP Avg. Repair/Replace Time Factor: Non Redundant Condition Replacement	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Restoration Time (hrs): Non Redundant Non-Condition Minor	0	0	0	0	No outage occurs here as this is a defect which is repaired while the unit is still in service
NP Avg. Restoration Time (hrs): Non Redundant Non-Condition Significant	2.3	5	4	2.6	Determined from records stored in the HV database

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
NP Avg. Restoration Time (hrs): Non Redundant Non-Condition Major	2.3	5	4	2.6	Determined from records stored in the HV database
NP Avg. Repair/Replace Time Factor: Non Redundant Condition Minor	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Condition Significant	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Condition Major	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Risk Factor: Redundant Condition Replacement	0.05	0.05	0.05	0.05	Non redundant asset has LAFF of 20, so overall factor becomes 1 to represent redundancy
NP Avg. Repair/Replace Time Factor: Non Redundant Non-Condition Minor	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Non-Condition Significant	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Non Redundant Non-Condition Major	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Risk Factor: Non Redundant Condition Minor	1	1	1	1	100% of load is lost when a fault occurs on a non redundant line
NP Avg. Risk Factor: Non Redundant Condition Significant	1	1	1	1	100% of load is lost when a fault occurs on a non redundant line
NP Avg. Risk Factor: Non Redundant Condition Major	1	1	1	1	100% of load is lost when a fault occurs on a non redundant line
NP Avg. Risk Factor: Non Redundant Condition	1	1	1	1	100% of load is lost when a fault occurs on a non

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
Replacement					redundant line
NP Avg. Risk Factor: Non Redundant Non-Condition Minor	1	1	1	1	100% of load is lost when a fault occurs on a non redundant line
NP Avg. Risk Factor: Non Redundant Non-Condition Significant	1	1	1	1	100% of load is lost when a fault occurs on a non redundant line
NP Avg. Risk Factor: Non Redundant Non-Condition Major	1	1	1	1	100% of load is lost when a fault occurs on a non redundant line

9.2.3.1.4 *Redundant Constants*

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
NP Avg. Restoration Time (hrs): Redundant Condition Minor	0	0	0	0	No outage occurs here as this is a defect which is repaired while the unit is still in service
NP Avg. Restoration Time (hrs): Redundant Condition Significant	2.3	5	4	2.6	Determined from records stored in the HV database
NP Avg. Restoration Time (hrs): Redundant Condition Major	2.3	5	4	2.6	Determined from records stored in the HV database
NP Avg. Restoration Time (hrs): Redundant Condition Replacement	0	0	0	0	A planned outage is made to replace on condition
NP Avg. Restoration Time (hrs): Redundant Non-Condition Minor	0	0	0	0	No outage occurs here as this is a defect which is repaired while the unit is still in service
NP Avg. Restoration Time (hrs): Redundant Non-Condition Significant	2.3	5	4	2.6	Determined from records stored in the HV database
NP Avg. Restoration Time (hrs): Redundant	2.3	5	4	2.6	Determined from records stored in the HV database

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
Non-Condition Major					
NP Avg. Repair/Replace Time Factor: Redundant Condition Minor	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Condition Significant	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Condition Major	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Restoration Time (hrs): Non Redundant Condition Replacement	0	0	0	0	A planned outage is made to replace on condition
NP Avg. Repair/Replace Time Factor: Redundant Non-Condition Minor	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Non-Condition Significant	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Repair/Replace Time Factor: Redundant Non-Condition Major	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Risk Factor: Redundant Condition Minor	0.05	0.05	0.05	0.05	For redundant assets (load at risk = 1/20th load lost). This is based on EA Technology's CBRM Experience with over 30 electrical utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Condition Significant	0.05	0.05	0.05	0.05	For redundant assets (load at risk = 1/20th load lost). This is based on EA

Setting Item	CBD	Rural Long	Rural Short	Urban	Justification
					Technology's CBRM Experience with over 30 electrical utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Condition Major	0.05	0.05	0.05	0.05	For redundant assets (load at risk = 1/20th load lost). This is based on EA Technology's CBRM Experience with over 30 electrical utilities in 10 countries worldwide
NP Avg. Repair/Replace Time Factor: Redundant Condition Replacement	1	1	1	1	Entire restoration time is to undertake repair or replacement
NP Avg. Risk Factor: Redundant Non-Condition Minor	0.05	0.05	0.05	0.05	For redundant assets (load at risk = 1/20th load lost). This is based on EA Technology's CBRM Experience with over 30 electrical utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Non-Condition Significant	0.05	0.05	0.05	0.05	For redundant assets (load at risk = 1/20th load lost). This is based on EA Technology's CBRM Experience with over 30 electrical utilities in 10 countries worldwide
NP Avg. Risk Factor: Redundant Non-Condition Major	0.05	0.05	0.05	0.05	For redundant assets (load at risk = 1/20th load lost). This is based on EA Technology's CBRM Experience with over 30 electrical utilities in 10 countries worldwide

9.2.3.1.5 ***Maximum Substation Load Default***

No default values have been assigned.

9.2.3.2 OPEX

9.2.3.2.1 Constants

Setting Item	Large	Medium	Small	Justification
Opex Avg. Consequences: Minor Failure	1955	3210	2650	Average SAP SD Notification OPEX Orders for the last 5 years
Opex Avg. Consequences: Significant Failure	18000	18000	12000	Average of Significant Failure SAP FM Notification OPEX Orders recorded against Transformers for the last 5 years
Opex Avg. Consequences: Major Failure	30000	30000	17000	Average of Major Failure SAP FM Notification OPEX Orders recorded against Transformers for the last 5 years
Opex Avg. Consequence: Condition Replacement	23000	23000	27000	Average of Condition replacements for the last 5 years. Large & medium assumed equal.
Opex Avg. Consequences: Minor Non-Condition Failure	1955	3210	2650	Average SAP SD Notification OPEX Orders for the last 5 years
Opex Avg. Consequences: Significant Non-Condition Failure	18000	18000	12000	Average of Significant Failure SAP FM Notification OPEX Orders recorded against Transformers for the last 5 years
Opex Avg. Consequences: Major Non-Condition Failure	30000	30000	17000	Average of Major Failure SAP FM Notification OPEX Orders recorded against Transformers for the last 5 years

9.2.3.3 CAPEX

9.2.3.3.1 Constants

Setting Item	Large	Medium	Small	Justification
Capex Avg. Consequence: Minor Failure	0	0	0	Minor Failures captured entirely by OPEX.
Capex Avg. Consequence: Significant Failure	5000	5000	0	Average CAPEX spend for Significant failures in Medium and Large Transformers for the last 5 years, determined from SAP FM Notifications. Cost of significant failure for small Transformer is entirely OPEX

Setting Item	Large	Medium	Small	Justification
Capex Avg. Consequence: Major Failure	1640000	1170000	260000	Average of Planned/unplanned installation cost for the last 5 years
Capex Avg. Consequence: Condition Replacement	1640000	1170000	260000	Average of Planned/unplanned installation cost for the last 5 years
Capex Avg. Consequence: Minor Non-Condition Failure	0	0	0	Minor Failures captured entirely by OPEX.
Capex Avg. Consequence: Significant Non-Condition Failure	5000	5000	0	Average CAPEX for Significant failures in Medium and Large Transformers for the last 5 years, determined from SAP FM Notifications. Cost of significant failure for small Transformer is entirely OPEX
Capex Avg. Consequence: Major Non-Condition Failure	1640000	1170000	260000	Average of Planned/unplanned installation cost for the last 5 years

9.2.3.4 Safety

9.2.3.4.1 *Consequences*

The safety consequences are valued in monetary terms, and have been assessed by establishing a value of a safety event in terms of its adverse cost on society. CBRM uses the following consequences to determine safety risk:

- Minor – The event leads to an individual requiring medical treatment only;
- Major – The event incurs a lost time injury;
- Fatality – The event causes death or permanent disability.

EA Technology established the values for the three consequence types through collaboration with the Network Asset Management Group from SA Power Networks, the process that was used is outlined in Section 2 of Attachment A.

9.2.3.4.1 *Average Consequences*

The average safety consequences look at the frequency of all the events across all models, their determination is outlined in Section 3 of Attachment A.

9.2.3.5 Environment

9.2.3.5.1 *Consequences*

Five significant environmental consequences have been identified that could arise as a result of a network asset failure:

- Loss of oil;
- Emission of SF6 gas into the atmosphere;

- A significant fire with smoke pollution;
- The production of contaminated waste; and
- Major disturbance such as traffic congestion or noise.

CBRM assigns a monetary value to the environmental consequences based on trading values for carbon emissions. The overall process that was used to determine this is outlined in Section 2 of Attachment A.

9.2.3.5.2 *Failure Scenario Constants*

The average safety consequences look at the frequency of all the events across all models, their determination is outlined in Section 3 of Attachment A.

A. CBRM Information Source Clarification Questions

Insert EA Technology Response PDF document here

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