

Substation Maintenance Instruction

PRIMARY SYSTEMS	Document No.	SMI 161
	Amendment No.	0
	Approved By	CE
	Approval Date	26/6/2015
	Review Date	26/6/2018

SMI 161 Condition assessment of assets using health index

SECTION 4 – CIRCUIT BREAKER

Contents

4.1	Asset description.....	2
4.2	Condition assessment.....	2
4.3	Condition rating	2
4.3.1	<i>Oil circuit breakers</i>	<i>2</i>
4.3.2	<i>SF6 circuit breakers</i>	<i>7</i>
4.3.3	<i>Vacuum circuit breakers.....</i>	<i>12</i>
4.3.4	<i>SF6 circuit breakers with vacuum interrupters.....</i>	<i>15</i>
4.4	Health index formulation	19
4.4.1	<i>Oil circuit breakers health index</i>	<i>19</i>
4.4.2	<i>SF6 circuit breakers health index</i>	<i>19</i>
4.4.3	<i>Vacuum circuit breakers health index.....</i>	<i>20</i>
4.4.4	<i>SF6 circuit breakers with vacuum interrupters health index.....</i>	<i>20</i>
4.4.5	<i>Health index calculation</i>	<i>21</i>
4.5	Health index results and condition assessment.....	21

4.1 Asset description

Circuit breakers in the transmission and distribution network are switching devices that can make, carry and interrupt electrical currents under normal and abnormal conditions. They operate infrequently. However, when an electrical fault occurs, circuit breakers must operate reliably and within a specified time frame to clear the fault without failing catastrophically. This health index covers the three main types of circuit breaker insulation within Endeavour Energy's network. They have oil/SF6/air insulation and are equipped with solenoid/spring/magnetic actuator operation mechanisms.

4.2 Condition assessment

Circuit breakers represent the most critical element of power systems. Circuit breakers serve as the end device of protective equipment systems, and must interrupt both load and fault currents reliably when required.

Circuit breakers have many moving parts that are subject to wear and stress. They 'make' and 'break' high currents and experience the arcing that accompanies such operations. Arcing produces heat and decomposition products that degrade contacts, insulation materials and other internal parts. The mechanical energy needed for high velocity operation of these assets adds mechanical deterioration to their degradation processes.

The components mentioned in Sections 4.1 and 4.2 are assessed based on set criteria and given a condition based rating. The assessed condition of these components is the foundation on which the Health Index is calculated from.

4.3 Condition rating

The condition rating process includes field inspections and detailed review of maintenance records and test reports. Each criterion represents a factor that is critical in determining the component's condition relative to potential failure.

The following tables contain specific definitions used for each condition rating for each component or test evaluated:

4.3.1 Oil circuit breakers

4.3.1.1 Bushing condition

Condition Rating	Description
A	- Bushings are not broken and no visible chips, cracks and flashover burns. - Cementing and fasteners are secure.
B	- Bushings are not broken, however minor chips and cracks are visible. - Cementing and fasteners are secure.
C	- Bushings are not broken, however major chips, cracks and some flashover burns are visible. - Cementing and fasteners are secure.
D	- Bushings are broken / damaged. - Cementing and fasteners are not secure.
E	Bushings, cementing or fasteners are broken / damaged beyond repair.

4.3.1.2 Tank and mechanism

Condition Rating	Description
A	- No rust or corrosion on main tank and mechanism cabinet. - No degradation of paintwork. - Mechanism cabinet has no evidence of condensation, moisture or insect ingress.
B	- No rust or corrosion. - Some evidence of slight moisture ingress or condensation in mechanism cabinet.
C	Some rust and corrosion on both main tank and mechanism cabinet.
D	- Significant corrosion on main tank and mechanism cabinet. - Defective mechanism cabinet sealing leading to water ingress and insects / rodent damage.
E	Corrosion, water ingress or insect / rodent damage / degradation are beyond repair.

4.3.1.3 Oil leaks

Condition Rating	Description
A	- No oil leakage or water ingress at any of the bushing to metal interfaces. - No oil leakage or water ingress at any of the flanges, covers, breathers, pipe work or gauges. - Oil levels are acceptable.
B	Minor oil leaks evident, no moisture ingress likely.
C	Clear evidence of oil leaks but rate of loss is not likely to cause any operational or environmental impacts.
D	Major oil leakage and probable moisture ingress at any location mentioned above.
E	Significant oil leakage and moisture ingress resulting in damage / degradation beyond repair.

4.3.1.4 Control and mechanism components

Condition Rating	Description
A	- Wiring terminal blocks, relays, contactors and switches all in good condition. - No reoccurring blown fuses. - Operating mechanism, trip and close coils, relays, auxiliary switches, motors, springs are all in good working condition (trip check). - No sign of overheating or deterioration. - Linkages, drive rods, trip latches are clean, free from cracks, distortion, abrasion or obstruction. - Mechanical integrity of dampers/dashpots, and oil levels, is acceptable. - No visible evidence of poor mechanism settings, looseness, loss of adjustment, excess bearing / gear wear or other out of tolerance operations.
B	Control and mechanism components show normal signs of wear.
C	One or two of the control and mechanism components are unacceptable.

D	More than two of the control and mechanism components are unacceptable.
E	Control and mechanism components are damaged / degraded beyond repair.

4.3.1.5 Overall CB condition

Condition Rating	Description
A	- Circuit breaker is externally clean, and corrosion free. - All primary connections (hotspots), secondary connections are in good condition. - No external evidence of overheating. - Number of CB operations on counter is below expected for age and location of CB. - Support steelwork and/or anchor bolts are secure and free from corrosion. - Earthing connections are secure, free from corrosion and made directly to tanks, cubicles and supports, without any intervening paint or corrosion.
B	Circuit breaker shows normal signs of wear.
C	Some external corrosion and/or signs of overheating.
D	Significant external corrosion and/or signs of overheating.
E	The circuit breaker is damaged / degraded beyond repair.

4.3.1.6 Timing test

Condition Rating	Description
A	Closing, tripping and inter-pole timing difference is in line with commissioning test results.
B	Closing, tripping and inter-pole time difference is not in line with the commissioning test results but within manufacturer's specified limits.
C	One of the closing, tripping or inter-pole timing differences are not within the manufacture's specified limits.
D	Two of the closing, tripping or inter-pole timing differences are not within the manufacture's specified limits.
E	The closing, tripping and inter-pole timing differences are not within the manufacture's specified limits.

Manufacturer and model	Maximum trip time (ms)	Maximum close time (ms)	Maximum inter-pole time (ms)
Westinghouse 33kV 345GCN	100	450	2
AEI 33kV LGIC44	100	450	2
Reyrolle 33kV L800	50	300	2
ABB 132kV HLR	35	130	3
ABB 66kV HLC	55	130	2
Sprecher and Schuh 66kV HPF	25	160	2
Magrini Galileo 33kV MGE	70	110	3
Magrini Galileo 33kV MG	70	110	3
GEC 11kV OLX	100		

Hawker Siddley 11kV Q & R series	100		
Reyrolle 11kV LMT	80		
South Wales Electric 11kV D series	100		
Westinghouse 11kV B18	100		
Westinghouse 11kV F250	115		
Westinghouse 11kV J18	100		
Westinghouse 11kV J22	100		
Other	100	*	*

* Contact Primary Systems for value.

Note: These values are for the purpose of calculating the health index. For maintenance limit requirements refer to Substation Maintenance Instruction SMI 200 – HV circuit breakers.

4.3.1.7 Bushing DDF test

Condition Rating	Description
A	Less than or equal to the pre-commissioning value if available or within manufacturer's limit, otherwise ≤ 10.0 mrad @ 20°C.
B	Less than 30% increase from the pre-commissioning value if available or within manufacturer's limit, otherwise between 10.0 – 13.0 mrad @ 20°C.
C	Between 30 – 70% increase from the pre-commissioning value if available or within manufacturer's limit, otherwise between 13.0 – 17.0 mrad @ 20°C.
D	Between 70 – 100% increase from the pre-commissioning value if available or within manufacturer's limit, otherwise between 17.0 – 20.0 mrad @ 20°C.
E	Greater than 100% increase from the pre-commissioning value if available or exceeds manufacturer's limit, otherwise ≥ 20.0 mrad @ 20°C.

4.3.1.8 Primary contact resistance

Condition Rating	Description
A	Less than or equal to the pre-commissioning value if available and within manufacture's specifications.
B	Less than 30% increase from the pre-commissioning value if available and within manufacture's specifications.
C	Between 30 – 70% increase from the pre-commissioning value if available and within manufacture's specifications.
D	Between 70 – 100% increase from the pre-commissioning value if available and within manufacture's specifications.
E	Greater than 100% increase from the pre-commissioning value if available or outside manufacture's specifications.

Manufacturer and model	Maximum contact resistance ($\mu\Omega$)
Westinghouse 33kV 345GCN	200
AEI 33kV LGIC44	200
Reyrolle 33kV L800	100
ABB 132kV HLR	50
ABB 66kV HLC	55
Sprecher and Schuh 66kV HPF	100
Magrini Galileo 33kV MGE	50
Magrini Galileo 33kV MG	50
GEC 11kV OLX	Rating <800A: 200
	Rating >800A: 100
Hawker Siddley 11kV Q & R series	Rating <800A: 200
	Rating >800A: 100
Reyrolle 11kV LMT	Rating <800A: 200
	Rating >800A: 100
South Wales Electric 11kV D series	Rating <800A: 200
	Rating >800A: 100
Westinghouse 11kV B18	Rating <800A: 200
	Rating >800A: 100
Westinghouse 11kV F250	Rating <800A: 200
	Rating >800A: 100
Westinghouse 11kV J18	200
Westinghouse 11kV J22	100
Other	200

Note: These values are for the purpose of calculating the health index. For maintenance limit requirements refer to Substation Maintenance Instruction SMI 200 – HV circuit breakers.

4.3.1.9 Insulation resistance (measured at 2.5kV)

Condition Rating	Description
A	Greater than 90% of previous IR test result.
B	Between 90 – 80% of previous IR test result.
C	Between 80 – 70% of previous IR test result.
D	Less than 70% of previous IR test result.
E	Less than minimum IR limit.

Manufacturer and model	Minimum IR limit (GΩ)
Westinghouse 33kV 345GCN	Phase - Earth: 10
	Phase - Phase: 5
AEI 33kV LGIC44	Phase - Earth: 10
	Phase - Phase: 5
Reyrolle 33kV L800	Phase - Earth: 10
	Phase - Phase: 5
ABB 132kV HLR	Phase - Phase: 50
ABB 66kV HLC	Phase - Phase: 20
Sprecher and Schuh 66kV HPF	Phase - Phase: 50
Magrini Galileo 33kV MGE	Phase - Phase: 50
Magrini Galileo 33kV MG	Phase - Phase: 50
Other	1

Note: These values are for the purpose of calculating the health index. For maintenance limit requirements refer to Substation Maintenance Instruction SMI 200 – HV circuit breakers.

4.3.1.10 Coil condition

Condition Rating	Description
A	Tripping and closing at 70% dc volts (low voltage check).
E	Not tripping and closing at 70% dc volts (low voltage check).

4.3.1.11 Inherent safety issues

Condition Rating	Description
A	No risk to safety, environment or network.
B	Minor risk to safety, environment or network.
C	Moderate risk to safety, environment or network.
D	Major risk to safety, environment or network.
E	Severe risk to safety, environment or network.

4.3.2 SF6 circuit breakers

4.3.2.1 Bushing condition

Condition Rating	Description
A	- Bushings are not broken and no visible chips, cracks and flashover burns. - Cementing and fasteners are secure.
B	- Bushings are not broken, however minor chips and cracks are visible. - Cementing and fasteners are secure.
C	- Bushings are not broken, however major chips, cracks and some flashover burns are visible. - Cementing and fasteners are secure.
D	- Bushings are broken / damaged. - Cementing and fasteners are not secure.
E	Bushings, cementing or fasteners are broken / damaged beyond repair.

4.3.2.2 Tank and mechanism

Condition Rating	Description
A	- No rust or corrosion on main tank and mechanism cabinet. - No degradation of paintwork. - Mechanism cabinet has no evidence of condensation, moisture or insect ingress.
B	- No rust or corrosion. - Some evidence of slight moisture ingress or condensation in mechanism cabinet.
C	Some rust and corrosion on both main tank and mechanism cabinet.
D	- Significant corrosion on main tank and mechanism cabinet. - Defective mechanism cabinet sealing leading to water ingress and insects / rodent damage.
E	Corrosion, water ingress or insect / rodent damage / degradation are beyond repair.

4.3.2.3 SF6 leaks

Condition Rating	Description
A	No SF6 leakage at any of the bushing to metal interfaces, tank or piping interfaces, as determined by inspection of the SF6 pressure gauge and SF6 refill maintenance records.
B	Minor SF6 leakage, no more than 0.5% per year, by weight, of the total quantity of SF6 in the breaker, as determined by inspection of SF6 pressure gauge and refill maintenance records.
C	SF6 leakage of up to 0.65% per year, by weight, of the total quantity of SF6 in the breaker, as determined by inspection of SF6 pressure gauge and refill maintenance records.
D	SF6 leakage of up to 0.8% per year, by weight, of the total quantity of SF6 in the breaker, as determined by inspection of SF6 pressure gauge and refill maintenance records.
E	SF6 leakage exceeding 1% per year, by weight, of the total quantity of SF6 in the breaker, as determined by inspection of SF6 pressure gauge and refill maintenance records.

4.3.2.4 Control and mechanism components

Condition Rating	Description
A	- Wiring terminal blocks, relays, contactors and switches all in good condition. - No reoccurring blown fuses. - Operating mechanism, trip and close coils, relays, auxiliary switches, motors, springs are all in good working condition (trip check). - No sign of overheating or deterioration. - Linkages, drive rods, trip latches are clean, lubricated, free from cracks, distortion, abrasion or obstruction. - Mechanical integrity of dampers / dashpots, and SF6 levels, is acceptable. - No visible evidence of poor mechanism settings, looseness, loss of adjustment, excess bearing wear or other out of tolerance operations.

B	Control and mechanism components show normal signs of wear.
C	One or two of the control and mechanism components are unacceptable.
D	More than two of the control and mechanism components are unacceptable.
E	Control and mechanism components are damaged / degraded beyond repair.

4.3.2.5 Overall CB condition

Condition Rating	Description
A	- Circuit breaker is externally clean, and corrosion free. - All primary connections (hotspots), secondary connections are in good condition. - No external evidence of overheating. - Number of CB operations on counter is below expected for age and location of CB. - Support steelwork and/or anchor bolts are secure and free from corrosion. - Earthing connections are secure, free from corrosion and made directly to tanks, cubicles and supports, without any intervening paint or corrosion.
B	Circuit breaker shows normal signs of wear.
C	Some external corrosion and/or signs of overheating.
D	Significant external corrosion and/or signs of overheating.
E	The circuit breaker is damaged / degraded beyond repair.

4.3.2.6 Timing test

Condition Rating	Description
A	Closing, tripping and inter-pole timing difference is in line with commissioning test results.
B	Closing, tripping and inter-pole time difference is not in line with the commissioning test results but within manufacturer's specified limits.
C	One of the closing, tripping or inter-pole timing differences are not within the manufacture's specified limits.
D	Two of the closing, tripping or inter-pole timing differences are not within the manufacture's specified limits.
E	The closing, tripping and inter-pole timing differences are not within the manufacture's specified limits.

Manufacturer and model	Maximum trip time (ms)	Maximum close time (ms)	Maximum inter-pole time (ms)
ABB 11kV GK1M	80		
ABB 11kV HB	75		
Merlin Gerin / Schneider 11kV SM6	55		
Yorkshire 11kV YSF6	100		
ABB 132/66kV ELK	18	36	1.5
Siemens 132/66kV 3AP1DT/FG	34	60	2
Areva 132kV F35	31	100	1.5
Hyosung 132kV HLSP	35	120	Trip: 3.3
			Close: 5
Hyundai 132kV 145-SP-1	34	96	Trip: 3.3
			Close: 5
Magrini Galileo 33kV 36GI-E25	63	72	1
Merlin Gerin 33kV FG4	55	90	2
GEC 132/66kV HGF	30	154	2
ABB 66/33kV EDF	35	60	3
Areva 66/33kV DT1/DT09	30	90	3
ABB 66kV ENK	60	60	3
Other	100	*	*

* Contact Primary Systems for value.

Note: These values are for the purpose of calculating the health index. For maintenance limit requirements refer to Substation maintenance Instruction SMI 200 – HV circuit breakers.

4.3.2.7 Primary contact resistance

Condition Rating	Description
A	Less than or equal to the pre-commissioning value if available and within manufacture's specifications.
B	Less than 30% increase from the pre-commissioning value if available and within manufacture's specifications.
C	Between 30 – 70% increase from the pre-commissioning value if available and within manufacture's specifications.
D	Between 70 – 100% increase from the pre-commissioning value if available and within manufacture's specifications.
E	Greater than 100% increase from the pre-commissioning value if available or outside manufacture's specifications.

Manufacturer and model	Maximum contact resistance ($\mu\Omega$)
Siemens 132/66kV 3AP1DT/FG	200
Magrini Galileo 33kV 36GI-E25	30
Merlin Gerin 33kV FG4	100
GEC 132/66kV HGF	200
ABB 66/33kV EDF	156
Areva 66/33kV DT1/DT09	156
Other	200

Note: These values are for the purpose of calculating the health index. For maintenance limit requirements refer to Substation Maintenance Instruction SMI 200 - HV circuit breakers.

4.3.2.8 Primary contact wear out

Condition Rating	Description
A	Greater than 80% of permissible number of interruptions remaining.
B	Between 80 – 60% of permissible number of interruptions remaining.
C	Between 60 – 40% of permissible number of interruptions remaining.
D	Between 40 – 20% of permissible number of interruptions remaining.
E	Less than 20% of permissible number of interruptions remaining. Interrupter replacement required soon.

Note: The permissible number of interruptions remaining can be estimated by the number of operations versus breaking current curve found in the manufacturer's manual.

4.3.2.9 Insulation resistance (measured at 2.5kV)

Condition Rating	Description
A	Greater than 90% of previous IR test result.
B	Between 90 – 80% of previous IR test result.
C	Between 80 – 70% of previous IR test result.
D	Between 70 – 60% of previous IR test result.
E	Less than 1 GΩ.

4.3.2.10 Inherent safety issues

Condition Rating	Description
A	No risk to safety, environment or network.
B	Minor risk to safety, environment or network.
C	Moderate risk to safety, environment or network.
D	Major risk to safety, environment or network.
E	Severe risk to safety, environment or network.

4.3.3 Vacuum circuit breakers

4.3.3.1 Bushing condition

Condition Rating	Description
A	- Bushings are not broken and no visible chips, cracks and flashover burns. - Cementing and fasteners are secure.
B	- Bushings are not broken, however minor chips and cracks are visible. - Cementing and fasteners are secure.
C	- Bushings are not broken, however major chips, cracks and some flashover burns are visible. - Cementing and fasteners are secure.
D	- Bushings are broken / damaged. - Cementing and fasteners are not secure.
E	Bushings, cementing or fasteners are broken / damaged beyond repair.

4.3.3.2 Control and mechanism components

Condition Rating	Description
A	- Wiring terminal blocks, relays, contactors and switches all in good condition. - No blown fuses. - Operating mechanism, trip and close coils, relays, auxiliary switches, motors, springs are all in good working condition (trip check). - No sign of overheating or deterioration. - Linkages, drive rods, trip latches are clean, lubricated, free from cracks, distortion, abrasion or obstruction. - Mechanical integrity of dampers / dashpots is acceptable. - No visible evidence of poor mechanism settings, looseness, loss of adjustment, excess bearing wear or other out of tolerance operations.
B	Control and mechanism components show normal signs of wear.
C	One or two of the control and mechanism components are unacceptable.
D	More than two of the control and mechanism components are unacceptable.
E	Control and mechanism components are damaged / degraded beyond repair.

4.3.3.3 Vacuum bottle assembly

Condition Rating	Description
A	Vacuum bottle assembly is clean, no chips, cracks, flashover burns or indications of overheating or PD traces. All cemented elements are secure.
B	Vacuum bottle assembly shows normal signs of wear.
C	Vacuum bottle assembly has some chips or cracks. Some indications of overheating or flashover burns or PD traces.
D	Vacuum bottle assembly has major chips or cracks. Severe indications of overheating or flashover burns or PD traces.
E	Vacuum bottle assembly is damaged / degraded beyond repair.

4.3.3.4 Overall CB condition

Condition Rating	Description
A	• Circuit breaker is externally clean, and corrosion free. • All primary connections (hotspots), secondary connections are in good condition. • No external evidence of overheating. • Number of CB operations on counter is below expected for age and location of CB. • Support steelwork and/or anchor bolts are secure and free from corrosion. • Earthing connections are secure, free from corrosion and made directly to tanks, cubicles and supports, without any intervening paint or corrosion.
B	• Circuit breaker shows normal signs of wear.
C	• Some external corrosion and/or signs of overheating.
D	• Significant external corrosion and/or signs of overheating.
E	• The circuit breaker is damaged / degraded beyond repair.

4.3.3.5 Timing test

Condition Rating	Description
A	• Closing, tripping and inter-pole timing difference is in time with commissioning test results.
B	• Closing, tripping and inter-pole time difference is not in time with the commissioning test results but within manufacturer's specified limits.
C	• One of the closing, tripping or inter-pole timing differences are not within the manufacture's specified limits.
D	• Two of the closing, tripping or inter-pole timing differences are not within the manufacture's specified limits
E	• The closing, tripping and inter-pole timing differences are not within the manufacture's specified limits.

Manufacturer and model	Maximum trip time (ms)	Maximum close time (ms)	Maximum inter-pole time (ms)
TAMCO 11/22kV	60		
ABB / Calor Emag 11kV VD4	45		
GEC 11kV SBV	60		
Reyrolle 11kV LMVP	50		
Schneider 11kV HWX	50		
Siemens 11kV 3AF series	70		
Siemens 11kV 3AH series	70		
Other	100	*	*

* Contact Primary Systems for value.

Note: These values are for the purpose of calculating the health index. For maintenance limit requirements refer to Substation Maintenance Instruction SMI 200 - HV circuit breakers.

4.3.3.6 Primary contact resistance

Condition Rating	Description
A	Less than or equal to the pre-commissioning value (if available) and within manufacture's specifications
B	Less than 30% increase from the pre-commissioning value (if available) and within manufacture's specifications.
C	Between 30 – 70% increase from the pre-commissioning value (if available) and within manufacture's specifications.
D	Between 70 – 100% increase from the pre-commissioning value (if available) and within manufacture's specifications.
E	Greater than 100% increase from the pre-commissioning value (if available) or outside manufacture's specifications.

4.3.3.7 Primary contact wear out

Condition Rating	Description
A	Greater than 80% of permissible number of interruptions remaining.
B	Between 80 – 60% of permissible number of interruptions remaining.
C	Between 60 – 40% of permissible number of interruptions remaining.
D	Between 40 – 20% of permissible number of interruptions remaining.
E	Less than 20% of permissible number of interruptions remaining. Interrupter replacement required soon.

Note: The permissible number of interruptions remaining can be estimated by the number of operations versus breaking current curve found in the manufacturers manual or vacuum bottle gauge or wiper or indicator window.

Manufacturer and model	Maximum contact wear limit
ABB / Calor Emag 11kV VD4	100 $\mu\Omega$
GEC 11kV SBV	$\geq 4\text{mm}$
Reyrolle 11kV LMVP	gauge
Schneider 11kV HWX	gauge
Siemens 11kV 3AF series	Indicator white line visible
Other	200 $\mu\Omega$

Note: These values are for the purpose of calculating the health index. For maintenance limit requirements refer to Substation Maintenance Instruction SMI 200 – HV circuit breakers.

4.3.3.8 Insulation resistance (measured at 2.5kV)

Condition Rating	Description
A	Greater than 90% of previous IR test result.
B	Between 90 – 80% of previous IR test result.
C	Between 80 – 70% of previous IR test result.
D	Between 70 – 60% of previous IR test result.
E	Less than 1 GΩ.

4.3.3.9 *Inherent safety issues*

Condition Rating	Description
A	No risk to safety, environment or network.
B	Minor risk to safety, environment or network.
C	Moderate risk to safety, environment or network.
D	Major risk to safety, environment or network.
E	Severe risk to safety, environment or network.

4.3.4 *SF6 circuit breakers with vacuum interrupters*4.3.4.1 *Bushing condition*

Condition Rating	Description
A	- Bushings are not broken and no visible chips, cracks and flashover burns. - Cementing and fasteners are secure.
B	- Bushings are not broken, however minor chips and cracks are visible. - Cementing and fasteners are secure.
C	- Bushings are not broken, however major chips, cracks and some flashover burns are visible. - Cementing and fasteners are secure.
D	- Bushings are broken / damaged. - Cementing and fasteners are not secure.
E	Bushings, cementing or fasteners are broken / damaged beyond repair.

4.3.4.2 *Control and mechanism components*

Condition Rating	Description
A	- Wiring terminal blocks, relays, contactors and switches all in good condition. - No blown fuses. - Operating mechanism, trip and close coils, relays, auxiliary switches, motors, springs are all in good working condition (trip check). - No sign of overheating or deterioration. - Linkages, drive rods, trip latches are clean, lubricated, free from cracks, distortion, abrasion or obstruction. - Mechanical integrity of dampers / dashpots is acceptable. - No visible evidence of poor mechanism settings, looseness, loss of adjustment, excess bearing wear or other out of tolerance operations.
B	Control and mechanism components show normal signs of wear.
C	One or two of the control and mechanism components are unacceptable.
D	More than two of the control and mechanism components are unacceptable.
E	Control and mechanism components are damaged / degraded beyond repair.

4.3.4.3 Vacuum bottle assembly

Condition Rating	Description
A	Vacuum bottle assembly is clean, no chips, cracks, flashover burns or indications of overheating or PD traces. All cemented elements are secure.
B	Vacuum bottle assembly shows normal signs of wear.
C	Vacuum bottle assembly has some chips or cracks. Some indications of overheating or flashover burns or PD traces.
D	Vacuum bottle assembly has major chips or cracks. Severe indications of overheating or flashover burns or PD traces.
E	Vacuum bottle assembly is damaged / degraded beyond repair.

4.3.4.4 SF6 leaks

Condition Rating	Description
A	No SF6 leakage at any of the bushing to metal interfaces, tank or piping interfaces, as determined by inspection of the SF6 pressure gauge and SF6 refill maintenance records.
B	Minor SF6 leakage, no more than 0.5% per year, by weight, of the total quantity of SF6 in the breaker, as determined by inspection of SF6 pressure gauge and refill maintenance records.
C	SF6 leakage of up to 0.65% per year, by weight, of the total quantity of SF6 in the breaker, as determined by inspection of SF6 pressure gauge and refill maintenance records.
D	SF6 leakage of up to 0.8% per year, by weight, of the total quantity of SF6 in the breaker, as determined by inspection of SF6 pressure gauge and refill maintenance records.
E	SF6 leakage exceeding 1% per year, by weight, of the total quantity of SF6 in the breaker, as determined by inspection of SF6 pressure gauge and refill maintenance records.

4.3.4.5 Overall CB condition

Condition Rating	Description
A	- Circuit breaker is externally clean, and corrosion free. - All primary connections (hotspots), secondary connections are in good condition. - No external evidence of overheating. - Number of CB operations on counter is below expected for age and location of CB. - Support steelwork and/or anchor bolts are secure and free from corrosion. - Earthing connections are secure, free from corrosion and made directly to tanks, cubicles and supports, without any intervening paint or corrosion.
B	Circuit breaker shows normal signs of wear.
C	Some external corrosion and/or signs of overheating.
D	Significant external corrosion and/or signs of overheating.
E	The circuit breaker is damaged / degraded beyond repair.

4.3.4.6 Timing test

Condition Rating	Description
A	Closing, tripping and inter-pole timing difference is in time with commissioning test results.
B	Closing, tripping and inter-pole time difference is not in time with the commissioning test results but within manufacturer's specified limits.
C	One of the closing, tripping or inter-pole timing differences are not within the manufacture's specified limits.
D	Two of the closing, tripping or inter-pole timing differences are not within the manufacture's specified limits
E	The closing, tripping and inter-pole timing differences are not within the manufacture's specified limits.

Manufacturer and model	Maximum trip time (ms)	Maximum close time (ms)	Maximum inter-pole time (ms)
Areva 33kV WS/WSA	50	70	*
Tamco 33kV GV30	60	60	3
Hawker Siddley 33kV Horizon	50	250	1
Areva 33kV OX36	50	100	2
Other	100	*	*

* Contact Primary Systems for value.

Note: These values are for the purpose of calculating the health index. For maintenance limit requirements refer to Substation Maintenance Instruction SMI 200 – HV circuit breakers.

4.3.4.7 Primary contact resistance

Condition Rating	Description
A	Less than or equal to the pre-commissioning value if available and within manufacture's specifications
B	Less than 30% increase from the pre-commissioning value if available and within manufacture's specifications.
C	Between 30 – 70% increase from the pre-commissioning value if available and within manufacture's specifications.
D	Between 70 – 100% increase from the pre-commissioning value if available and within manufacture's specifications.
E	Greater than 100% increase from the pre-commissioning value if available or outside manufacture's specifications.

4.3.4.8 Primary contact wear out

Condition Rating	Description
A	Greater than 80% of permissible number of interruptions remaining.
B	Between 80 – 60% of permissible number of interruptions remaining.
C	Between 60 – 40% of permissible number of interruptions remaining.
D	Between 40 – 20% of permissible number of interruptions remaining.
E	Less than 20% of permissible number of interruptions remaining. Interrupter replacement required soon.

Note: The permissible number of interruptions remaining can be estimated by the number of operations versus breaking current curve found in the manufacturers manual or vacuum bottle gauge or wiper or indicator window.

Manufacturer and model	Maximum contact resistance ($\mu\Omega$)
Hawker Siddley 33kV Horizon	Rating 1250A: 65
	Rating 200A: 45
Areva 33kV OX36	200
Other	200

Note: These values are for the purpose of calculating the health index. For maintenance limit requirements refer to Substation Maintenance Instruction SMI 200 – HV circuit breakers.

4.3.4.9 Insulation resistance (measured at 2.5kV)

Condition Rating	Description
A	Greater than 90% of previous IR test result.
B	Between 90 – 80% of previous IR test result.
C	Between 80 – 70% of previous IR test result.
D	Between 70 – 60% of previous IR test result.
E	Less than 1 GΩ.

4.3.4.10 Inherent safety issues

Condition Rating	Description
A	No risk to safety, environment or network.
B	Minor risk to safety, environment or network.
C	Moderate risk to safety, environment or network.
D	Major risk to safety, environment or network.
E	Severe risk to safety, environment or network.

4.4 Health index formulation

The circuit breaker is rated against set criteria for each condition parameter. The ratings are converted to a factor and multiplied by the given weight to obtain a health index score. The following table contains the associated weight for each condition criterion:

4.4.1 Oil circuit breakers health index

#	Condition Criteria	Weight (W _i)	Condition Rating	Factors (S _i)	Maximum Score (T _i)
1	Bushing	5	A, B, C, D, E	4, 3, 2, 1, 0	20
2	Tank and mechanism	5	A, B, C, D, E	4, 3, 2, 1, 0	20
3	Oil leaks	5	A, B, C, D, E	4, 3, 2, 1, 0	20
4	Control and mechanism components	10	A, B, C, D, E	4, 3, 2, 1, 0	40
5	Overall CB condition	5	A, B, C, D, E	4, 3, 2, 1, 0	20
6	Timing test	20	A, B, C, D, E	4, 3, 2, 1, 0	80
7	Bushing DDF test*	10	A, B, C, D, E	4, 3, 2, 1, 0	40
8	Primary contact resistance	5	A, B, C, D, E	4, 3, 2, 1, 0	20
9	Insulation resistance	15	A, B, C, D, E	4, 3, 2, 1, 0	60
10	Inherent safety issues	20	A, B, C, D, E	4, 3, 2, 1, 0	80
		100			400

* If DDF test is not required as part of routine maintenance then the weighting allocated to the DDF test is to be added to Insulation resistance condition weighting.

4.4.2 SF6 circuit breakers health index

#	Condition Criteria	Weight (W _i)	Condition Rating	Factors (S _i)	Maximum Score (T _i)
1	Bushing	5	A, B, C, D, E	4, 3, 2, 1, 0	20
2	Tank and mechanism	5	A, B, C, D, E	4, 3, 2, 1, 0	20
3	SF6 leaks	5	A, B, C, D, E	4, 3, 2, 1, 0	20
4	Control and mechanism components	10	A, B, C, D, E	4, 3, 2, 1, 0	40
5	Overall CB condition	5	A, B, C, D, E	4, 3, 2, 1, 0	20
6	Timing test	20	A, B, C, D, E	4, 3, 2, 1, 0	80
7	Primary contact resistance	11	A, B, C, D, E	4, 3, 2, 1, 0	44
8	Primary contact wear out	17	A, B, C, D, E	4, 3, 2, 1, 0	68
9	Insulation resistance	17	A, B, C, D, E	4, 3, 2, 1, 0	68
10	Inherent safety issues	5	A, B, C, D, E	4, 3, 2, 1, 0	20
		100			400

4.4.3 Vacuum circuit breakers health index

#	Condition Criteria	Weight (W _i)	Condition Rating	Factors (S _i)	Maximum Score (T _i)
1	Bushing	5	A, B, C, D, E	4, 3, 2, 1, 0	20
2	Control and mechanism components	10	A, B, C, D, E	4, 3, 2, 1, 0	40
3	Vacuum bottle assembly	10	A, B, C, D, E	4, 3, 2, 1, 0	40
4	Overall CB condition	5	A, B, C, D, E	4, 3, 2, 1, 0	20
5	Timing test	20	A, B, C, D, E	4, 3, 2, 1, 0	80
6	Primary contact resistance	11	A, B, C, D, E	4, 3, 2, 1, 0	44
7	Primary contact wear out	17	A, B, C, D, E	4, 3, 2, 1, 0	68
8	Insulation resistance	17	A, B, C, D, E	4, 3, 2, 1, 0	68
9	Inherent safety issues	5	A, B, C, D, E	4, 3, 2, 1, 0	20
		100			400

4.4.4 SF6 circuit breakers with vacuum interrupters health index

#	Condition Criteria	Weight (W _i)	Condition Rating	Factors (S _i)	Maximum Score (T _i)
1	Bushing	5	A, B, C, D, E	4, 3, 2, 1, 0	20
2	Control and mechanism components	5	A, B, C, D, E	4, 3, 2, 1, 0	20
3	Vacuum bottle assembly	10	A, B, C, D, E	4, 3, 2, 1, 0	40
4	SF6 leaks	5	A, B, C, D, E	4, 3, 2, 1, 0	20
5	Overall CB condition	5	A, B, C, D, E	4, 3, 2, 1, 0	20
6	Timing test	20	A, B, C, D, E	4, 3, 2, 1, 0	80
7	Primary contact resistance	11	A, B, C, D, E	4, 3, 2, 1, 0	44
8	Primary contact wear out	17	A, B, C, D, E	4, 3, 2, 1, 0	68
9	Insulation resistance	17	A, B, C, D, E	4, 3, 2, 1, 0	68
10	Inherent safety issues	5	A, B, C, D, E	4, 3, 2, 1, 0	20
		100			400

4.4.5 Health index calculation

All scores are entered into the formula below to convert to a rating out of 100:

$$HI = \left(\frac{\sum_{i=1}^N (S_i \times W_i)}{\sum_{i=1}^N T_i} \right) \times 100$$

where:

Oil:

$$\sum_{i=1}^N T_i = 400$$

$$N = 10$$

SF6:

$$\sum_{i=1}^N T_i = 400$$

$$N = 10$$

Vacuum:

$$\sum_{i=1}^N T_i = 400$$

$$N = 9$$

SF6/Vacuum:

$$\sum_{i=1}^N T_i = 400$$

$$N = 10$$

4.5 Health index results and condition assessment

An overall health index for a circuit breaker can be derived from the above methodology. The overall health index is then compared to the Health index scale in Section 2.3 to determine the overall condition of the asset. The resultant overall condition will dictate the strategic asset management requirements of the asset.