

Circuit Breaker, Vacuum, 4 - 34 kV - Indoor and Outdoor									
Component Classification Categories									
Criticality	I	X					DC, SS, TDC, TSS locations that serve O'Hare & Midway Airports		
	II		X				Locations exclusive of Criticality I, DC, and ≤34kV ESS locations		
	III			X			DC locations		
	IV				X		≤34kV ESS locations		
Duty Cycle	Heavy Load	N/A	N/A	N/A	N/A	N/A			
	Normal Load	N/A	N/A	N/A	N/A	N/A			
Service Condition	In Service	X	X	X	X				
	Spare					X	Designated spare equipment		
Condition Monitoring Tasks							Task Frequencies	Failure Codes	Comments
Check Red (Closed) Indicating Lamp		5W	10W	3M	6M	N/A	2a		
Visual Inspection		5W	10W	3M	6M	10W	5a-b, 6a-b		
Thermography		1Y	1Y	1Y	4Y	N/A	4b		
Contact Resistance (Ductor) Test		6Y	6Y	6Y	6Y	N/A	1c, 3d, 4a		
Hi Pot Test on Vacuum Bottles		6Y	6Y	6Y	6Y	N/A	2c, 3e, 5b		
Time Directed Tasks		Task Frequencies				Failure Codes	Comments		
Exercise Mechanism		3Y	3Y	3Y	3Y	3Y	1a, 1d, 2a, 2d, 3b, 3f		
Aux Contact Block Inspection		6Y	6Y	6Y	6Y	6Y	1a, 2a, 3b		
Cubicle / Cabinet Maintenance		6Y	6Y	6Y	6Y	6Y	1a, 2a, 3b, 6a-b	Includes racking mechanism on switchgear breakers	
Mechanism Lubrication / Maintenance		6Y	6Y	6Y	6Y	N/A	1b, 2b, 3c		
Inspect Vacuum Bottles		6Y	6Y	6Y	6Y	N/A	1c, 2c, 3d	Includes contact wear indicator	
Failure Finding Tasks		Task Frequencies				Failure Codes	Comments		
Check Control Cabinet / Cubicle Heaters		5W	10W	3M	6M	10W	1a, 2a, 3a		
Condition Directed Tasks		Task Frequencies				Failure Codes	Comments		
None		N/A	N/A	N/A	N/A	N/A			

FAILURE MODES

1. Fails to Close

2. Fails to Open

3. Fails to Interrupt

4. Fails to Provide Conduction Path
4. Fails to Provide Conductive Path

5. Fails to Provide Adequate Insulation Level
5. Fails to Provide Adequate Insulation Level
5. Fails to Provide Adequate Insulation Level

6. Fails to Maintain Boundary Integrity
6. Fails to Maintain Boundary Integrity
6. Fails to Maintain Boundary Integrity

FAILURE CAUSES

- 1a. Control Circuit Failure
- 1b. Lack of/Improper Lubrication
- 1c. Interrupter Failure
- 1c. Interrupter Failure
- 1d. Stored energy Failure

- 2a. Control Circuit Failure
- 2a. Control Circuit Failure
- 2a. Control Circuit Failure
- 2a. Control Circuit Failure
- 2a. Control Circuit Failure
- 2b. Lack of/Improper Lubrication
- 2c. Interrupter Failure
- 2c. Interrupter Failure
- 2d. Stored energy Failure

- 3a. Open Coil Failure
- 3b. Control Circuit Failure
- 3b. Control Circuit Failure
- 3b. Control Circuit Failure
- 3c. Lack of/Improper Lubrication
- 3d. Interrupter Failure
- 3d. Interrupter Failure
- 3e. Mechanical/Linkage Failure
- 3f. Stored Energy Failure

- 4a. High Resistance Connection
- 4b. Bus Connections Failure

- 5a. External Contamination
- 5b. Solid Dielectric Failure
- 5b. Solid Dielectric Failure

- 6a. Frame Weld Failure
- 6a. Frame Weld Failure
- 6b. Frame Corrosion

MAINTENANCE TASKS

- Exercise Mechanism
- Check Control Cabinet / Cubicle Heaters
- Cubicle / Cabinet Maintenance
- Aux Contact Block Inspection
- Mechanism Lubrication / Maintenance
- Contact Resistance (Ductor) Test
- Inspect Vacuum Bottles
- Exercise Mechanism

- Exercise Mechanism
- Check Control Cabinet / Cubicle Heaters
- Cubicle / Cabinet Maintenance
- Aux Contact Block Inspection
- Check Red (Closed) Indication Lamp
- Mechanism Lubrication / Maintenance
- Hi Pot Test on Vacuum Bottles
- Inspect Vacuum Bottles
- Exercise Mechanism

- Check Control Cabinet / Cubicle Heaters
- Exercise Mechanism
- Cubicle / Cabinet Maintenance
- Aux Contact Block Inspection
- Mechanism Lubrication / Maintenance
- Contact Resistance (Ductor) Test
- Inspect Vacuum Bottles
- Hi Pot Test on Vacuum Bottles
- Exercise Mechanism

- Contact Resistance (Ductor) Test
- Thermography

- Visual Inspection
- Visual Inspection
- Hi Pot Test on Vacuum Bottles

- Visual Inspection
- Cubicle / Cabinet Maintenance
- Visual Inspection

FAILURE MODES

6. Fails to Maintain Boundary Integrity

FAILURE CAUSES

6b. Frame Corrosion

MAINTENANCE TASKS

Cubicle / Cabinet Maintenance

TASK	DEFINITION
Aux Contact Block Inspection	Verify tightness of connections, check for signs of arcing, check for brittleness of insulation, check labeling.
Check Control Cabinet / Cubicle Heaters	Visual / physical verification that cabinet heaters are operational.
Check Red (Closed) Indicating Lamp	Verify red indicating lamp is lit on all closed breakers to ensure trip circuit continuity and control fuses.
Contact Resistance (Ductor) Test	Apply DC current (100 Amps DC) between terminals of equipment under test to measure current path resistance. Contact resistance testing is done prior to performing maintenance and after completion of maintenance. The as-found and as-left resistance values are used to verify maintenance effectiveness.
Cubicle / Cabinet Maintenance	<p>This task includes the following:</p> <ul style="list-style-type: none"> -- Check wiring and terminals for tightness and corrosion, check for signs of arcing, check for brittleness of insulation, check labeling -- Check fuses for integrity -- Check that all indicating lamps and receptacles are working -- Check all doors, latches and weather seals are effective -- Check grounding connections for tightness -- Inspect for rodent or insect presence -- Clean all dust and debris from enclosure -- Check condition of position indicator -- Visually inspect bus ports (cubicle side) for evidence of leaking compound -- Maintain and lubricate the racking mechanism on switchgear breakers
Exercise Mechanism	Open and close breaker electrically.

TASK	DEFINITION
Hi Pot Test on Vacuum Bottles	Clean exterior of vacuum bottle prior to testing. Perform high potential test to verify vacuum integrity in interrupter bottles.
Inspect Vacuum Bottles	Visually inspect vacuum bottles and check contact erosion indicators.
Mechanism Lubrication / Maintenance	<p>Off-line detailed inspection of the operating mechanism. Checks include:</p> <ul style="list-style-type: none"> -- Operate breaker from local and remote control -- Trip from manual trip device and check electrical interlocks -- Check solenoids, limit switches, position indicators and counter for proper operation -- Verify all clearance dimensions (stops, latches, rollers, switches and links) -- Check wiring terminal blocks for tightness -- Wipe and clean accessible linkages, roller guides and wear points -- Apply approved lubricants to bearings and other specified areas on mechanism, including linkage wear points. Lubrication should not be added to sealed bearings. -- Manually roll latching bearings to verify smooth movement
Thermography	Infrared inspection of electrical equipment and power path components to identify any hot spots that may exist either in the contacts, bus connections or within control cabinets. Open cubicle doors on switchgear breakers.

TASK

Visual Inspection

DEFINITION

Visual assessment of the condition of the equipment.

Items to check include:

- Check for signs of arcing / flashover
- Check integrity of compartment
- Verify mechanical position indicator for correct position and check operations counter
- Check mechanism spring charged
- Check mechanism cabinet for general cleanliness, evidence of moisture and signs of wildlife or insect infestation
- Check for signs of loose or worn parts in mechanism
- Check cabinet door for degradation of the door seal and for proper operation of the door latch. Check interior components, wiring terminals and fuse holders for rust or corrosion.
- Check for proper grounding
- Where visible, check closing and trip solenoid coils for evidence of heating. Check closing contactors for cleanliness and heating or burning of contacts.

4-34 kV Vacuum Breaker Template Summary

The Preventive Maintenance program is documented via maintenance templates. Templates have been developed that address transmission, substation, and distribution equipment that is owned and maintained by Exelon Utilities. Each template documents the program tasks, frequencies, failure modes, and maintenance basis for the associated equipment. Tasks and associated frequencies are designed to address known failure modes of the equipment covered by the template. In general, the tasks included in the maintenance templates are the result of good industry practices, industry experience, and manufacturer recommendations.

References:

IEEE C57.152-2013 "IEEE Guide for Diagnostic Field Testing of Fluid-filled Power Transformers, Regulators and Reactors"
Internal reports and operating experience
OEM Maintenance Manuals and Interviews
EPRI 1001779 Guidelines for the Life Extension of Substations

Boundary Definition

The boundary of a vacuum circuit breaker is defined from bushing terminal to bushing terminal, including:

- Bushings
- Live parts
- Operating mechanism
- Linkage
- Contacts

Excluded from this treatment are: protective relays, DC supply, AC supply, switchgear

Failure Experience

Failures are subject to ACE/RCI investigation. Findings/recommended corrective actions are incorporated into the template as required.

Vendor Recommendations

OEM manuals were referenced and interviews conducted during the development of this template.

Disposition of Vendor Recommendations

Recommendations were incorporated into the template as appropriate based on operating experience.

Basis For Template Tasks

Aux Contact Block Inspection: For switchgear type breakers, alignment and secure connections between the cubicle contact block and mating contact assembly on the breaker are required for proper operation of the control, alarm and interlock circuits.

~~**Check Control Cabinet/ Cubicle Heaters:** Continuous heater operation mitigates corrosion of components in the control cabinet.~~

~~**Check Red (Closed) Indicating Lamp:** The red light is in series with the trip coil and when lit, indicates integrity of the trip circuit.~~

Contact Resistance (Ductor) Test: Performed bushing terminal to bushing terminal. Measures increased resistance at connection points along the current conduction path. Used to diagnose, or determine, problems internal to the breaker that would require an inspection.

Cubicle / Cabinet Maintenance: General cleanliness of the cabinet / cubicle lessens possibility of mechanism and contactor / interposing relay malfunction. Racking mechanism maintenance and lubrication ensures trouble-free insertion and removal of circuit breaker.

Exercise Mechanism: This redistributes the lubricants in bearings and on other surfaces and prevents bearing set at pressure points.

Hi Pot Test on Vacuum Bottles: Performed to verify integrity of the vacuum interrupter and other insulation components in parallel with the interrupter.

Inspect Vacuum Bottles: Bottle damage or deterioration of seals may result in partial or full loss of vacuum. Excessive contact erosion will limit ability of breaker to interrupt current per design.

Mechanism Lubrication / Maintenance: The mechanism of a circuit breaker is composed of multiple bearings and sliding surfaces that require periodic re-lubrication due to minimum movement of parts during breaker operation. CIGRE studies have concluded that the dominant failure mode of breakers is mechanism failure.

Thermography: IEEE C57.152 identifies thermography as a primary tool for detection of connection issues, bushing issues, and issues with the cooling systems.

Visual Inspection: This inspection approximates real-time condition monitoring that can detect developing problems and degradation, and provides condition data used to initiate corrective actions.

Revision 0		Date 03/02/2015
Writer	Chris Stefanski (Exelon Utilities)	
Reviewer(s)	Ken Wendt	
Approver(s)	Michael Moy (UFAM ComEd)	
Reason Written	Revised criticality definitions and modified document to serve as the ComEd maintenance standard.	

Revision 1		Date 03/07/2018
Writer	Hugo Castaneda (Material Condition)	
Reviewer(s)	Dale Player (Mgr Material Condition), Doug Mason (T&S Equipment Stds)	
Approver(s)	Michael Moy (UFAM ComEd)	
Reason Written	3 year review. Modified the Spare maintenance to align with the EU standard and updated industry standards in Maintenance Basis.	