Voltage Regulator - ≥500kVA						
Component Classification Categories						
Criticality	I	X				DC, SS, TDC, TSS locations that serve O'Hare & Midway Airports; excludes DC-in-a-Box (DCIAB) locations
	II		X			Locations exclusive of DCs and Criticality I locations
	III			X		DC locations; excludes DC-in-a-Box (DCIAB) locations
Duty Cycle	Heavy Load	N/A	N/A	N/A		
	Normal Load	N/A	N/A	N/A		
Service Condition	In Service	X	X	X		
	Spare	N/A	N/A	N/A		

Condition Monitoring Tasks	**Task Frequencies**			**Failure Codes**	**Comments**
Monitor Output Voltage	**5W**	**10W**	**3M**	**2a-c**	
Visual Inspection	**5W**	**10W**	**3M**	**1a-b, 2a, 2c, 4a-c, 5a-e, 6a-b**	
Oil DGA	**1Y**	**1Y**	**1Y**	**4d-e**	Where sample valve exists
Oil Quality Test	**1Y**	**1Y**	**1Y**	**4d**	Where sample valve exists
Thermography	**1Y**	**1Y**	**1Y**	**1a, 3a-c**	
Time Directed	**Task Frequencies**			**Failure Codes**	**Comments**
None	**N/A**	**N/A**	**N/A**		
Failure Finding Tasks	**Task Frequencies**			**Failure Codes**	**Comments**
None	**N/A**	**N/A**	**N/A**		
Condition Directed Tasks	**Task Frequencies**			**Failure Codes**	**Comments**
Calibrate the Voltage Control	**AR**	**AR**	**AR**	**2b, 6b**	Triggered by results of Operations Counter or Output Voltage monitoring

Voltage Regulator - < 500kVA						
Component Classification Categories						
Criticality	I	X				DC, SS, TDC, TSS locations that serve O'Hare & Midway Airports; excludes DC-in-a-Box (DCIAB) locations
	II		X			Locations exclusive of DCs and Criticality I locations
	III			X		DC locations; excludes DC-in-a-Box (DCIAB) locations
Duty Cycle	Heavy Load	N/A	N/A	N/A		
	Normal Load	N/A	N/A	N/A		
Service Condition	In Service	X	X	X		
	Spare	N/A	N/A	N/A		

Condition Monitoring Tasks	**Task Frequencies**			**Failure Codes**	**Comments**
Monitor Output Voltage	**5W**	**10W**	**3M**	**2a-c**	
Visual Inspection	**5W**	**10W**	**3M**	**1a-b, 2a, 2c, 4a-c, 5a-e, 6a-b**	
Oil DGA	**AR**	**AR**	**AR**	**4d-e**	DGA can be taken to diagnose a problem if suspected
Oil Quality Test	**AR**	**AR**	**AR**	**4d**	Oil Quality can be taken to diagnose a problem if suspected
Thermography	**1Y**	**1Y**	**1Y**	**1a, 3a-c**	
Time Directed	**Task Frequencies**			**Failure Codes**	**Comments**
None	**N/A**	**N/A**	**N/A**		
Failure Finding Tasks	**Task Frequencies**			**Failure Codes**	**Comments**
None	**N/A**	**N/A**	**N/A**		
Condition Directed Tasks	**Task Frequencies**			**Failure Codes**	**Comments**
Calibrate the Voltage Control	**AR**	**AR**	**AR**	**2b, 6b**	Triggered by results of Operations Counter or Output Voltage monitoring

REGULATOR FAILURE MODES

FAILURE MODE	FAILURE CAUSES	MAINTENANCE TASKS
1. Fails to Provide Adequate Cooling	1a. Clogged/Corroded Cooler/Radiator	Visual Inspection
1. Fails to Provide Adequate Cooling	1a. Clogged/Corroded Cooler/Radiator	Thermography
1. Fails to Provide Adequate Cooling	1b. Loss of Oil	Visual Inspection
2. Fails to Regulate Voltage	2a. Control Circuit Failure	Visual Inspection
2. Fails to Regulate Voltage	2a. Control Circuit Failure	Monitor Output Voltage
2. Fails to Regulate Voltage	2b. Control Out of Calibration	Calibrate the Voltage Control
2. Fails to Regulate Voltage	2b. Control Out of Calibration	Monitor Output Voltage
2. Fails to Regulate Voltage	2c. Motor Failure	Visual Inspection
2. Fails to Regulate Voltage	2c. Motor Failure	Monitor Output Voltage
3. Fails to Provide Conduction Path	3a. Contacts High Resistance	Thermography
3. Fails to Provide Conduction Path	3b. Loose Connection	Thermography
3. Fails to Provide Conduction Path	3c. Winding High Resistance	Thermography
4. Fails to Provide Adequate Insulation Level	4a. External Contamination	Visual Inspection
4. Fails to Provide Adequate Insulation Level	4b. Cracked/Broken Bushing	Visual Inspection
4. Fails to Provide Adequate Insulation Level	4c. Loss of Oil	Visual Inspection
4. Fails to Provide Adequate Insulation Level	4d. Poor Oil Quality	Oil Quality Test
4. Fails to Provide Adequate Insulation Level	4d. Winding Dielectric Failure	Oil DGA
4. Fails to Provide Adequate Insulation Level	4e. Solid Dielectric Failure	Oil DGA
5. Fails to Maintain Boundary Integrity	5a. Gasket Failure	Visual Inspection
5. Fails to Maintain Boundary Integrity	5b. Weld Failure	Visual Inspection
5. Fails to Maintain Boundary Integrity	5c. Tank Corrosion	Visual Inspection
5. Fails to Maintain Boundary Integrity	5d. Loose Connections	Visual Inspection
5. Fails to Maintain Boundary Integrity	5e. Control Cabinet Contamination	Visual Inspection
6. Regulator Operates Too Frequently	6a. Control Circuit Failure	Visual Inspection
6. Regulator Operates Too Frequently	6b. Control Out of Calibration	Calibrate the Voltage Control
6. Regulator Operates Too Frequently	6b. Control Out of Calibration	Visual Inspection

REGULATOR MAINTENANCE TASK DEFINITION

TASK	DEFINITION
Calibrate the Voltage Control	Perform calibration of voltage control to ensure proper band-center, band-width, load-drop compensation, and time-delay settings.
Monitor Output Voltage	Record and verify proper output voltage at the test terminals of the regulator controls.
Oil DGA	Take syringe samples. Follow sampling procedures for appropriate sample quantity. Data to be trended. Oil DGA Lab Analysis: Perform per ASTM D3612. The minimum scope for analysis and trending includes: Hydrogen, Carbon Monoxide, Ethylene, Ethane, Methane, Acetylene, Total Dissolved Combustible Gas, Oxygen, Nitrogen, and Carbon Dioxide. Moisture test should also be performed.
Oil Quality Test	Take 1 jar sample. Oil Quality Lab Analysis per sample: • Dielectric Strength (ASTM D877) • Moisture Content (ASTM D1553) • Color (ASTM D1500) • Sediment (ASTM D1698 or visual) Oil Quality Lab Analysis performed at least annually: • Interfacial Tension (ASTM D971) • Acid Number (ASTM D974). • Power Factor @100 deg C (ASTM D924)
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. Comparisons should be made phase to phase or on tank walls to determine if contact heating can be found or to determine oil levels within all tanks and verify level gauge.
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. These items should be checked: - Check for unusual noises and smells - Check range of operation and present tap position - Visually inspect for damage, cracked or chipped porcelain insulators - Check for signs of oil leakage from bushings, tank penetrations, gaskets and flanges - Check for loose, missing or damaged hardware - Check oil level, where applicable - Check / record operations counter

REGULATOR MAINTENANCE BASIS

Regulator 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

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References:

IEEE C57.15, "IEEE Standard Requirement, Terminology, and Test Code for Step-Voltage Regulators"

IEEE C57.12.00 "IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers"

IEEE Std C57.152-2013 IEEE Guide for Diagnostic Field Testing of Fluid-filled Power Transformers, Regulators and Reactors

General Electric GEH-585, "Type VR-1 Single-phase Step Voltage Regulators, Installation, Operation, Maintenance"

Cooper Power Systems Service Information S225-10-10, "McGraw-Edison VR-32 Regulator and CL-5 Series Control Installation, Operation and Maintenance Instructions and Parts Replacement

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Boundary Definition

This template applies to oil filled induction and step type voltage regulators. Air-blast regulators are not included in the scope of this template.

The boundary of a substation regulator for the purpose of this document is defined to include:

- Regulator tank
- Bushings
- Core, coil, insulating oil
- Operating mechanism
- Controls integral to the regulator

Excluded from this treatment are: associated secondary equipment that interfaces with the regulator controller such as the scada controls.

Failure Experiences

In general equipment failures are subject to ACE/RCI investigation. Findings/recommended corrective actions are incorporated into the template as required.

REGULATOR MAINTENANCE BASIS

(AR 00025463) January 2006 ComEd Experienced a failure of an 8000 KVA OA/FA three phase regulator at TSS107 Dixon due to low oil level. During conduct of the ACE, a question was raised as to why the rev. 0 template did not specify routine oil samples (oil quality & DGA) similar to what is performed on transformer LTC's. As a result, it was determined that routine oil samples for all three phase regulators located on the low-side of a transformer that are 500 KVA and above would be

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 deemed necessary.

Basis for Template Tasks

Calibrate the Voltage Control This is a condition directed task triggered by excessive operations (more than 700 operations per month).

Monitor Output Voltage: Verify that the equipment is performing as designed.

Oil DGA: IEEE Standard C57.152 identifies dissolved gas analysis as a primary tool for use in determination of the condition of insulating oil. The minimum scope for analysis and trending includes: Hydrogen, Carbon Monoxide, Ethylene, Ethane, Methane, Acetylene, Total Dissolved Combustible Gas. Additionally, the following are included in the minimum scope to trend insulation degradation, identify leaks, monitor the integrity of the oil preservation system and verify the quality

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Oil Quality Test: IEEE Standard C57.152 identifies oil quality tests as a tool for monitoring aging and condition of the insulating system. Oil quality tests provide indication of oil condition. The scope of testing includes: Dielectric Strength, Interfacial Tension, Color, Appearance (visual check for presence of sediment / contaminants), Moisture Content, Acid Number. It is important to obtain the temperature of the equipment at the time of the sample to ensure accurate calculation of H2O saturation.

Option at OpCo Discretion:
Power Factor, Interfacial Tension and Acid Number can be tested annually if trending results indicate no significant change over time that could result in equipment failure

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Thermography: IEEE Standard C57.152 identifies thermography as a primary tool for detection of connection issues, bushing issues, and issues with the cooling systems. EPRI 1002913 identifies thermography as a tool for detection of connection issues and insulator degradation.

Visual Inspection: (Operator Rounds) This inspection approximates real-time condition monitoring that can detect developing problems and degradation, and provides condition data used to initiate

REGULATOR TEMPLATE DEVELOPMENT HISTORY

	Revision 0	**Date 06/17/2005**
Writer	Drew Reindel (Strategic Programs)	
Reviewer(s)	1/28/05 Template Challenge Session Attendees	
Approver(s)	Kathy McHugh (FAM Maintenance Planning)	
Reason Written	To document the maintenance program tasks, frequencies, failure modes, and maintenance basis	

	Revision 1	**Date 09/05/2006**
Writer	Drew Reindel (Strategic Programs)	
Reviewer(s)	George Leinhauser, Chris Stefanski, Brian Graham, John Garavaglia, Miguel Ortega, G. William Lang, Tom Finchum, Dave Goodwin, Dave Lemmerman, Gregg Mathewson, Bill Bradley, Darryl Mitchell, Edward Adams, Ben Kao, Caren Anders, Bill McBride, Joe Svachula, Kelvin Owens	
Approver(s)	Kathy McHugh (FAM Maintenance Planning)	
Reason Written	To include Oil Quality and DGA samples annually for 3 Phase Regulators 500 KVA and above. Reference A/R 00025463. Scrub template to ensure consistency. Incorporate learnings from 1 year of implementation.	

	Revision 2	**Date 11/13/2006**
Writer	Drew Reindel (Strategic Programs)	
Reviewer(s)		
Approver(s)	Kathy McHugh (FAM Maintenance Planning)	
Reason Written	Task and periodicity review / update.	

	Revision 3	**Date 11/30/2010**
Writer	Chris Stefanski	
Reviewer(s)	Ken Wendt (Mgr. Material Condition), Drew Reindel (Mgr. T&S Enginering)	
Approver(s)	Bill Fluhler , Bill Gannon, Nitin Patel, Jim Crane, Bill Sullivan	
Reason Written	Added note to ensure template changes are communicated to affected work groups.	

	Revision 4	**Date 04/29/2011**
Writer	Chris Stefanski (Material Condition)	
Reviewer(s)	Ken Wendt, Drew Reindel, Jim Crane	
Approver(s)	Bill Fluhler (ComEd) , Bill Sullivan (PECO)	

REGULATOR TEMPLATE DEVELOPMENT HISTORY

Reason Written	Modified criticality definitions and incorporated 10-week and 3-month inspection task frequencies

	Revision 0	**Date 12/14/2012**
Writer	Chris Stefanski (Material Condition)	
Reviewer(s)	Ken Wendt, Drew Reindel, Jim Crane	
Approver(s)	Bill Fluhler (ComEd) , J. Coffman (PECO), Chris Lotz (UFAM BGE)	
Reason Written	Changed document number and document template to align with Exelon Utilities Management Model. Changed sheet 1 applicability to ≥500kVA; sheet 2 < 500 kV; excluded DCIAB locations.	

	Revision CE 0	**Date 02/06/2015**
Writer	Chris Stefanski (Exelon Utilities)	
Reviewer(s)	Ken Wendt, Charles McDonald	
Approver(s)	Michael Moy (UFAM ComEd)	
Reason Written	Created to document the ComEd maintenance program tasks, frequencies, failure modes, and maintenance basis.	

	Revision CE 1	**Date 01/26/2018**
Writer	Hugo Castaneda (Material Condition)	
Reviewer(s)	Dale Player (Manager Material Condition); Charles McDonald (T&S Equipment Stds)	
Approver(s)	Michael Moy (UFAM ComEd)	
Reason Written	3 Year Review. Updated Oil DGA and Quality task details to clarfy the required lab tests. Updated IEEE references in Maintenance Basis.	