Voltage Regulators

Functional Specification for Substation and Overhead Single-Phase 32-Step Voltage Regulator with Communication-Ready Controls

1. Scope

1.1. This specification covers electrical, mechanical, and safety features and characteristics of outdoor, single-phase, fluid-immersed, step-type voltage regulators. The voltage regulator must be completely self-contained and provide ±10% regulation in thirty-two (32) steps of approximately 5/8% each. In order to minimize losses, ensure long life, and provide required overload ability, forced air (ONAF) ratings are not acceptable to achieve the voltage regulator nominal KVA rating.

2. Voltage Regulator

2.1. Ratings

2.1.1. The regulators furnished under this specification shall be designed, manufactured, and tested in accordance with IEEE Std C57.15™-2009 standard. That standard shall be a part of this specification.

2.1.2. Voltage regulator rating(s) (voltage, current, and kVA) and regulated voltage shall be specified on the inquiry (or specified here).

2.1.3. Regulators of the voltage ratings shown in Table 1 shall have internal and external tap settings for operation at the standard regulated voltages listed. Unless otherwise noted, the units will be shipped from the factory at the nominal voltage rating.

Table 1 - Regulated Voltage Ratings

Nominal Voltage Rating	Standard Regulated Voltages							
60 Hz								
2,500 V	2,500	2,400						
5,000 V	5,000	4,800	4,160	2,400				
7,620 V	8,000	7,970	7,620	7,200	6,930	4,800	4,160	2,400
13,800 V	13,800	13,200	12,470	12,000	7,970	7,620	7,200	6,930
14,400 V	14,400	13,800	13,200	12,000	7,970	7,620	7,200	6,930
19,920 V	19,920	17,200	16,000	15,242	14,400	7,970	7,620	7,200
34,500 V	34,500	19,920						
50 Hz								
6,600 V	6,930	6,600	6,350	6,000	5,500			
11,000 V	11,600	11,000	10,000	6,930	6,600	6,350	6,000	5,500
15,000 V	15,000	14,400	13,800	13,200	12,000	11,000	10,000	8,660
22,000 V	23,000	22,000	20,000	19,100	15,000	12,700	11,000	10,000
33,000 V	33,000	30,000	22,000	20,000	11,600	11,000	10,000	

2.1.4. Regulators shall be rated and name-plated for 55/65 °C average winding rise.

2.1.5. Regulators shall be furnished with ANSI Type II mineral oil per ASTM D-3487 or Envirotemp™ FR3™ type fluid. The oil shall contain less than 1 part per million PCBs at time of manufacture, and this shall be so stated on the regulator nameplate.

2.2. Internal Construction

2.2.1. The regulators shall be designed such that they can be partially or completely untanked for inspection and maintenance without disconnecting any internal electrical or mechanical connections. (External connections must be disconnected.) Two military specification-style quick-disconnect circular connectors shall be provided with a solid-state automatic current transformer shorting device located in a junction box located on the cover.

2.2.2. The tap-changing mechanism shall be of the Quik-Drive type and shall be completely liquid-immersed. The tap-changer, in the manual position, shall have the ability to operate from –16L to +16R in less than 10 seconds.

2.2.3. An electrical feedback circuit shall be incorporated with the tap-changer motor circuit and control to ensure accurate indication of tap position and number of operations. Accuracy is to be maintained for all dielectric fluids used with the voltage regulator.

2.2.4. Regulator control system shall have Class 1 accuracy for all ratings of load voltage regulation by the use of load side voltage transformers or utility windings Control calculations, using tap position, are not acceptable for regulation of the normal load-side voltage.

2.2.5. The regulator main coil, reactor, and potential transformer shall include thermally upgraded insulation to permit operation up to 65 °C rise without loss of life to the insulating system. At 65 °C rise, the regulator shall provide 12% extra current capacity over the base current rating. A suitably patterned, epoxy-coated insulation paper shall be used in all windings. Prior to assembly of the main core and coil assembly, the windings are to be baked with sufficient mechanical pressure exerted on the sides of the coil to maximize a complete bonding of the insulation to maintain required short-circuit current withstand.

2.2.6. Step-voltage regulators shall be designed and constructed to withstand the mechanical and thermal stresses associated with external short circuits producing maximum current values of 25 times the base rms symmetrical rated load current or a maximum of 16 kA rms symmetrical, whichever is less. The first-cycle asymmetrical peak current the voltage regulator is required to withstand shall be determined as shown in Equation (1) and Table 13 of IEEE Std C57.15™-2009 standard.

2.2.7. The regulator shall be supplied with a center-tapped reactor for the purpose of maintaining continuity while the tap-changer is changing position. The reactor shall be isolated from ground to provide protection from lightning and switching surges. Construction of the reactor shall be core-type, wherein the windings occupy each of the two core limbs in order to provide balanced windings, reduce leakage current, and minimize no-load losses.

2.2.8. Internal secondary wiring shall be color coded and labeled for easy identification.

2.3. Standard External Features

2.3.1. The BIL rating of the bushings shall be compatible with the BIL of the regulator, and all bushings 15 kV and above shall have a minimum creep distance of 18 inches. The bushing designations (S, L, and SL) shall be permanently marked on the regulator cover adjacent to the bushings. The S, L, and SL bushings must be interchangeable with each other.

2.3.2. Material of threaded studs and connectors shall be tin-plated bronze. For regulators rated 1200 A and below, each bushing shall include a threaded 1.125" - 12 UNF-2A stud. For regulators rated 1201 to 2000 A, each bushing shall include a 1.5" - 12UNF-2A stud. For regulators rated above 2000 A, each bushing shall include a 2.0" - 12UNF-2A stud. Connectors integral to the bushing are not acceptable. Refer to Table 2 for standard terminals that will be provided.

Table 2 - Bushing Connectors	
Current Rating	**Terminals**
150 A and below	Clamp-type terminals for #6 to 250 MCM Conductor
151 A to 668 A	Clamp-type terminals for #6 to 800 MCM Conductor
669 A to 1200 A	4-hole spade 0.375 in. minimum thickness
1201 A to 2000 A	4-hole spade 0.5 in. minimum thickness

2.3.3. All regulators shall be provided with an external UltraSIL, Evolution URT (MOV) type bypass arrester connected across the series winding. For units rated less than 22 kV, the series arrester shall be rated 3 kV. For units rated 22 kV or larger, the series arrester shall be rated 6 kV.

2.3.4. A fluid sight gauge shall be provided that indicates fluid color and critical level at –20 °C.

2.3.5. An external, corrosion-resistant position indicator shall indicate the tap-changer position. The position indicator shall be polymer constructed, mounted above the oil level, and slanted downward at a 45-degree angle for ease of reading when the regulator is mounted above ground level.

Table 3 - ADD-AMP Adjustments	
Regulation (%)	**Current (%)**
±10.0	100
±8.75	110
±7.5	120
±6.25	135
±5.0	160

2.3.6. Regulators rated 668 A and below shall include an ADD-AMP type feature which will permit additional current-carrying capabilities at reduced regulation, as shown in Table 3, but not to exceed 668 A. The ADD-AMP type adjustment shall be located inside the position-indicator faceplate to prevent inadvertent adjustment. In addition, a SOFT ADD-AMP type feature shall be available which allows for adjustment through the control keypad.

2.3.7. Stainless steel mounting bosses shall be provided for the addition of lightning arresters adjacent to the source (S), load (L), and source-load (SL) bushings. The bosses shall be fully welded around their circumference. Spot welding is not acceptable.

2.3.8. All regulators shall have a 1" drain valve with sampling device and a 1" upper filter press connection.

2.3.9. A hand-hole shall be provided on the cover of the regulator for inspection purposes and to access terminals used to reconnect the regulators for operation at large variations of system voltage.

2.3.10. Regulators rated 250 kVA and below shall be pole-mountable and provided with welded-on hanger brackets. Regulators rated 167 kVA and above shall be provided with a base suitable for securing them to an elevating structure. All regulators must be capable of being secured to elevating structures.

2.3.11. Regulators with pole-mounting hanger brackets shall be provided with two stainless steel 1/2" –13 UNC welded ground bosses located diagonally opposite from each other. Regulators with substation base mounts shall have two stainless steel ground pads located diagonally opposite from each other. Each pad shall have two stainless steel 1/2"-13 UNC ground provisions. All grounding provisions are to be located near the base of the regulator.

2.3.12. Each regulator shall be provided with two laser-etched nameplates, one mounted on the control enclosure and the other mounted on the regulator tank. The nameplates shall have the manufacturer code and serial number bar-coded with "3 of 9" coding with a 0.25" minimum height.

2.3.13. The regulator shall be of a sealed-tank construction to permit operation at 65 °C rise without increasing the oxidation rate of the oil. A 5 PSIG, 50 SCFM pressure-relief device shall be supplied above the 110 °C fluid level.

2.3.14. The voltage regulator shall remain effectively sealed for a top fluid temperature range of –20 °C to +110 °C for continuous operation at rated kilovoltamperes and under operating conditions as described in loading guide IEEE Std.C57.91™-2011 standard, without gaskets and O-rings seizing or deteriorating, for the life of the voltage regulator.

2.3.15. The external parts of the tank and control enclosure shall be painted light gray, Munsell 5BG7.0/0.4, and meet the coating and security requirements of IEEE Std C57.12.31™-2010 standard. The inside of the tank and bottom of the cover shall also be primed and/or painted.

2.3.16. An external electrical connection between the cover and tank shall be supplied to allow the cover-suspended internal assembly and tank to be grounded together to eliminate voltage differentials during energizing.

2.3.17. Thermometer provisions shall be provided for all substation voltage regulators.

2.3.18. A multi-conductor neoprene 600 V, –50 ºC to 105 ºC cable with disconnect plugs at each end shall provide the connection between the internal circuitry of the voltage regulator and the control.

2.3.19. An electronic device shall be provided to protect the internal CT from high voltages due to the control cable being disconnected or cut while the voltage regulator is energized.

3. Regulator Control

3.1. Introduction

3.1.1. Accuracy: The control system of a voltage regulator shall have an overall system error not exceeding ±1%. The accuracy requirement is based on the combined performance of the control device and the voltage and current sensing apparatus. The voltage source accuracy shall be determined on a nominal secondary voltage base of 120 V and a burden of 10 VA. The current source accuracy shall be determined on a nominal 0.2 A secondary current and a burden of 3.5 VA.

3.1.2. Temperature Rating: The control shall operate in an operating environment temperature range of –40 ºC to +65 °C. Control device components shall withstand a temperature range –40 °C to +85 °C without damage or loss of control.

3.1.3. Environmental Interference: Control shall meet all environmental, insulation coordination, electrostatic discharge, RFI and interference tests specified in IEEE Std C57.15™-2009 standard.

3.1.4. Enclosure: The regulator control shall be mounted in a weather-resistant enclosure, which is capable of being padlocked, absent other appropriate security options. The control enclosure shall have an external 1/2"–13 UNC stainless steel welded ground boss.

3.1.5. Mounting: The control panel shall be hinge-mounted and designed for easy replacement. The control panel shall be constructed to provide direct interchangeability without removal of the control enclosure. Visible means shall be provided in the back of the enclosure to de-energize the control panel and associated circuitry in the back of the enclosure, and to short the voltage regulator's internal current transformer prior to testing or removal of control.

3.1.6. Wire Leads: All leads in the control enclosure shall be color coded and connections labeled for easy identification.

3.1.7. Terminal Strips: The terminal strips of the control back panel shall consist of dead front clamp-style quick connectors for ease of access and protection of operator.

3.1.8. Circuit Boards: All printed circuit boards shall be conformal coated for fungi and moisture protection.

3.1.9. Ratio-Correction Transformers: A ratio-correction transformer for each internal voltage supply shall be provided inside the control enclosure for easy access and fine voltage adjustment. Ratio-correction taps and the corresponding system voltage shall be clearly identified on unit nameplates.

3.2. Mutliphase Operation

3.2.1. When specified, the regulator control shall be capable of operating two or three apparatuses. A Multiphase control shall include the following features:

3.2.1.1. A single control for up to three regulators

3.2.1.2. Capability of operating all tap changer types

3.2.1.3. Front Panel (for each phase):

3.2.1.3.1. Independent neutral light

3.2.1.3.2. Independent manual control

3.2.1.3.3. Voltage test terminals

3.2.1.3.4. Auto/Remote-Off-Manual operation switch

3.2.1.3.5. Internal-Off-External power switch

3.2.1.3.6. Raise-Off-Lower control switch

3.2.1.3.7. Motor Fuse

3.3. Front Panel

3.3.1. Control Panel Features

3.3.1.1. A full numeric keypad for quick, easy modification of control parameters.

3.3.1.2. Access to control settings and features via function codes, nested menus and shortcut keys.

3.3.1.3. Metering-PLUS keys on the front panel of the control that are factory programmed to provide easy access to frequently used regulator control and operation information.

3.3.1.4. A USB drive port for control programming and data retrieval capabilities using a USB drive mass storage device.

3.3.1.5. A backlit LCD display, 4 lines by 20 characters each, for displaying relevant information. The display shall have an adjustment for contrast.

3.3.1.6. Password protection that provides four levels of user access.

3.3.1.7. Four user-selectable languages (English, Spanish, French, Portuguese), three user-selectable date formats (MM/DD/YYYY, DD/MM/YYYY, YYYY/MM/DD), and two user-selectable time formats (12 hour AM/PM, 24 hour).

3.3.1.8. A Configuration setting for Daylight Savings selection.

3.3.1.9. A six-digit electronic operations counter, which counts every tap change.

3.3.1.10. A USB port to be used for a temporary direct communications connection to a personal computer. The port must be capable of uploading and downloading data without the need for special cables or connectors.

3.3.1.11. A motor fuse, which is replaceable. Fuse size shall be clearly marked near the fuse holder. A spare fuse shall be included within the control enclosure.

3.3.2. Additional Control Panel Features

3.3.2.1. Switches

3.3.2.1.1. A three-position voltage source switch, labeled INTERNAL-OFF-EXTERNAL, which allows the control to be energized from the regulator's internal voltage supply or from an external source. Inadvertent energization of the internal supply is to be prevented while applying external source to control. The OFF position is provided to de-energize the control.

3.3.2.1.2. A three-position, AUTO/REMOTE-OFF-MANUAL control switch, which allows for automatic/remote or manual/local operation of the voltage regulator. Monitoring of the control is available at all positions.

3.3.2.1.3. A momentary three-position RAISE-OFF-LOWER control switch, which shall be active only when the adjacent control switch is in the MANUAL position. The switch must be hardwired and capable of operating the tap-changer even when the control CPU is not functional.

3.3.2.1.4. A position-indicator drag-hand reset switch.

3.3.2.1.5. A supervisory switch which will inhibit tap-changer motor control and parameter changing via digital SCADA, but will allow for monitoring of the control database via SCADA.

3.3.2.2. Terminals

3.3.2.2.1. High-impedance voltmeter test terminals which monitor the load-side voltage (L bushing) of the regulator. On board short-circuit protection components shall be provided to inhibit an accidental back-feed loop in the voltage regulator by way of the voltmeter test terminals.

3.3.2.2.2. External voltage source terminals to allow tap-changer and control operation from an external 120 Vac source. Ground terminal shall be clearly identified. An interlocking means shall be provided to inhibit energizing of the high-voltage bushings from the external source.

3.3.2.2.3. Additional earth ground terminal for the front panel, prominently and clearly identified.

3.3.2.3. LED Indicators

3.3.2.3.1. Dual neutral position LEDs that are actuated via the tap-changer to provide neutral position indication. These LEDs must be of the high-intensity type and easily readable in direct sunlight.

3.3.2.3.2. LED indicators to indicate whether the voltage is inside or outside of the set voltage band, and whether the voltage is high or low.

3.3.2.3.3. LED indicators for Alarms, configurable via the interface software provided by the manufacturer.

3.3.2.3.4. LED indicators for Warnings, configurable via the interface software provided by the manufacturer.

3.3.2.3.5. LED indicator for a diagnostics test failure.

3.3.2.3.6. Transmit and Receive LEDs for all communication ports located on the front panel of the control for user visibility.

3.3.2.3.7. LED indicators to indicate whether the voltage is inside or outside the voltage limiter settings, when active, and whether the voltage is high or low.

3.3.2.3.8. LED indicator to indicate activation of a Tap-Changer-Auto-Blocked condition.

3.3.2.3.9. LED indicator to indicate activation of a reverse power flow mode in the Reverse direction.

3.3.2.3.10. LED indicator to indicate activation of the voltage reduction feature.

3.3.2.3.11. LED indicator for user-defined output of programmable I/O, configurable via the interface software.

3.4. Front-Panel Programming

3.4.1. The control shall be microprocessor-based, shall be accessible from the keypad via a combination structure using function codes and a scrollable nested menu, and shall have provisions for programming of the following parameters:

3.4.1.1. Set voltage settings adjustable from 100.0 to 135.0 V in increments of 0.1 V both for forward and reverse power flow.

3.4.1.2. Bandwidth settings adjustable from 1.0 to 6.0 V in increments of 0.1 V both for forward and reverse power flow.

3.4.1.3. Time delay settings adjustable from 5 seconds to 180 seconds in 1-second increments both for forward and reverse power flow.

3.4.1.4. Line Drop Compensation settings, resistance and reactance, adjustable from -96.0 to +96.0 V in increments of 0.1 V both for forward and reverse power flow. A means shall be provided to set the polarity.

3.4.1.5. System configuration, Wye (Star), Delta Lead and Delta Lag settings for ease of programming. Separate setting of phase angle for Delta connections is not acceptable.

3.4.1.6. Tap-changer compatibility programmed in the control that enables it to correctly operate a range of tap-changers common in the industry including the three models of Eaton Cooper Power series Quik-Drive Tap-Changers. The settings must be automatically configured when the appropriate tap-changer type selection is made. The compatibility should not require fine tuning manual adjustments.

3.4.1.7. Three control operating modes: Sequential, Voltage Averaging and Time Integrating.

3.5. Alarms

3.5.1. The control shall allow for 20 user-configurable Status (binary) and 20 Data (analog) alarms. Alarms shall be able to turn on an LED viewed on the front panel, generate time-tagged Events or Profile snapshots, and be used as a programmable I/O input.

3.6. Digital Metering

3.6.1. Digital Metering Package: Class 1 accuracy which shall provide the following information:

3.6.2. Instantaneous values of load voltage, compensated voltage, current, power factor, kVA load, kW load, kvar load, voltage harmonics, and current harmonics. Voltage and current harmonics shall include, at a minimum, total harmonic distortion.

3.6.3. Demand values of load voltage, compensated voltage, current, kVA load, kW load, and kvar load. For each of these values, the present value, highest value since last reset, and lowest value since last reset shall be provided. Highest and lowest values shall be time and date tagged. Power factor at maximum and minimum kVA load shall be provided. Metering values must be available for both forward and reverse power flow conditions.

3.6.4. The metering data must be easily accessible at the control.

3.7. Data Acquisition

3.7.1. Profiler: The control shall have a profiler that consists of up to 60 user-selectable metering values with configurable sample time intervals. It shall be capable of storing at least 1000 data items.

3.7.2. Event Recorder: The control shall allow for date and time-tagged recording of user-definable Events. The last 50 Events shall be viewable through the LCD display.

3.8. Control Communications

3.8.1. The voltage regulator control shall include the following communications features:

3.8.2. Flash drive port with programming and data retrieval capabilities. The control shall be capable of uploading or downloading parameters and data via a flash drive mass storage device without requiring the use of external computers or hand-held devices. If removable Flash media is used, the control must be capable of formatting new media.

3.8.3. A front-panel data port for a temporary direct communication connection for uploading or downloading data without the need for special cables or connectors.

3.8.4. Two permanent communications ports for use with communication accessories.

3.8.5. Protocol DNP 3 (Serial and Ethernet) and IEC 60870-5-(101)(104) resident and the options of DATA 2179, MODBUS, IEC 61850 in the control and user-configurable for all communication ports.

3.8.6. DNP 3 protocol certified level 2 compliant.

3.8.7. The following communication card options shall be available: RS-232, Serial Fiber ST, RS-485, Ethernet Fiber ST, Ethernet Single-Mode LC, Ethernet Multi-Mode MTRJ, Ethernet ST, Ethernet SC, and Ethernet RJ-45.

3.9. Analog SCADA

3.9.1. The control shall have provisions to allow remote override of auto regulator operation via discrete (analog) supervisory control. Terminals shall be provided on the back panel of the control enclosure as follows:

3.9.2. For motor raise: Two terminals for normally-open, momentary-close contacts.

3.9.3. For motor lower: Two terminals for normally-open, momentary-close contacts.

3.9.4. For auto inhibit: Terminal for latch-closed contact.

3.10. Digital SCADA

3.10.1. The control shall have the ability to include optional communication modules to support connections to a digital SCADA network. The control shall be capable of supporting two communication boards. The available communications options shall include at a minimum:

3.10.2. Fiber-Optic/RS-232 communications interface board for use in SCADA communications. Fiber Optic implementation must support Fiber-Loop configuration option for looping multiple controls together.

3.10.3. Fiber-Optic/RJ-45 Ethernet communications interface board for use in SCADA communications.

3.10.4. RS-485 communications interface board for use in SCADA communications. RS-485 implementation must include on board terminating resistors that can be activated for end of line devices.

3.11. Configurable Logic

3.11.1. The control shall have Configurable Logic capabilities, which will allow the user to write logical equations to perform user-defined control and communication operations.

3.11.2. The control shall have three discrete 120 Vac inputs for discrete I/O interfacing. The user shall add an accessory option to add multiple I/Os.

3.12. Standard Control Features

3.12.1. Tap Position Indication: A tap position indication capability, which tracks the operation of the tap-changer, shall provide the present tap position and the highest and lowest positions since last reset. The highest and lowest values shall be date and time tagged. Tap position indication feature shall use the Neutral and extreme positions, 16 raise and 16 lower, to check the accuracy of its tracking. Tap position shall correct itself in those positions if an error is found. Tap Position Tracking feature shall maintain a counter to record all self-corrections performed at Neutral and the extreme positions, 16 raise and 16 lower.

3.12.2. Voltage Limiting: A voltage-limiting capability that prevents the regulator from making additional tap changes once the regulator output voltage meets a programmed upper- or lower-limit setting. If the source voltage should change, causing the regulator output voltage to exceed either limit, the control, after an initial fixed shorten-time delay, dependent on the voltage swing outside the voltage limit, shall have the tap-changer step the voltage to within the voltage-limiter setting.

3.12.3. Voltage Reduction: A configurable voltage reduction capability which consists of at least three distinct modes as follows:

3.12.4. A minimum of three voltage-reduction values shall be able to be set locally at the control or remotely via a digital SCADA/communications system from 0.0 to 10.0 percent in 0.1% steps.

3.12.5. Remote voltage reduction shall allow any one of the three voltage reduction values to be activated remotely by applying voltage to the appropriate discrete input points on the control. Each of the three reduction values shall be independent of each other and shall be programmable from 0.0 to 10.0 percent. I/O terminals and a whetting voltage to be used for this purpose shall be available as a standard or optional accessory. The whetting voltage shall be available at the discrete I/O terminal.

3.12.6. Pulse-activated voltage reduction shall provide a programmable number of steps of reduction, from 0 to 10.0 percent in increments of 0.1 percent. Total allowable reduction shall be limited to 10.0 percent. Stepping shall be accomplished by momentarily applying voltage to an input contact on the back panel of the control enclosure. Immediate reset to 0 percent shall be accomplished by applying a voltage signal to a second terminal on the back panel. I/O terminals and a whetting voltage to be used for this purpose shall be available as a standard or optional accessory. The whetting voltage shall be available at the discrete I/O terminal.

3.12.7. Reverse Power Flow: A Reverse Power Flow Detector that automatically senses a power reversal and can provide indication that a power reversal is taking place. The regulator control shall incorporate separate forward and reverse control settings for voltage level, bandwidth, time delay, and line-drop compensation R and X. At a minimum, the following modes of reverse power operation shall be provided:

3.12.7.1. Locked forward mode

3.12.7.2. Locked reverse mode

3.12.7.3. Reverse idle mode

3.12.7.4. Bidirectional mode

3.12.7.5. Neutral idle mode

3.12.7.6. Cogeneration mode

3.12.7.7. Reactive bidirectional mode

3.12.8. Source Voltage Calculation: A configuration point which, when turned on, will calculate the source voltage, based on tap position, regulator type, and internal impedance. The regulator types are either Type A or Type B per IEEE Std C57.15™ standard. The calculated source voltage will enable reverse power flow operation without the use of a source-side supply from an additional internal potential transformer or utility winding.

3.13. Tap-Changer Diagnostics and Maintenance

3.13.1. Duty Cycle Monitor: When connected to a Cooper Power Systems Quik-Drive mechanism the control shall have a "Duty Cycle Monitor" that will calculate the life used for all arcing edges of stationary and moveable contacts of the tap-changer based upon actual service conditions and the individual regulator and tap-changer designs.

3.13.2. Preventive Maintenance Tapping (PMT): The control shall be able to perform PMT preventive maintenance tapping, which is the ability for the control to exercise the tap-changer based upon user-defined conditions on a routine basis to prevent the build-up of carbon deposits on the contacts (contact coking). Two modes shall be available allowing for various degrees of configurability and the ability to exercise all stationary and moveable contacts.

3.13.3. Tap-Changer Trouble Status Alarm: This status is to indicate an inability of the tap-changer motor to perform/complete any operation either called for by the control or remote SCADA.

3.13.4. TIME-ON-TAP Feature: The control shall have a TIME-ON-TAP feature that provides specific information about the amount of time as a percentage of the total that the regulator has spent on each tap position.

3.14. Advanced Control Features

3.14.1. Software: A single software program must be available that is capable of fully configuring the control and downloading all metering, voltage regulator operation and maintenance data. The required use of multiple software programs to fully interface with the control is not acceptable.

3.14.2. Logical I/O Programming

3.14.3. The control shall have programmable I/O capabilities, which will allow the user to write logical equations to perform user-defined control and communication operations. These logical equations shall have the ability to relate control status, conditions, I/Os and metering points. Based on the results of these logical equations, definitive control action can be taken.

3.14.4. The control shall have the option of three discrete 120 Vac inputs for discrete I/O interfacing. The user shall add an accessory option to add multiple I/Os.

3.14.5. Auto Restore Local: Control shall have the ability when communications to a SCADA host is lost to restore specific configuration settings. These settings shall be specified by the user when the function is enabled on the control. At a minimum, the following settings should be restored when communications is lost: Forward and reverse settings for set voltage, bandwidth, time delay, and line-drop compensation; Auto-Block feature state; Reverse Power mode; Voltage Reduction; Tap-to-Neutral, and SOFT ADD-AMP.

3.14.6. Alternate Configuration: Control shall have the ability to utilize an additional set of configuration settings. These settings shall be selected by the user, or can be incorporated into the logical I/O programming scheme to allow the control to automatically select a specific group of settings based on control status, conditions, or metering points.

3.14.7. Programmable SOFT ADD-AMP Feature: The control shall have the ability to apply SOFT ADD-AMP feature settings to match those of the mechanical ADD-AMP feature of the PI, based on logical I/O functions. When enabled, these functions shall automatically apply the soft limit setting based on control status, conditions, or metering points. The SOFT ADD-AMP feature increases the capacity of the regulator by restricting the range of regulation.

3.14.8. Leader/Follower Scheme: Control scheme designed to keep two or three voltage regulators on the same mechanical tap position. When utilized with single phase controls, the scheme will use a fiber optic intelligence loop between the phases to provide the communications necessary to initialize a tap change and provide positive feedback in maintaining equal tap positions. When utilized in a multi-phase control, no fiber optic loop or communications cards shall be necessary.

3.14.9. Max Deviation Scheme: Control scheme designed to keep two or three regulators in a predetermined moving tap position window. This feature will limit the maximum number of tap positions the regulators can differ. When active, this mode constrains the regulator tap positions to a user defined maximum deviation. When utilized with single phase controls, the scheme will use a fiber optic intelligence loop between the phases to provide the communications necessary. When utilized in a multi-phase control, no fiber optic loop or communications cards shall be necessary.

4. Optional Equipment

4.1. Regulator Options

4.1.1. 10’, 20’, 30’, 40’, 50’, 60’, or 120’ long control cable

4.1.2. Armored control cable (First 8 feet or Full Length)

4.1.3. Shielded control cable

4.1.4. Environmentally friendly Envirotemp™ FR3™ dielectric fluid in lieu of mineral oil

4.1.5. Shunt arresters for the Source, Load or Source Load bushings (Qty 1, 2, or 3)

4.1.6. Four (4) hole NEMA® spade bushing terminal

4.1.7. #2-1000MCM clamp bushing terminal

4.1.8. Bushing and series arrester bird guards

4.1.9. Ground Connector(s) on tank

4.1.10. Ground Connector on control box

4.1.11. A source-side internal differential potential transformer (IDPT) to provide control accuracy of ±1% (ANSI® Class 1) under reverse power flow conditions. (Control allows for reverse power without this with control accuracy of ±1.5%)

4.1.12. Dial Type Fluid Thermometer

4.1.13. Dial Type Liquid Level Gauge

4.1.14. Dial Type Pressure / Vacuum Gauge

4.1.15. All 304 Stainless Steel unit

4.1.16. External Stainless Steel hardware only

4.1.17. Fan Cooling

4.1.18. Alternate top-coat color

4.1.19. Adjustable galvanized-steel elevating structure for raising the regulator to meet specified live part-to-ground clearances

4.1.20. Dial Type Fluid Thermometer with alarm contacts

4.1.21. Liquid Level Gauge with alarm contacts

4.1.22. Pressure / Vacuum Gauge with alarm contacts

4.1.23. Rapid Rise Pressure relay with alarm contacts

4.1.24. Optional ADD-AMP feature maximum of 875 A shall be provided when specified for regulators rated 438–668 A.

4.2. Regulator Control Options

4.2.1. The following communications interface options are to be available: Fiber-Optic (multi-mode using ST style connectors), RS-232, Fiber-Optic Ethernet (multi-mode using ST style connectors), Copper Ethernet (RJ-45) and RS-485.

4.2.2. Thermostatically controlled control enclosure heater.

4.2.3. Stainless Steel control box.

4.2.4. Radio Ready Controls (please contact Cooper Power Systems for more information

5. Regulator Efficiency

5.1. The regulators will be “Loss Evaluated” in that their cost of losses will factor into the purchasing decision. The A factor is $4.00/watt and the B factor is $1.50/watt.

5.2. Guaranteed regulator no-load (core) and load (winding) losses shall be provided during bidding.

5.3. No-load losses at Neutral and 1R positions and load losses at 16R, 15R, 15L and 16L positions for Type A and Type B designs shall be provided.

5.4. No-load losses at Neutral, 15R and 16R positions and load losses at 16R, 15R, 15L and 16L positions for Series Transformer designs shall be provided.

5.5. These losses shall be corrected to a reference temperature of 75 °C.

6. Testing

6.1. Testing shall include the following:

6.1.1. Ratio tests on all windings and tap connections

6.1.2. 1000 operations using external voltage supply

6.1.3. Operational test using rated voltage

6.1.4. Polarity test

6.1.5. Resistance measurements of all windings excluding control and tap-changer voltage supplies. Tapped windings shall have resistance measurements made at 16R, 15R, 15L and 16L

6.1.6. Insulation power factor test

6.1.7. Insulation resistance test

6.1.8. No-load (core) losses

6.1.9. Load (winding or copper) losses and Impedance at rated current and frequency

6.1.10. Applied potential test

6.1.11. Induced potential test

6.1.12. Routine Lightning Impulse test

6.2. All regulator designs are to be certified design-tested for required temperature, impulse and short circuit performance criteria per IEEE Std C57.15™-2009 standard. Certified design type test reports must be supplied upon request.

7. Documentation

7.1. Information required at time of bid include:

7.1.1. Outline & nameplate drawings.

7.1.2. No-load and load losses per above

8. Shipping

8.1. Regulators are to be shipped "F.O.B. Destination." The destination shall be indicated either in the specification or in the order documentation.

9. Customer Support

9.1. Supplier must have a dedicated service group and support line for voltage regulators and offer training on the control, tap changer, and maintenance upon request.

10. Deviation from Specification

10.1. It is expected that any regulators supplied by the vendor will be in strict accordance with this specification unless appropriately noted with the original bid and agreed to by vendor in writing.