

## Distribution/Substation Transformer

Functional Specification Guide

Type VFI, Vacuum Fault Interrupter Transformer Option

**PS202011EN**

### Functional specification for 15 kV, 25 kV, or 35 kV vacuum fault interrupter distribution/substation transformer option

#### 1. Scope

- 1.1. This specification is intended to be a supplement to the PS202002EN Distribution Transformer specification guide when VFI protection is required.
- 1.2. This specification applies to [select: three-phase; single-phase], 50-60 Hz, fully dead front, [select: pad-mounted distribution; substation] transformers. Overcurrent protection shall be accomplished utilizing a resettable vacuum fault interrupter (VFI) which shall be provided with [select: three-phase or single-phase], [select: three-pole ganged or single-phase] operation. [select: The unit shall have provisions for a motor operator to be added; the unit shall have a motor operator; or the unit shall be manually operated].
- 1.3. The VFI unit is to be used for [select: loop protection; transformer protection].
- 1.4. The unit is to be insulated with Envirotemp™ FR3™ less-flammable dielectric fluid. The unit shall utilize vacuum interrupters for all fault current interruption such that the dielectric media is not consumed or contaminated by normal operations of the interrupters. The unit shall be designed for installation on a concrete or fiberglass pad at ground level.
- 1.5. The transformer shall use resettable interrupter controls and shall not use fuses.
- 1.6. This specification shall only cover the purchase and shipment of transformers. The purchaser and/or user shall be responsible for all site-work, electrical connections, and installation.

#### 2. Applicable Standards

- 2.1. IEEE Std C37.60™-2003 standard – IEEE Standard Requirements for Overhead, Pad-Mounted, Dry Vault, and Submersible Automatic Circuit Reclosers and Fault Interrupters for Alternating Current Systems Up to 38 kV
- 2.2. IEEE Std 386™-1995 standard – Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V.
- 2.3. IEEE Std C37.90™-1989 standard – IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus.
- 2.4. IEEE Std C37.90.2™-1995 standard – Standard for Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers.
- 2.5. IEEE Std C57.12.00™ standard – Standard for Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.
- 2.6. IEEE Std C57.12.28™ standard – Pad-Mounted Equipment - Enclosure Integrity.

- 2.7. IEEE Std C57.12.29™ standard - IEEE Standard for Pad-Mounted Equipment - Enclosure Integrity for Coastal Environments – applicable when stainless steel construction is specified.
- 2.8. IEEE Std C57.12.34™ standard – IEEE Standard Requirements for Pad-Mounted, Compartmental-Type, Self-Cooled, Three-Phase Distribution Transformers (2500 kVA and Smaller) - High Voltage: 34500GrdY/19920 Volts and Below; Low-Voltage: 480 Volt 2500 kVA and Smaller (issued in March 2005 - combines C57.12.22 and C57.12.26).
- 2.9. IEEE Std C57.12.90™ standard – IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers and IEEE Guide for Short-Circuit Testing of Distribution and Power Transformers.
- 2.10. IEEE Std C57.12.91™ standard – Guide for Loading Mineral-Oil-Immersed Transformers.
- 2.11. NEMA TR 1-1993 (R2000) – Transformers, Regulators and Reactors, Table 0-2 Audible Sound Levels for Liquid-Immersed Power Transformers.
- 2.12. NEMA 260-1996 (2004) – Safety Labels for Pad-Mounted Switchgear and Transformers Sited in Public Areas.
- 2.13. 10 CFR Part 431 – Department of Energy – Energy Conservation Program for Commercial Equipment: Distribution Transformers Energy Conservation Standards; Final Rule.

### 3. Ratings

The transformer Vacuum Fault Interrupter shall be rated\* as [select: 15kV (12.5 kA interrupt); 15 kV (16 kA interrupt); 25 kV (12.5 kA interrupt); 35 kV (12.5 kA interrupt)] per the table below.

Nominal Voltage		15 kV	15 kV	25 kV	35 kV
Maximum Design Voltage, kV		15.5	15.5	27.0	38.0
BIL, kV		95	95	125	150
1-Minute Withstand Voltage (60 Hz), kV		35	35	40	50
Momentary Current, 10 Cycles (sym.), kA		12.5	16.0	12.5	12.5
3-second Withstand Current (sym.), kA		12.5	16.0	12.5	12.5
Fault Interrupter	Continuous Current, (max), A	600	600	600	600
	Interrupting Current (sym./asym.)	12.5/20.0	16/25.8	12.5/20.0	12.5/20.0
	Making Current (sym.), kA	12.5	16.0	12.5	12.5
	Cable Charging Interrupting Current, A	10.0	10.0	25.0	40.0
Load-Break Switch	Continuous Current, (max), A	600	600	600	600
	Load Switching, A	600	600	600	600
	3-Shot Make and Latch (asym.), kA	20.0	25.8	20.0	20.0
Minimum Full Life Fault Interrupting Duty Cycle per IEEE Std C37.60™ standard (2 duty cycles)		Number of Operations			
Percent of Interrupting Current Rating:	15-20%	88	88	88	88
	45-55%	112	112	112	112
	90-100%	32	32	32	32
Total		232	232	232	232

\* Continuous and short-circuit currents may be limited by ratings of selected bushings.

### 3.1.1. Vacuum Fault Interrupters

The transformer shall incorporate a vacuum fault interrupter for overcurrent protection only, such that the major dielectric media is never contaminated by circuit interruption arc products. The device shall interrupt all fault currents up to its maximum rated current of [select (see table in Section 3): 12,500 (15, 25 or 35 kV) or 16,000 (15 kV only) RMS amperes symmetrical]. The interrupter shall be manually resettable, with no consumable parts (i.e. fuses). The maximum interrupting time from issuance of a trip signal from the electronic control shall be 2 cycles.

To maximize safety to the operator, the interrupter shall incorporate a trip-free mechanism to prevent the possibility of holding the interrupter mechanism closed under a faulted circuit condition.

The vacuum fault interrupter shall act as a [select: three-phase group operated circuit breaker, or, as three single-phase independent circuit breakers.] The trip mechanisms for each phase shall be [select: mechanically linked and the electronic control shall be set so that an overcurrent condition on any one phase shall simultaneously trip all three phases, or independent single-phase devices.] A [select: single operating handle, or three (3) independent handles] shall be provided for manual opening, reset and closing. The operating handle(s) shall be mounted on the front plate of the tank in close relation to the VFI being controlled and shall have three distinct operating positions corresponding to the vacuum fault interrupter positions of closed, open, or tripped. A pointer attached to the handle shall be provided for ready identification of the handle's position. The handle shall be designed for operation with a lineman's hot stick and have a push to close / pull to open / pull to reset operation requiring no more than 75 lbs. of force and 60 degrees of movement for complete operation. Except when equipped with the optional motor operator, when the vacuum fault interrupter is tripped by automatic action of the VFI control, the operating handle shall drop to an intermediate position between its closed and open positions, to provide indication that it is tripped. The operating handle assembly shall include provisions to padlock the handle in the open position.

## 4. Electronic Trip Control

- 4.1. Overcurrent sensing shall be accomplished with an electronic trip control that shall be Eaton's Cooper Power series type Tri-Phase Control with Ground (TPG) control.
- 4.2. The control shall use internally mounted 1000:1 bushing current transformers (CTs) to sense line current and shall also provide the control operating power, eliminating the effects of system voltage conditions. The control shall be self-contained and includes the following:
  - 4.2.1. Meet the specified time-current curve immediately upon energization.
  - 4.2.2. No "warm-up", initialization, or arming time delays adjustments shall be necessary.
  - 4.2.3. No minimum load requirement or battery back-up device shall be necessary to meet the specified time-current characteristics.
  - 4.2.4. The control shall have a minimum operating temperature range of -30 °C to +65 °C with no more than a ±5% variation in time-current response characteristics from its response at +25 °C.
- 4.3. The standard control shall provide minimum phase overcurrent trip settings that are field selectable (in 10 amp increments) from 20 amps to 1290 amps. Trip settings may be changed while the transformer is energized (so service is not interrupted). An instantaneous trip feature shall be provided as a standard feature of the control. Instantaneous trip shall be a field selectable multiple of 1X, 3X, 5X,...15X times the phase overcurrent trip settings or it may be selected to be disabled. The instantaneous trip feature shall provide a fixed 0.025-second response time characteristic.
- 4.4. A single time-current curve shall be provided that is common to all three phases. Time-current trip curves shall be changeable via plug-in Eaton's Cooper Power series TCC modules. The time-current curve provided shall be the Cooper Power Systems type [select: for Tri-Phase with Ground – EF, KF, TF, F or H on phase and ground]), and shall emulate the time-current characteristics of its associated fuse type.

- 4.5. The control and its enclosure shall be mounted on the inside of the cabinet door of the VFI tap compartment. The control enclosures shall be [Select option: mild steel or stainless steel (as specified for the unit)] and vented in design to prevent trapping of moisture within the control. The control cabinet shall provide sufficient space for [select: the future (or present) addition of a SCADA / accessory board that shall be mounted within the same control cabinet assembly as the TPG control.]
- 4.6. TPG Ground Trip Element: The minimum trip selection for each phase element and for ground element shall be independently settable. Minimum ground trip settings shall be selectable from 10 to 640 amps, in 10 amp increments. A separate instantaneous trip feature shall be provided for ground as a standard feature that shall provide a selection of 1X, 3X, 5X....15X the ground minimum trip setting for the instantaneous trip pick-up or it may be disabled. The instantaneous trip feature shall provide a fixed 0.025-second response time characteristic.
- 4.6.1. The overcurrent trip response time for ground trip shall be governed by a separate time-current curve plug-in module.
- 4.6.2. The ground trip sensing portion of the control shall be capable of being de-activated via a ground trip block switch.
- 4.7. [Select: A SCADA / Accessory board shall be provided that is mounted within the same control cabinet assembly. This accessory shall include its own battery backup utilizing long life lithium batteries as required to support proper activation of the inrush restraint feature upon power up from a de-energized state and for proper operation of the trip indication targets. This accessory shall provide:
- 4.7.1. A minimum trip multiplier feature that shall be activated by a separate toggle switch located within the control housing. This feature shall allow normal minimum trip levels for each phase and ground to be raised from 1.1X to 13.7X their normal setting while this feature is active. This multiplier shall be field selectable and shall be independently settable for each phase and for ground. A contact output shall be supplied for remote status indication.
- 4.7.2. An inrush restraint feature that shall allow the control to automatically raise the set minimum trip levels for phase and ground to a field selectable multiple of 1X to 32X, in increments of 1X, for a selectable time interval of 0.5 to 32 seconds, in increments of 0.5 seconds. The feature shall also have the field selectable provision to block ground trip during the interval that the inrush restraint is active.
- 4.7.3. Trip indication targets shall be provided on the circuit board with separate targets for each phase and ground. After a trip event, these targets shall give visual indication where the fault occurred. The phase target shall reset after restoration of line current in the affected phase. The ground target shall reset after restoration of current in any phase. Contacts for remote indication of a trip event shall be provided for each phase and ground.
- 4.7.4. A separate ground trip block toggle switch shall be provided within the control enclosure to allow easy activation of ground trip when a known phase unbalance condition will be created due to switching or maintenance operations that may cause an unwanted ground trip. A contact shall be provided for remote status indication of the switch.
- 4.7.5. A separate three-pole toggle switch shall be provided within the control enclosure that shall function as a CT shorting switch. This toggle switch shall allow the operator to easily de-energize the control for maintenance, or disable the control from sensing and tripping on over-currents. A contact shall be provided for remote status indication of the switch.
5. **[Select: Optional Features] (One or Multiple Selections can be made)**
- 5.1. **[Select: Motor Operator Mounting Provisions]**
- 5.1.1. When specified, the VFI transformer shall be provided with mounting provisions for future addition of motor operators. The provisions shall include auxiliary switches with one "a" and one "b" contact, mounting studs for motor operator mounting brackets, switch operating handles with provision for attachment to motor operators, studs and channels for routing cable connections to the future motor operator control, stud mounting provisions.

**5.2. [Select: Motor Operators]**

5.2.1. When specified, a DC motor operator, with control shall be supplied for the VFI transformer. The unit shall include all standard motor operator mounting provisions specified above. The motor operator shall utilize 24-Vdc motor actuators to open and close the respective VFI. The time required to open or close the VFI shall be approximately 8 seconds. The motor control shall be equipped with a 2.5 amp-hour sealed lead acid gel-cell battery to supply energy to activate the motor operator and control functions. Battery charge shall be maintained by a temperature/voltage regulated charger within the motor control that shall be capable of fully re-charging a low battery within 24 hours.

The motor control shall utilize a user supplied 120-Vac two-wire grounded supply. [optional: The control shall also have provisions for accepting a second, alternate 120-Vac supply and shall provide a transfer relay to transfer to the alternate supply if the primary 120-Vac supply is lost.] If a potential transformer for power supply to the motor control has been specified, the unit shall be provided with all necessary wiring factory installed.

The motor control shall include the following features:

- Open, Close, and Stop pushbuttons shall be provided for operation of the motor actuator.
- Open and Closed indicating lights shall be provided to indicate status of the VFI. These status lights shall use auxiliary switch inputs from the source VFI to determine open or closed status.
- Opening and closing indicating lights shall be provided to verify that the motor actuator is in process of opening or closing a switch. A lamp test pushbutton shall be provided to confirm that indicating lights are functional
- A Power On/Off toggle switch shall be provided that shall disconnect the dc voltage supply from the control and the motor actuator and shall function as a dc circuit breaker to interrupt the dc supply in the event of a short circuit or overload.
- An indicator shall be provided to verify that 120-Vac power is present and that the battery charging circuit is providing a charging voltage to the battery. A battery test pushbutton shall be supplied with test points to apply a voltmeter for testing the condition of the battery.
- A Local/Remote toggle switch shall be provided. In the Local position, the switch shall allow operation of the motor actuator by the pushbuttons on the control panel only and shall not allow remote or SCADA operation. In the Remote position, the switch shall only respond to the remote or SCADA operation of the motor actuator.
- The control shall include a terminal strip for connection to SCADA or remote control equipment. The terminal strip shall have connections for reading the Open/Closed status of the VFI, initiating a Open or Close operation via a momentary dry contact, and reading the Opening/Closing status of the motor actuator as it performs the required operation.
- [select: The control shall also include provisions to add a hand-held extended control accessory and an interconnecting cable (length to be specified, maximum is 200 ft.). This accessory shall provide the same motor selection and operating pushbuttons as the main control that is mounted with the transformer so as to temporarily allow operation of the motor actuator from a more remote and convenient location.]

**5.3. [Select: Visible Break Window]**

5.3.1.1. The contacts of the visible break switch will be clearly visible through a 4" x 11" view window.

**5.4. [Select: Open/Closed Semaphores]**

5.4.1. When specified, an Open (green) /Closed (red) semaphore shall be provided for each way, which shall indicate the open or closed status of the vacuum fault interrupter. The semaphore shall be visible through a window on the tank in direct logical proximity to the operating handle of its fault interrupter.

**5.5. [Select: Kirk-Key Interlock Provisions]**

5.5.1. When specified, mounting provisions for Kirk key interlocks shall be provided on each switched and VFI protected way. The actual interlocking key scheme and the interlocks will be furnished by the purchaser.

**5.6. [Select: Auxiliary Switches]**

5.6.1. When specified, the VFI shall be provided with [select: one set; two sets] of stage “a” and “b” auxiliary switches for the purpose of remote indication of status. These auxiliary switches shall be rated for 15-amps @ 120-Vac / 1-amp @ 125-Vdc and wired to an external terminal strip.

**5.7. [Select: Partial Range Current Limiting Fuses in series with VFI]**

5.7.1. When specified, the VFI shall be provided with separate partial range current limiting fuse. The VFI will be connected in series with the partial range current limiting fuse. The partial range current limiting fuse will provide protection up to 50 kA.

**6. Quality Assurance**

- 6.1. The manufacturer shall be a company specializing in medium voltage distribution transformers with at least fifteen years of documented experience.
- 6.2. Equipment shall be built in accordance with the industry standards for medium voltage equipment.
- 6.3. The manufacturer shall be registered and certified as ISO 9001 compliant by a recognized international and independent body.

**7. Approved Manufacturers**

Eaton's Cooper Power series Type VFI Vacuum Fault Interrupter Transformer

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