Functional specification for critical application and Envirotran HDC substation distribution transformers 300–12,000 kVA

1.0 Scope

1.1. This specification covers the electrical and mechanical characteristics of Eaton's Cooper Power series 300–12,000 kVA three-phase substation distribution transformers. Product is per catalog data CA202001EN. The transformers will be applied to critical load, so the design, manufacture, and test of the transformers must yield unwavering quality.

2.0 Applicable Standards

2.1. All characteristics, definitions, and terminology, except as specifically covered in this specification, shall be in accordance with the latest revision of the following IEEE®, Department of Energy, and NEMA® standards.

IEEE Std C57.12.00™-2010 – IEEE Standard for Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers

IEEE Std C57.12.28™-2014 – Sections 5.3, 5.4, 5.5 – Coating System Requirements

IEEE Std C57.12.36™- 2007 – IEEE Standard Requirements for Liquid-Immersed Distribution Substation Transformers

IEEE Std C57.12.70™-2011 – IEEE Standard for Terminal Markings and Connections for Distribution and Power Transformers

IEEE Std C57.12.90™-2010 – IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers and IEEE Guide for Short-Circuit Testing of Distribution and Power Transformers

NEMA® TR 1-1993 (R2000) – Transformers, Regulators and Reactors, Table 0-2 Audible Sound Levels

10 CFR Part 431 – Department of Energy–Energy Conservation Program: Energy Conservation Standards for Distribution Transformers; Final Rule

3.0 **Ratings**

3.1. The transformer shall be designed in accordance with this specification and the base kVA rating shall be one of the following:

300, 500, 750, 1000, 1500, 2000, 2500, 3000, 3750, 5000, 7500, 10000 or 12000

3.2. The high voltage and the basic lightning impulse insulation level (BIL) shall be selected from Table 1.

OR

The transformer shall have a dual high voltage to be reconnected with an externally operable, de-energized switch. The voltages provided and the basic lightning impulse insulation level (BIL) shall be chosen from Table 1 and shall not exceed a 3:1 ratio.

OR

The high voltage and the basic lightning impulse insulation level (BIL) shall be specified on the data sheet.

Table 1 – High voltage ratings and BIL

High voltage ratings (volts)	Basic impulse insulation level – BIL (kV)
2400 Delta	60
4160 Delta	75
4800 Delta	75
7200 Delta	95
12000 Delta	110
12470 Delta	110
13200 Delta	110
13800 Delta	110
14400 Delta	110
16340 Delta	110
34500 Delta	200
4160GrdY/2400	75
8320GrdY/4800	95
12470GrdY/7200	110
13200GrdY/7620	110
13800GrdY/7970	110
22860GrdY/13200	150
23900GrdY/13800	150
24940GrdY/14400	150
34500GrdY/19920	200

* Note to specifier – The above table is not intended to list every voltage available.

3.3. The low voltage and the basic lightning impulse insulation level (BIL) shall be chosen from Table 2.

Table 2 – Low voltage ratings and BIL

Low voltage ratings (volts)	Basic impulse insulation level – BIL (kV)
208Y/120	45
480Y/277	45
575Y/332	45
600Y/347	45
690Y/398	45
4160Y/2400	75
240 Delta	45
480 Delta	45
240 Delta with 120 Mid-Tap	45
480 Delta with 240 Mid-Tap	45
4160 Delta	75

* Note to specifier – The above table is not intended to list every voltage available.

3.4. One of the following shall indicate the high voltage and low voltage connections of the transformer. If a special connection is required it shall be requested on the inquiry.

[ ] Delta - Wye
For Delta - Wye configurations the low voltage neutral shall be a fully insulated X_o bushing. The low voltage shall lag the high voltage by 30°.

[ ] Delta - Grounded Wye
For Delta - Grounded Wye configurations the low voltage neutral shall be a fully insulated X_o bushing with ground strap. The low voltage shall lag the high voltage by 30°.

[ ] Delta - Delta
For Delta - Delta configurations the transformer shall be provided without a neutral bushing. There shall be no phase shift between the high voltage and low voltage.

[ ] Grounded Wye - Wye
For Grounded Wye - Wye configurations the high voltage neutral shall be internally tied to the low voltage neutral and brought out as the H_oX_o bushing. There shall be no phase shift between the high voltage and low voltage.

[ ] Wye - Grounded Wye
For Wye - Grounded Wye configurations the high voltage neutral shall be brought out as the H_o bushing on the high voltage side and the low voltage neutral shall be brought out as the X_o bushing with ground strap on the low voltage side. There shall be no phase shift between the high voltage and low voltage.

[ ] Wye - Delta
For Wye - Delta configurations the high voltage neutral shall be brought out as the H_o bushing on the high voltage side. The low voltage shall lag the high voltage by 30°.

3.5. The transformer shall be furnished with full capacity high-voltage taps. The tap-changer shall be clearly labeled to reflect that the transformer must be de-energized before operating the tap-changer as required in Section 4.3 of IEEE Std C57.12.34™-2009 standard. The tap-changer shall be operable on the higher voltage only for transformers with dual high voltages. The unit shall have one of the following tap configurations:

[ ] Two – 2 ½% taps above and below rated voltage (split taps)
[ ] No Taps
[ ] Four – 2 ½% taps below rated voltage (four below)
[ ] NEMA® taps (14400, 13800, 13200, 12870, 12540)
[ ] Non-standard tap configuration: _____

3.6. The dielectric coolant shall be listed less-flammable fluid meeting the requirements of National Electrical Code® Section 450-23 and the requirements of the National Electrical Safety Code® (IEEE Std C2™-2002 standard), Section 15. The dielectric coolant shall be non-toxic*, non-bioaccumulating and be readily and completely biodegradable per EPA OPPTS 835.3100. The base fluid shall be 100% derived from edible seed oils and food grade performance enhancing additives. The fluid shall not require genetically altered seeds for its base oil. The fluid shall result in zero mortality when tested on trout fry *. The fluid shall be certified to comply with the US EPA Environmental Technology Verification (ETV) requirements, and tested for compatibility with transformer components. The fluid shall be Factory Mutual Approved®, UL® Classified Dielectric Medium (UL-EOUV) and UL® Classified Transformer Fluid (UL-EOVK), Envirotemp™ FR3™ fluid.
*(Per OECD G.L. 203)

3.6.1. The transformer, filled with Envirotemp™ FR3™ fluid, shall have a 65°C average winding temperature rise rating. The above winding temperature rise shall not exceed 65°C when loaded at base kVA rating.

OR

The transformer, filled with Envirotemp™ FR3™ fluid, shall have a 55/65°C average winding temperature rise rating. The above winding temperature rise shall not exceed 55°C when loaded at base kVA rating. The transformer shall provide an additional 12% continuous operating capacity at the 65°C rating.

(**Note:** For additional PEAK (75°C) ratings please refer to PS202010EN)

3.7. The percent impedance voltage, as measured on the rated voltage connection, shall be per Table 5 of IEEE Std C57.12.36™-2007 standard.

3.8. The transformer shall be cooled by the natural circulation of air over the tank surface and any corrugate or radiators if required, allowing only the base kVA rating shall be provided with Class KNAN.

OR

The transformer shall be cooled by the natural circulation of air over the tank surface, with an additional rating obtained by forced air circulated over the radiators or corrugate. The unit shall be provided with KNAN/KNAF rated cooling including fans and control equipment. Control power shall be provided by others. Additional capacity ratings shall be as follows; 15% for 750-2,000 kVA, 25% for 2,500-10,000 kVA, 33% for 12,000 kVA.

OR

The transformer shall be cooled by the natural circulation of air over the tank surface, with future kVA capacity built into the cooling surfaces and conductors. The unit shall be provided with KNAN/Future KNAF rated cooling. Additional capacity ratings shall be as follows; 15% for 750-2,000 kVA, 25% for 2,500-10,000 kVA, 33% for 12,000 kVA.

3.9. UL® Listing/Classification and FM® Approval

3.9.1. The transformer shall be UL® Listed (certifying compliance with IEEE® standards only) per UL® XPLH.

3.9.2. The transformer shall be combination UL® Listed & Classified to comply with NEC® 450-23 listing restrictions for installations on, near, or inside of buildings per UL® XPLH.

OR

The transformer shall be FM® Global (FM) Approved to comply with NEC® 450-23 listing restrictions for installations on, near, or inside of buildings.

4.0 Construction

4.1. The core and coil shall be vacuum processed to ensure maximum penetration of insulating fluid into the coil insulation system. While under vacuum, the windings will be energized to heat the coils and drive out moisture, and the transformer will be filled with preheated filtered degassed insulating fluid. The core shall be manufactured from burr-free, grain-oriented silicon steel and shall be precisely stacked to eliminate gaps in the corner joints. The coil shall be insulated with B-stage, epoxy coated, diamond pattern, insulating paper, which shall be thermally cured under pressure to ensure proper bonding of conductor and paper.

4.2. Panel type radiators or corrugate type cooling are welded directly to the tank when additional cooling is required.

OR

Panel type, removable radiators, complete with flanged shut off valves on the tank side shall be provided.

4.3. The tank must be welded using precision cut, cold-rolled steel plate and equipped with extra-heavy duty, welded-in-place lifting lugs and jacking provisions. The tank base must be designed to allow skidding or rolling in any direction.

4.4. The transformer shall be of sealed tank construction of sufficient strength to withstand a pressure of 7 psig without permanent distortion, and 15 psig without rupturing.

4.5. The tank shall include a pressure relief device as a means to relieve pressure in excess of pressure resulting from normal operation. The venting and sealing characteristics shall be as follows:

Cracking Pressure: 10 psig +/-2 psig
Resealing Pressure: 6-psig minimum
Zero leakage from reseal pressure to -8 psig
Flow at 15 psig: 50 SCFM minimum

4.6. The tank shall be cleaned with an alkaline cleaning agent to remove grease and oil. An iron phosphate coating shall then be chemically bonded to the metal to assure coating adhesion and retard corrosion. The tank shall be primed with an electrodeposited powder epoxy to provide a barrier against moisture, salt, and corrosives. The top-coat shall be a liquid polyurethane coating to seal and add ultraviolet protection. The tank coating shall meet all requirements in IEEE Std C57.12.28™-2014 standard.

4.7. At the specifier's option the high voltage and low voltage terminations shall each be located on the cover or enclosed in one of the following:

[ ] Throat
A throat is used on a transformer with sidewall-mounted bushings for connecting the transformer with bus duct. It extends 8 inches above and below the centerline of the bushings.

[ ] Flange (required with high voltage air disconnect switch)
A flange is used on a transformer with sidewall mounted bushings for direct connection to metal clad switchgear, and is required with the high voltage air disconnect switch option. The flange extends 8 inches above and 32 inches below the bushing centerline.

[ ] Partial height, bottom entry air terminal chamber
The partial height bottom entry chamber extends approximately 24 inches below the centerline of the bushings, and has a bottom removable plate that can accommodate cable glands or conduit hubs. The chamber shall include [a hinged door with padlockable handle and a {pentahead} {hexhead] bolt] [a lift-off front panel].

[ ] Partial height, top entry air terminal chamber
The partial height top entry air terminal chamber has a chimney with a removable cover that extends 24 inches above the bushing centerline and can be equipped with cable glands or conduit hubs. Bus duct can be adapted to match the top of

the chimney for bus termination. The chamber shall include [a hinged door with padlockable handle and a {pentahead} {hexhead] bolt] [a lift-off front panel].

[ ] Full height, bottom entry cabinet
A full height bottom entry air terminal chamber is a weather-resistant metal enclosure around sidewall mounted bushings that extends downward to the transformer base level and upward approximately 10 inches above the bushing centerline. It is intended for underground feed and is provided with facilities for distribution arresters. The chamber shall include [a hinged door with padlockable handle and a {pentahead} {hexhead] bolt] [a lift-off front panel].

[ ] Full height, top entry cabinet
A full height top entry air terminal chamber is a weather resistant metal enclosure around sidewall mounted bushings that extends downward to the transformer base level and upward approximately 24 inches above the centerline of the bushings. The chamber shall include [a hinged door with padlockable handle and a {pentahead} {hexhead] bolt] [a lift-off front panel].

4.8. The tank shall be complete with an anodized aluminum laser engraved nameplate. This nameplate shall meet IEEE Std C57.12.00™-2010 standard for Nameplate B.

4.9. High voltage bushings and terminals

4.9.1. The transformer shall be provided with three (3) [sidewall] [cover]-mounted high voltage bushings plus an H_o neutral bushing for WYE connected transformers rated for full three-phase duty with a [2] [4]-hole spade or an eyebolt connector. The high voltage bushings shall be mounted in segment [1] [2] [3] [4] of the transformer.

OR

The transformer shall be provided with [three (3)] [six (6)] sidewall mounted high voltage bushings, [200 amp wells with inserts] [600 amp dead-break] for deadfront application and arranged for [radial] [loop] feed configuration. The high voltage bushings shall be mounted in segment [2] [4] of the transformer.

OR

The applicable bushing configuration shall be specified on the inquiry.

4.10. Low voltage bushings and terminals

4.10.1. The low voltage bushings shall be [sidewall] [cover]-mounted. For voltages less than 1000V bushings shall be molded epoxy with a [4][6][8][12][16]-Hole NEMA® spade. Low voltage bushings above 1000 V and all cover-mounted bushings shall be electrical grade wet process porcelain. The low voltage bushings shall be located in the segment opposite of the specified high-voltage configuration.

OR

The applicable bushing configuration (phasing) shall be specified on the inquiry.

4.11. Overcurrent protection and switching

4.11.1. The optional overcurrent protection scheme provided with the transformer shall consist of one of following attributes. If for any reason a special protection scheme is required it shall be clearly stated on the inquiry.

[ ] The high-voltage overcurrent protection scheme provided with the transformer shall be a loadbreak Bay-O-Net assembly with a flapper valve to minimize oil spillage. Overcurrent protection shall be provided by a Bay-O-Net expulsion fuse mounted in series with partial range under-oil ELSP current-limiting fuses with a maximum interrupting rating of 50,000 A rms symmetrical.

OR

[ ] The transformer primary shall include a Vacuum Fault Interrupter (VFI). The VFI shall have a maximum interrupting rating of [12.5] [16] kA RMS symmetrical with resettable fault protection up through [35] [15 (for 16 kA)] kV. The VFI shall also include Tri-Phase control with Ground (TPG) with over 100 minimum trip settings and 5 selectable time current curves. The trip settings curve shall be clearly stated on the inquiry.

(**Note**: See G210-12-VFI for additional details/options)

OR

[ ] Primary Air Load-break Switch ((5, 15, 25, & 35 kV) 600A)) shall be provided that is in accordance with IEEE Std C37.20.3™-2013 standard and NEMA® SG-5. The switch shall include an EPR-insulated copper cable transition and provisions for mounting surge arresters. The switch shall be a three-pole, two-position gang operated air interrupter to include a manual stored energy mechanism for ease of operation. The switch shall be enclosed in modular self-supporting, bolted design including an electrostatically applied paint finish exceeding IEEE Std C37.20.3™-2013 standard and a 500 W cabinet heater. A 1200 A Primary Air Load-break Switch is available as an option. **Note:** The transformer must be specified with the High Voltage Flange in order to provide the primary air disconnect switch.

[ ] The transformer primary shall be non-fused. It shall include a copper bus transition to the transformer. **Note:** Required when full load current exceeds 600A.

[ ] The transformer primary air load-break switch shall include non-disconnect power fuses.

[ ] The transformer primary air load-break switch shall include disconnect power fuses.

[ ] The transformer primary air load-break switch shall include current-limiting non-expulsion power fuses.

4.12. Overvoltage Protection

4.12.1. The overvoltage protection scheme provided with the transformer shall consist of one of the following attributes. If for any reason a special protection scheme is required it shall be clearly stated on the inquiry. **Note:** External arresters will not be provided in throats or flanges.

[ ] Primary overvoltage protection shall be provided by externally mounted, UltraSIL polymer-housed Evolution Distribution Class MOV arresters.

[ ] Primary overvoltage protection shall be provided by externally mounted, UltraSIL polymer-housed VariSTAR Intermediate Class MOV arresters.

[ ] Primary overvoltage protection shall be provided by externally mounted, UltraSIL Polymer-Housed VariSTAR Station Class MOV surge arresters.

[ ] Primary overvoltage protection shall be provided by VariSTAR [light-duty] [heavy-duty] under-oil MOV Distribution Class arresters.

[ ] Provisions for arresters

[ ] Primary overvoltage protection shall consist of elbow type MOVE arresters in conjunction with deadfront bushing wells and inserts.

5.0 **Finish Performance Requirements**

5.1. The tank coating shall meet all requirements in IEEE Std C57.12.28™-2014 standard including:

- Salt Spray
- Crosshatch adhesion
- Humidity
- Impact
- Oil resistance
- Ultraviolet accelerated weathering
- Abrasion resistance–taber abraser

6.0 **Production Testing**

6.1. All units shall be tested for the following:

- Ratio, polarity and phase relation tests using all tap settings
- Winding resistance measurement tests
- Insulation power factor
- Full wave and reduced wave impulse test
- Applied and Induced potential tests
- No-Load losses at rated current
- Total losses at rated current
- Percent impedance at rated current
- Excitation current (100% voltage) test
- Leak test

6.2. Transformers shall conform to efficiency levels for liquid immersed distribution transformers, as specified in the Department of Energy ruling “10 CFR Part 431 Energy Conservation Program: Energy Conservation Standards for Distribution Transformers; Final Rule; April 18, 2013.” Manufacturer shall comply with the intent of all regulations set forth in noted ruling (commonly referred to as DOE 2016).

6.3. Each transformer shall go through the following production leak testing. This is to ensure maximum reliability for this critical application.

6.3.1. Empty tank – Cap all openings to tank, pressurize with air, and check for weld leaks via soap solution
6.3.2. Perform visual inspection of all welds on front plate and tank.
6.3.3. 24 hour production leak test – Once cover is applied, pressurize unit to at least 5 psi and hold for 24 hours. Certify that pressure remained unchanged.

6.4. The manufacturer shall provide certification upon request for all design and other tests listed in IEEE Std C57.12.00™-2010 standard, including verification that the design has passed short circuit criteria per IEEE Std C57.12.00™-2010 and IEEE Std C57.12.90™-2010 standards.

6.5. In the event of proposal bid evaluated with guaranteed losses due to a loss evaluation (see section 11.0), manufacturer shall conform to guaranteed average losses as specified in IEEE Std C57.12.00™-2010 standard. The no-load losses of a transformer shall not exceed the specified no-load losses by more than 10%, and the total losses of a transformer shall not exceed the specified total losses by more than 6%.

7.0 **Approved Manufacturers**

7.1. Eaton’s Cooper Power Systems Division

8.0 **Accessories**

8.1. The following standard accessories shall be provided:

- De-energized tap-changer
- 1.0” upper fill plug with filter press connection

- 1.0” drain valve with sampling device
- Cover-mounted automatic pressure relief device
- Welded cover with bolted manhole
- Lifting lugs (4)
- Liquid level gauge
- Dial type thermometer
- Pressure/vacuum gauge
- SS ground pads (4)
- Nitrogen blanket with purge valve
- Touch-up paint (2 aerosol cans)

8.2. The following optional accessories shall be provided if specified:

[ ] Copper low voltage bushings (standard with all-copper windings)
[ ] Bleeder valve
[ ] NEMA® 4 control box (standard with fan package)
[ ] NEMA® 4X control box (stainless steel)
[ ] NEMA® 7 control box (explosion proof)
[ ] Rapid pressure rise relay
[ ] Seal-in panel for rapid pressure rise relay
[ ] Forced air fan control package
[ ] Winding temperature indicator
[ ] Auxiliary contacts for liquid level gauge
[ ] Auxiliary contacts for dial type thermometer (standard with fan package)
[ ] Auxiliary contacts for pressure/vacuum gauge
[ ] Auxiliary contacts for pressure relief device
[ ] 1.0” globe-type upper fill valve

9.0 **Special Features**

9.1. The following special features may be provided if specified:

[ ] All copper windings
[ ] Primary air disconnect switch
  [ ] 1200 A loadbreak rating (requires 1200 A copper bus bar)
  [ ] Outer front door (covers viewing area and switch)
  [ ] Key interlocks for interlocking switch with secondary
  [ ] Porcelain bus insulators
  [ ] Copper bus transition to transformer (required for 600 A and greater)
  [ ] Auxiliary switch (remote indication of primary switch position)
  [ ] Line-side bus (bottom entry only)
  [ ] Thermostat for space heater
[ ] Vacuum Fault Interrupter, 600 A continuous, 12.5 kA RMS Interrupting
[ ] Dead front HV termination
  [ ] Loop feed
  [ ] Radial feed
[ ] Sectionalizing switch, 4-position T-blade, 600 A, make-before-break option

[ ] 304L stainless steel construction
- **[ ]** Tank base
- **[ ]** Primary enclosure
- **[ ]** Secondary enclosure
- **[ ]** 100% 304L stainless steel construction

[ ] Cooling
- **[ ]** Mild steel radiators
  - **[ ]** Welded
  - **[ ]** Removable
- **[ ]** Stainless steel radiators
  - **[ ]** Welded
  - **[ ]** Removable
- **[ ]** Galvanized steel radiators (removable and unpainted)

[ ] K-factor transformer
[ ] Positive nitrogen pressure oil preservation system
[ ] Current transformers for relaying/metering
[ ] Containment pan for indoor use for 100% fluid containment
[ ] Factory Mutual® (FM) approved transformer (for NEC® Code-listed installations on, near, or inside of buildings)
[ ] UL® Listed and Classified transformer (for NEC® Code-listed installations on, near, or inside of buildings) per UL® XPLH
[ ] UL® Listed transformer (certifying compliance with IEEE® standards only) per UL® XPLH
[ ] Transformers shall be shrink wrapped prior to shipment

10.0 **Optional transformer evaluation**

[ ] No unit evaluation, but include quote losses as reference only on bid.
[ ] Unit loss evaluation, guaranteed average losses. Criteria to properly evaluate quoted losses:
- Core loss evaluation (A-factor) ____ $/watt
- Winding loss evaluation (B-factor) ____ $/watt

(Eaton may be contacted for sample loss evaluation method)

11.0 **Shipping**

11.1. Transformers shall be loaded and unloaded with overhead cranes. No pallet shall be provided.

12.0 **Data with proposal**

12.1. The following data shall be submitted with the proposal:

- Core losses (when requested per Sections 6.5 and 10.0).
- Winding losses (when requested per Sections 6.5 and 10.0).
- Percent impedance

- Typical bid drawing

12.2. The following checked data shall be submitted with the proposal:

[ ] Exciting Current @ 100% and 110% rated Voltage.
[ ] Efficiencies must be provided at loading levels of 100%, 75%, 50%, and 25%.
[ ] Percent regulation must be provided at 0.8 PF and 1.0 PF.

13.0 **Drawings**

13.1. The following should be provided after receipt of order:

[ ] Construction drawings
[ ] Record drawings
[ ] Approval drawings
[ ] CAD drawings

14.0 **Service**

14.1. The manufacturer of the transformer shall have regional service centers located within 2 hours flight time of all contiguous 48 states. Service personnel shall be factory trained in commissioning and routine service of quoted transformers.