MASTER SPECIFICATION
FOR

Renewable Generation Main Power Transformer (MPT)

Revision 9.0

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Approval Provided by:
Approval Date:

REVISION HISTORY

Date	Revision	Change Description
4-2-2017	1.0	Enhancements; Required Format
5-3-2017	2.0	Appendices Reorganized
6-1-2017	3.0	Enhancements
8-22-2017	4.0	Appendix 4 Modified
10-30-2017	5.0	Enhancements
5-26-21	6.0	Updated from Wind Farm to Renewable MPT
12-28-21	7.0	Added Notes to Drafter on page 32.
10-11-22	8.0	Added GIC section 4.0, updated Dehydrating Breather section 17 B.
11-17-22	9.0	Auxiliary Equipment Changes

GENERAL

DESCRIPTION

This specification defines the technical requirements for the supply of the specified quantity of transformers for use on a new renewable generation project (Wind Farm, Solar or Energy Storage Main Power Transformers or MPT's). The MPT's are used to connect the renewable generation to the transmission system and are installed in the renewable generation collection system substation.

The low side voltage rating of the MPT is 34,500V. The high side nominal voltage rating of the MPT is determined by the transmission line operating voltage (typically 115 KV, 161 KV, 230 KV or 345 KV).

MPT transformers include a +/- 10% on load tap changer (OLTC) on the high side winding, and an unloaded Delta tertiary winding. See the appendices to this specification for additional technical requirements.

SUMMARY

Supplier shall design, test and deliver the specified quantity of 3-phase, 60 Hz, oil-filled MPT's. Transformers shall be equipped with a high voltage on-load tap changer and a 35% rated 13,800V tertiary winding. Transformer ratings shall be as specified in Appendix 6 (See Data sheet for each type of transformer).

Supplier shall be responsible for the following:

a. Design, testing and delivery of MPT's to the project site as specified herein.
b. Delivery of transformer oil
c. MPT unloading and setting
c. Field assembly
d. Oil drying and vacuum oil filling
e. MPT field testing

Company shall be responsible for the following:

a. MPT foundation(s)
b. MPT electrical connections (primary, secondary, and control connections).
c. MPT grounding connections

Supplier shall allow Company personnel access to its factory during transformer assembly and for witness testing. Supplier shall provide transformer manufacturing schedule and updates to the schedule to the Company. Travel costs for Company personnel for site factory visits are the responsibility of the Company.

APPLICABLE CODES AND STANDARDS

- State and local codes, laws, ordinances, rules and regulations
- ANSI - American National Standards Institute
- ASTM - American Society for Testing and Materials
- ICEA - Insulated Cable Engineers Association
- IEEE - Institute of Electrical and Electronic Engineers
- NEMA - National Electrical Manufacturer's Association
- NFPA - National Fire Protection Association
- OSHA - Occupational, Health and Safety Administration
- UL - Underwriter's Laboratories

In the event of conflict or disagreement between codes and standards, the more stringent conditions shall govern.

TECHNICAL REQUIREMENTS

DESIGN FEATURES AND CONSTRUCTION

1. Environmental

MPT's shall be designed and constructed to withstand site environmental conditions. See Appendix 4 for site specific environmental conditions.

2. Ratings

A. Transformer ratings shall be as specified in Appendix 6 Data Sheets.

B. Transformers shall include a Delta connected tertiary winding rated at 35% MVA capacity (.35 per unit) of the HV winding MVA capacity 100% (1.0 per unit) and LV winding MVA capacity 100% (1.0 per unit).

3. Short Circuit, Overvoltage, and Harmonic Distortion Capacity

A. MPT's shall be capable of withstanding, without damage, the mechanical and thermal stresses caused by short circuits on the external terminals of any winding or windings, with 105% rated voltage maintained across the terminals of any other winding

connected to an energy source for two seconds.

B. MPT and its components shall be capable of being operated at maximum MVA rating for voltages up to an including 113% of the nominal high voltage rating (3% above the highest OLTC tap position) without saturating the MPT core iron

C. The MPT shall be capable of operating under up to 5% total harmonic current distortion at 100% duty cycle.

4. Geomagnetic Induced Current (GIC)

Transformers rated 230 kV and above shall be capable of operating at full load while subjected to either of the following two signatures of GIC without exceeding the corresponding Temperature limits indicated in the table below:

- A GIC pulse of 100 A/phase magnitude and a 2 - minute duration
- A GIC base value of 20 A/phase magnitude and a 30 - minute duration

Equipment	Short Duration GIC Pulse (2 minute)	Base GIC (30 minute)
Windings	160 °C	140 °C
Structural Parts	180 °C	160 °C

Upon request, the Supplier shall provide the calculations, modeling, and analysis performed that demonstrate the effects of short-term and long-term GIC events at both nameplate and specified overload ratings. The following information shall also be provided:

- Magnitudes of resulting magnetizing current, associated reactive power (VAR) demand, and current harmonics for the above specified GIC levels
- Graphs of the hottest spot temperatures vs. time for both winding and structural parts for both GIC signatures
- GIC capability curves indicating calculated permissible GIC magnitudes as a function of the percent of nameplate rating for both GIC signatures

5. Transformer Losses

A. See Appendix 6 for loss evaluation details.

6. High Voltage Phase Bushings

A. High voltage phase bushings shall be cover mounted, oil-filled, porcelain-clad, with liquid level indicators. Voltage class and BIL shall be as specified in Appendix 6. Draw lead connections with silver plated threaded studs shall be provided.

B. Transformer high voltage bushing terminals shall be designed and constructed for connection to overhead conductors via NEMA four-hole flat pads.

C. Each high voltage bushing shall have bushing current transformers as specified in Appendix 6.

D. Transformer design shall not utilize reduced clearance capabilities specific only to one (1) bushing manufacturer on HV, LV, or Tertiary bushings. Transformer design shall allow for interchangeability of all approved manufacturer's bushings in accordance with IEEE C57.19.00.

E. 115 KV Nominal Voltage Approved Bushings:
- ABB 115W0800 or 115W1216AK
- PCore POC550G0800S or POC550G1216RS

F. 161 KV Nominal Voltage Approved Bushings:
- ABB 161W0800AA
- PCore POC750G0800S

G. 230 KV Nominal Voltage Approved Bushings:
- ABB 230Z0800A
- PCore POC900G0800S

H. 345 KV Nominal Voltage Approved Bushings:
- ABB 345Z0800AA
- PCore POC1175G0800CPS

7. High Voltage Neutral Bushing

I. High voltage neutral bushing shall be cover mounted, oil-filled, porcelain-clad, with liquid level indicators. Voltage class and BIL shall be as specified in Appendix 6. Draw lead connections with silver plated threaded studs shall be provided.

J. Transformer high voltage neutral bushing terminals shall be designed and constructed for connection to overhead conductors via NEMA four-hole flat pads.

K. Each high voltage bushing shall have bushing current transformers as specified in Appendix 6.

L. 115 KV Nominal to 345 KV Nominal Voltage Approved Bushings:
- ABB 069Z0412UC

- PCore B88013-70

8. Low Voltage Bushings

A. Low voltage phase and neutral bushings shall be oil-filled, porcelain-clad as specified in Appendix 6.

B. Transformer low voltage bushing terminals shall be designed and constructed for connection to overhead conductors via NEMA flat pads.

C. Each low voltage bushing shall have bushing current transformers as specified in Appendix 6.

D. 34.5 KV Nominal Voltage Approved Bushings:
- ABB 034Z3000AS
- PCore 88853-700-70 or 88833-700-70

9. Tertiary Bushings

A. Tertiary bushings (two bushings labelled Y1, Y2) shall provide a grounded delta corner-ground connection external to the transformer tank. Each bushing shall be connected from each adjacent winding forming a corner of the delta winding connection. Bushings shall be located on the tank cover with a removable copper strap between the bushing terminals and a two-hole ground pad welded to the transformer tank. The transformers shall be shipped with the tertiary winding bushings and copper strap installed.

B. Tertiary bushings shall be cover mounted. Voltage class and BIL shall be as specified in Appendix 6.

C. Tertiary bushings shall have bushing current transformers as specified in Appendix 6.

D. Approved Bushings:
- ABB 034Z0412UT
- PCore B-89393-70

10. High Voltage Surge Arrestors

A. Three (3) IEEE C62.11 station-class, polymer, metal oxide surge arrestors shall be provided for each high voltage phase.

B. A copper ground loop connecting the three surge arresters to two (2) separate ground pads at separate corners of the tank shall be furnished. Arrester rating shall be as specified in Appendix 6.

C. Surge arrester line terminals shall be tin-plated, NEMA four-hole flat

pad and shall be constructed for connection to an overhead line.

D. 115 KV Nominal Voltage Approved Surge Arrestors:
- Hubbell 314076-3001
- Siemens 3EL2 096-2PJ31-4NH5

E. 161 KV Nominal Voltage Approved Surge Arrestors:
- Hubbell 314106-3001
- Siemens 3EL2 132-2PP32-4NH5

F. 230 KV Nominal Voltage Approved Surge Arrestors:
- Hubbell EVP015200-3001
- Siemens 3EL2 192-2PJ31-4NH5

G. 345 KV Nominal Voltage Approved Bushings:
- Hubbell SVN288FA230AA
- Siemens 3EL2 288-3PM42-4NH5

11. Low Voltage Surge Arrestors

A. Three (3) IEEE C62.11 station-class, polymer, metal oxide surge arrestors shall be provided for each high voltage phase.

B. A copper ground loop connecting the three surge arresters to two (2) separate ground pads at separate corners of the tank shall be furnished. Arrester rating shall be as specified in Appendix 6.

C. Surge arrester line terminals shall be tin-plated and shall be constructed for connection to overhead line NEMA four-hole flat pad.

D. 34.5 KV Nominal Voltage Surge Arrestors:
- Hubbell EVP002400-3001
- Siemens 3EL1 030-1PE21-4XH5

12. High Voltage Bushing Test Links

A. High Voltage phase bushings shall include a PCORE Electric test terminal.

13. Shipping Bushings

B. Shipping bushings shall be factory installed for all high voltage, low voltage and neutral bushings prior to shipping. Shipping bushings will be used for SFRA (Sweep Frequency Response Analysis) testing purposes.

C. Shipping bushings shall be grounded and have protective covers installed prior to shipping.

14. Grounds

A. Tank Grounds: Two (2) stainless steel, NEMA four-hole ground plates on opposite corners, and stainless steel, NEMA four-hole ground plates located near the base of the transformer for the H0,and X0 bushing(s), and stainless steel, NEMA two-hole ground plates adjacent to each core ground bushing, and adjacent to the Y1 / Y2 bushings.

B. Core Ground: The core ground shall be brought through the tank wall using a 5 kV-rated (minimum) bushing of appropriate ampacity. Ground connection shall be made to a NEMA drilled and tapped, copper faced, steel ground pad located near the bushing. The transformer core ground connection shall be accessible without removing any oil from the transformer tank or climbing into the tank. Core ground bushings shall have a protective cover with a permanent non-rusting metal nameplate with the words “CORE GROUND ACCESS” engraved with minimum of 1/2” high letters.

C. Grounding Brackets: Two (2) grounding brackets for connection of Company-provided portable grounds shall be provided per high and low voltage side of the transformer for a total of four (4) grounding brackets. The brackets shall be made of copper or stainless steel and shall be brazed if copper or welded if stainless-steel to the tank near each corner on both the high and low voltage sides. The brackets shall not be painted. Grounding brackets shall be in accordance with Appendix 2.

D. HO Bushing Ground: Provide an electrical ground connection using ¼ inch x 3-inch copper bus bar from the HO neutral bushing terminal to a ground pad near the base of the transformer. If necessary, a braided flexible jumper connection from the HO bushing to the copper bus bar may be provided. Flexible jumper to be rated for 400 Amps minimum. Bus bar is to be electrically isolated from the tank with 95 KV BIL minimum porcelain standoff insulators, Meister part number 70170 or engineer approved equal.

E. XO Bushing Ground: Provide an electrical ground connection using ¼ inch x 3-inch copper bus bar from the XO neutral bushing terminal to within 24 Inches of the base of the transformer. End of bus bar to include NEMA 4-hole pad connection provisions for connecting a customer supplied grounding reactor. If necessary, a braided flexible jumper connection from the XO bushing to the copper bus bar may be provided. Flexible jumper to be rated for 3000 Amps minimum. Bus bar is to be electrically isolated from the tank with 95 KV BIL minimum porcelain standoff insulators, Meister part number 70170 or engineer approved equal.

F. Tertiary Corner Ground: Provide an electrical ground connection using ¼ inch x 3-inch copper bus bar between the Tertiary bushings

and from the tertiary bushings to the transformer tank.

15. Core and Coils

A. Cores and coils shall be braced to withstand short-circuit forces limited only by the transformer impedance without damage or displacement of the coil on the core under conditions described in this Specification and IEEE C57.116. Core and coil bracing shall withstand normal moving and handling without the use of shipping braces. Transformer manufacturer shall have tested and proven its bracing system by having conducted full short circuit testing at a high-power testing laboratory on similar transformers. Short circuit testing records of similar transformers shall be available upon request.

B. Winding impedance shall be measured per IEEE C57.12.90. Impedance tolerance shall be per IEEE standards. The zero-sequence impedance shall be equal to or less than the positive sequence impedance

C. Transformer coils shall be copper. The coils shall be insulated from the core and from each other with enough insulation to withstand the standard impulse and low frequency tests for transformers of the designed voltage class. Insulation materials shall be asbestos-free.

D. Rectangular windings are not acceptable for main, tertiary, tap, or regulating windings.

E. Transformer windings shall be designed to be free-buckling and shall not rely on winding tubes for short circuit strength.

F. Core and coil assembly and all other internal components shall be dried by vapor-phase process to assure proper dryness of the insulation material.

G. The core legs shall have a solid support from the bottom to the top clamp to prevent sideways deformation and bulging of the outermost laminations. The core shall be adequately braced to the core clamping structure, so that it cannot move in any direction. The windings shall be tight to prevent sideways movements. The core and coil assembly and other internal components shall be supported by permanent bracing to the interior of the tank.

16. On-Load Load Tap Changer (OLTC)

A. The OLTC is installed within the transformer to provide a fine adjustment to the high-voltage bus voltage on the transformer. The OLTC provides a +/- 10% high voltage range in .625% steps (16 steps above nominal and 16 steps below nominal voltage). OLTC insulating fluid shall be mineral oil.

B. The OLTC shall be suitable for use on a wind farm application where frequent changes in wind farm generation require the OLTC tap setting to change. OLTC shall be suitable for a 400,000-operation maintenance interval. The OLTC shall also be capable of withstanding a minimum of 200 operations over the life of the transformer at an overload of 150% of the transformer's top nameplate MVA rating.

C. The OLTC shall consist of two portions, one in the main tank, and one in a segregated, mineral oil filled compartment. The segregated compartment shall house any arc producing switching components. Tap switching shall employ a vacuum interrupting device. The segregated compartment shall be fitted with a pressure relief device, and protective devices monitoring gas accumulation and pressure changes. Oil filtration shall be provided if deemed appropriate by the OLTC manufacturer.

D. The OLTC shall be an MR Reinhausen Vacutap VR type family tap changer.

E. The OLTC shall be supplied with a Schweitzer SEL 2411 to control and monitor the OLTC with a Beckwith M-0329B as a backup.

F. Voltage source for the OLTC motor and controls are single phase 120/240VAC.

17. Oil Preservation System

A. The oil preservation system shall be a sealed conservator with flexible bladder which prevents oil contact with the atmosphere and allows expansion and contraction of the oil volume due to temperature fluctuations. The conservator shall have a capacity which accommodates the full range of oil temperature. The conservator shall include an oil level gauge on the conservator set to alarm before reaching a low oil level. The oil level gauge shall be visible from the ground. All conservator alarm contacts shall be wired to the main control cabinet.

B. An automatic desiccant recharge dehydrating breather shall be supplied to dry the air entering the conservator (on the air side of the flexible bladder). The breather shall include silica gel that is dried though contact with 120VAC rated heating elements. Heating elements shall be energized periodically to remove moisture from the desiccant and drain moisture off. The breather shall be a Dual Column Breather model DCB-A01 manufactured by Prolec-GE Waukesha, Inc.

C. The oil preservation system shall include a Buchholz gas detector relay and a sampling valve located at ground level. Access opening shall be provided at the conservator for cleaning and inspection purposes. The relay shall be installed in the piping between the main

tank and the conservator. Gas detector relay shall be Buchholz model BF80-10, twin-float relay DR80. Model 09-236 with Form C contacts or approved equal.

D. All tanks and enclosures subject to operating pressures of the oil preservation system shall be designed to withstand 125% of the maximum operating pressures.

E. The oil preservation system shall be designed with enough bracing and strength to permit full vacuum filling with insulating liquid.

F. The conservator tank shall have a 1 ½" oil fill and a 2" NPT oil drain valve.

G. A shut-off valve shall be provided on each end of the connection piping to the main tank.

18. OLTC Oil Preservation System

G. The OLTC oil preservation system shall include an automatic desiccant recharge dehydrating breather (ARDB). The ARDB shall include silica gel that is dried though contact with 120VAC rated heating elements. Heating elements shall be energized periodically (adjustable between five days and forty days) to remove moisture from the desiccant and drain moisture off. ARDB shall be an SPX Transformer Solutions Model ARDB2-0X1X or engineer approved equal.

H. The OLTC tank shall include a 1 ½" or 2" oil fill and a 1 ½" or 2" NPT oil drain valve. Drain valve shall allow for draining the oil as completely as possible but to at least within one inch of the bottom of the OLTC tank.

I. For in tank mounted OLTC diverter compartments, a one-inch (painted iron or stainless steel) pipe shall be installed from the OLTC tank or the diverter tank down to a one-inch NPT globe valve with a 3/8" NPT sampling port. The piping shall be run to within 3-4 feet of the bottom of the main tank. The piping shall allow sampling the OLTC oil and/or draining the LTC to within one inch of the bottom of the OLTC tank.

19. Cooling Equipment

A. Integrally mounted equipment shall be furnished to provide the cooling capacity necessary to maintain the transformer rating. Temperature control shall be provided by an assembly of devices arranged and designed to automatically vary the transformer cooling equipment capacity in steps proportional to transformer load and temperature.

B. Cooling fan motors shall be 240V, 1-phase, 60 Hz. Motors shall be totally enclosed, non-ventilated, with sealed, pre-lubricated ball bearings and rated for all-weather outdoor operation. Non-metallic bearings for fan motors are not acceptable.

C. The transformer cooling equipment control shall be via Electronic Temperature Monitor (ETM). See “ETM” section herein for additional requirements.

D. The transformer cooling equipment control system shall utilize control contacts furnished on the winding temperature indicator. Where multiple thermal relays are provided, thermal relay temperature control contacts shall be wired for parallel control of the cooling equipment.

E. Controls shall be provided for manually alternating the cooling fan operation sequence. Manual control switches shall be provided in the control cabinet to allow testing and maintenance of the cooling fans.

F. Cooling equipment shall be interruptible by an 86 (Lockout relay) type device such as an 86T, 86U or by fire detection.

G. Suitable alarm actuating devices with form C contacts shall be provided to indicate failure of any or all motors and loss of power.

H. Transformer cooling equipment shall be designed and arranged to allow individual radiators to be removed from the transformer without removing the transformer from service, draining oil from any other transformer component, or loss of oil past valve with 5 psi positive pressure on main tank.

I. Manually operated shutoff valves shall be provided, as required, for cooling equipment removal. All shutoff valves shall be bolted flange mounted and shall have provisions for padlocking in the open or closed position.

J. Each removable radiator shall be furnished with vent and drain valves for evacuation and oil filling.

K. The design of the radiators shall accommodate significant amounts of dust/ash particles in the air and shall operate without clogging. Integrally mounted equipment shall be furnished to provide the cooling capacity necessary to maintain the transformer rating.

20. Transformer Tank

A. All tanks, bases, radiators, covers, junction boxes when required, and any other attached compartments shall be fabricated from steel of suitable strength to withstand normal service stresses and vacuum filling without distortion or damage to any part. The base shall be

extra heavy (3/4-inch minimum thickness) and suitable for rolling or skidding in any direction.

B. All joints in transformer tanks, radiators, bases, etc., shall be made gas-tight and oil-tight by welding, except that the connections between oil coolers, pumps, and tanks shall be provided with gasketed, bolted flanges. All covers shall be welded in place.

C. Transformers shall be equipped with welded cover lifting lugs, jack bosses (located not less than 16 inches above the base and shall provide a minimum unobstructed jack clearance of 6 inches from tank wall or other obstruction), pulling eyes, skids, and jacking pads to accommodate rollers.

D. Tank finish color shall be ANSI 70, gray. Supplier's surface preparation, painting procedures and materials used shall be submitted with bid proposal for Company review. Products containing lead are prohibited.

E. All interiors and exteriors of tanks, enclosures, cabinets and other metal parts which are not galvanized, stainless steel or of corrosion resistant material and are exposed to oil and weather shall be thoroughly cleaned and painted as required.

F. The interior color of the transformer tank and control cabinet(s) shall be white and shall be fully capable of withstanding transformer operating conditions without degradation such as chipping, cracking, or peeling.

G. The top of the transformer tank shall be covered with skid resistant paint, which is the same color as the exterior tank walls.

H. Tank side seams and the connection point of the tank sides to the tank bottom shall be welded both inside and outside.

I. A minimum of two (2) 24-inch diameter manholes shall be provided on top of the transformer tank. One (1) of the required manhole covers shall include a 1-inch threaded nipple and a flanged vacuum fitting for a connection of a 4-inch diameter vacuum hose. The 4-inch (nominal) vacuum fitting shall have eight (8) 3/4-inch diameter bolt holes, equally spaced on a 7 1/2-inch diameter bolt circle. The vacuum-fitting flange shall be mounted sufficiently distant from the manhole cover to allow for easy access for removing and replacing bolts and nuts.

J. All piping connections for Owner use shall be American standard threads or flanges.

K. Gaskets and gasketed joints shall be designed such that gaskets shall not be exposed to the weather or standing water and shall be provided with mechanical stops to prevent crushing. Nitrile gaskets

or engineer approved equal shall be provided for applications where the temperature is below 110 Deg. C. Applications where the operating temperature is above 110 Deg. C shall use Viton gaskets or engineer approved equal.

21. Wiring

A. All wire shall be stranded, tinned copper conductor with 600V flame-retardant, cross-linked synthetic polymer insulation, type XHHW or equal. The minimum wire size for control and alarm functions shall be stranded No. 14 AWG. The minimum wire size for motor circuits and power circuits shall be No. 12 AWG. CT circuits shall be No. 10 AWG minimum.

B. Wiring shall not be spliced or tapped. All interconnections shall be made and identified with wire markers at equipment terminals or terminal blocks. Wire markers shall indicate the destination information for the wire (i.e. indicate termination of wire on opposite end).

C. All control wiring, including CT circuits, shall be terminated with Burndy type YAV HYLUG non-insulating, seamless barrel ring tongue lugs.

D. All CT secondary leads shall be terminated to short-circuiting type terminal blocks located in the control cabinet. CT terminal blocks shall be 6-point, shorting type 600V, 30A class minimum, Marathon type 1506, GE type EB-27, or Penn union type 606.

E. All CT secondary leads shall be brought to terminal blocks mounted in a junction box outside the transformer tank. CT terminal blocks shall be 6-point, shorting type 600V, 30A class minimum, Marathon type 1506, GE type EB-27, or Penn union type 606.

F. Control terminal blocks shall be 12-point, 600V, 30A class minimum, Marathon type 1512, GE type EB-25, or Buchanan type 2B112.

G. DC power Blocks shall be 600V class GE type EB-1.

H. Terminals shall be labeled with white terminal identification marking strips. Terminal blocks shall be mounted on the sides or back walls of the transformer control cabinet and shall be easily accessible with normal tools.

I. Rigid galvanized steel conduit shall be used for all power, control, and alarm external wiring. When the wiring terminates at an externally tank-mounted power, control, or alarm device, rigid conduit shall be provided to a suitable location near the device. Wiring may be routed through tank support channels as an alternate to rigid conduit.

J. Liquid-tight, flexible, metal conduit may be provided from a point near the device to the device itself.

K. Associated terminal blocks shall be grouped together to facilitate the use of multi-conductor cables for interconnecting equipment. Common voltage rated control and power terminal blocks shall be grouped together (i.e. 120VAC control terminal blocks and wiring physically separated from 125VDC control terminal blocks and wiring). A minimum of 10% spare terminal blocks shall be provided and shall be grouped and reserved for Company's use only.

L. Plastic self-locking tie wraps shall not be used for lead support.

M. All conduit, cable, and fittings shall be weatherproof, and securely fastened to the transformer at regular intervals. Rubber covered cable is acceptable for fans and gauges, and external wiring runs of less than 4 feet, however, its use shall be limited.

N. No more than two (2) wires are permitted to terminate at a given terminal.

22. Auxiliary Equipment and Accessories

A. A single weatherproof control cabinet shall be provided for all external conduit/cable connections, control components. The cabinet shall be accessible from ground level and shall be sized large enough to house all forced air-cooling equipment control components.

B. Control Cabinet

a. The control cabinet shall be supplied with thermostatically controlled space heaters to prevent condensation. Space heaters shall be rated 240 VAC but shall be sized for a normal operating voltage of 120 VAC. Space heater circuits shall be individually protected with molded case circuit breakers. Molded case circuit breakers shall be manufactured by General Electric, Square D, or Eaton.
b. The cabinet shall include vertically hinged doors arranged to permit ready access to the cabinet from the ground level. A locking device shall be provided to hold the doors in the fully open position. Locking device, cabinet door, and hinges shall be heavy duty and suitable for use in high wind conditions. Should design of cabinets be such that door width is in excess of 30 inches, double doors shall be provided, and the doors shall be hinged for center opening. Hinge material shall be stainless steel.
c. Doors shall have 3-point latches for the closed position and shall include provisions for attaching padlocks. Bolts or screws to secure the door shall not be used.
d. The top of the control cabinet shall not be more than 7 feet

above the bottom of the tank. The bottom of the control cabinet shall be located a minimum of 2.5 feet above the bottom of the tank.

e. A removable, gasketed plate, minimum size 12 inches by 16 inches, shall be provided in the bottom of the control cabinet to permit field drilling and installation of control system conduits. The Contractor shall not place the plate directly under any device within the control cabinet that would encumber the pulling of control conductors into the cabinet.
f. Each auxiliary equipment branch circuit shall be protected by an individual molded case circuit breaker properly coordinated with the Control Power Transformer (CPT) breakers. Molded case circuit breakers shall be manufactured by General Electric, Square D, or Eaton.
g. The control cabinet shall be provided with a 120 VAC, duplex (3-wire) with ground fault interruption (GFI) receptacle and switched cabinet light, wired to a 20-amp, molded case circuit breaker. The circuit breaker line side shall be wired to control cabinet terminal blocks. Molded case circuit breakers shall be manufactured by General Electric, Square D, or Cutler-Hammer.
h. The control cabinet shall be equipped with a “Loss of DC Alarm Voltage” alarm relay, with alarm and trip contacts wired to a terminal block in the cabinet.
i. All control relays shall have enclosed, dust tight contacts.
j. All devices and terminal blocks mounted in the control cabinet shall be clearly labeled with a designation. This label shall be located on or near the device and be affixed in such a manner that they will not become detached during the life of the transformer (Dymo Tape or similar embossed plastic tapes are not acceptable).
k. A metal oxide arrestor (MOV) surge suppressor shall be mounted across the 125 VDC supply terminal within the control cabinet. The MOV shall be rated for a minimum of 10 kA, 200 joules capability with a maximum peak discharge voltage of 500V.
l. All control devices, controllers, and control systems and assemblies shall be in accordance with NEMA ICS 1 and 2 and shall meet the requirements of this Standard.
m. For each transformer, an automatic voltage seeking transfer switch shall be provided to supply power to the transformer auxiliary equipment. Two (2) sources of nominal 240/120V, 1-phase, 3-wire, 60 Hz power to feed this switch will be provided. The automatic transfer equipment shall be of rated to transfer the total cooling equipment, control circuit, OLTC loads, and space heater load from the normal source to the standby source upon failure of the normal source voltage. Voltage failure relays shall be installed in order to monitor the normal and standby source voltages. Each relay shall provide a contact closure on loss of voltage. The contacts shall be wired to terminal blocks in the control cabinet. Control power

for the transfer controls shall be 120 VAC.

n. A fiber optic cable management system shall be supplied. It shall include splice and connector housing, and multimode patch cord between the housing and the remote I/O module. The splice and connector housing shall include provisions for twelve (12) multimode fiber connections using ST type connectors and a splice tray for twelve (12) splices. The splice and connector housing shall be Corning SPH-01P with connector panel Corning CCH-CP12-5T-P03KH, or approved equivalent. The patch cord shall have ST type connectors.

C. Alarm and Auxiliary Contacts:

The following minimum alarm and auxiliary contacts shall be provided. Alarm and auxiliary contacts shall be Form C, non-grounded and suitable for operation on ungrounded 125VDC systems. Contacts shall be furnished on all gauges and relays. Alarm contacts shall be brought out to a terminal board located in the main control cabinet and shall not be wired together at a common side. One side of the Purchaser specified shall be reserved for Purchaser's external cable connections only. Mercury wetted contacts are not allowed.

Alarm and Relay trip contacts:

a. Top Oil Temperature – (26Q)
b. Winding Temperature – Monitor One Winding (49T)
c. Liquid Level Indicator – Main Tank/Conservator – Normal High (71Q-1(MT)/HA)
d. Liquid Level Indicator – Main Tank/Conservator – Normal Low (71Q-2(MT)/LA)
e. Liquid Level Indicator – Main Tank/Conservator – Emergency Low (71Q-3(MT)/LT)
f. Transformer Gas Detection – Buchholz Relay (71GD(MT)) – wired to seal in relay, Qualitrol 909-300-01 or engineer approved equal.
g. Rapid Pressure Rise Relay – Main Tank, (63SP-1(MT)), wired to seal in relay, Qualitrol 909-300-01 or engineer approved equal.
h. Rapid Pressure Rise Relay – LTC Tank, (63SP-1(LTC)), wired to seal in relay, Qualitrol 909-300-01 or engineer approved equal.
i. Pressure Relief Device – Main Tank (63P-1(MT))
j. Pressure Relief Device- LTC Compartment (63P-1(LTC))
k. AC Supply – Loss of Main AC Supply (27-1)
l. Stage 1 Cooling – Loss of AC (27-2)
m. Stage 2 Cooling – Loss of AC (27-3)
n. Loss of Cooling Control Voltage – AC (27-4)
o. Loss of LTC Control Voltage – AC (27-5)
p. Loss of DC Control Voltage – DC (27-6)
q. LTC Lockout Relay – (86/68(LTC))

r. LTC Vacuum Bottle Alarm
s. Loss of Potential to LTC - (74-DB)
t. LTC Auto/manual Alarm – (74A/M)
u. LTC First-Protect/Regulator Backup Alarm – (90BU)
v. LTC Regulating Relay (90 Self-Test, 90 User Programmable)
w. LTC Level Indicator – LTC Compartment – Low Level (71Q-4-LTC)
x. Auto-Recharging Dehydrating Breather Failure – Main Tank (ARDB-MT).
y. Auto-Recharging Dehydrating Breather Failure – LTC (ARDB-LTC).

D. Pressure Relief

Tank cover pressure relief devices shall be supplied for each oil-filled compartment. Each device shall be equipped with form C alarm contacts, a manual reset, and mechanically operated flag, to indicate that the relief device has operated. Released oil shall be directed away from all control cabinets or where personnel may be standing. Alarm contacts shall be wired to terminal blocks in the control cabinet. Pressure relief device shall be Qualitrol 213 series.

E. Liquid Level Indicators

Liquid level indicators (main tank and all other oil-filled compartments) shall be provided with all alarm contacts wired to terminal blocks located in control cabinets. Additional requirements:

a. The main tank shall either have a single, magnetic-type level indicator with two (2) low level and one (1) high level alarm contacts or two (2) separate, magnetic-type level indicators. All contacts shall be Form “C” contacts.
b. All other oil filled compartments shall have single indicators with Form “C” contacts at the lowest level considered safe for continued operation of the transformer and wired to terminal blocks in the main control cabinet.
c. All liquid level indicators shall be readable from ground level.

F. Electronic Temperature Monitor (ETM)

An ETM shall be provided as follows:

a. The ETM shall monitor winding hot spot temperature and main tank top oil temperature.
b. A minimum of six (6) form C dry contact outputs [with auxiliary interposing relays as required to accommodate a 125 VDC contact make/break rating for four (4) of the six (6) contacts (output contacts used for first and second stage temperature alarm levels on each of the top oil and hot spot winding temperatures), with the other contacts used for controlling the cooling system (responsive to the simulated winding hottest

spot temperature)].

c. Form C alarm and trip contacts shall be wired out and terminated to terminal blocks in the transformer main control cabinet.
d. The ETM shall be mounted adjacent to or within the transformers main control cabinet, at an approximate height of 5 feet above the base of the transformer for easy viewing from ground level.
e. Source to the ETM shall be from a 125 VDC input power supply. On loss of DC, all stages of fans shall be triggered to energize.
f. A minimum of two (2) 0 to 1 mA DC analog (corresponding to 0 to 200°C) SCADA outputs for both top oil temperature and hot spot winding temperature.
g. Weather-tight NEMA 4X or better enclosure with outdoor-rated display and controls accessible without opening the enclosure's front door. A switch or operator accessible front panel menu for manual control of the system.
h. Basic Temperature error (including probe) to be less than 1°C.
i. RS232/485 digital interface and MS Windows-based programming software for setup and monitoring from a PC.
j. ETM shall be Dynamic Ratings DR-C50 Transformer Monitoring system DR-C59-CCDDABBNN-S-0, or owner approved equal.
k. ETM shall include:
    i. (2) Digital Inputs modules (26 Digital inputs)
    ii. 1) [SE-070] Ambient RTD w/ Weather Shield
    iii. (1) [SE-060] Cut-to-Length RTD Probe – Single Element w/Connection Head
    iv. Up to (4) [CT-S] Split Core CT 's
    v. Provisions for future addition of monitoring up to (6) bushings
        (1) (3) HV & (3) LV bushings
        (2) Temperature and load correlation

G. Valves and Fittings

Transformers shall be equipped with the following valves and fittings:

a. A combination drain and lower filter valve shall be provided to drain the oil as completely as possible but to at least within 1 inch of the bottom of the main tank and for outlet to the filtering means. The drain valve shall be 2-inches with a built-in 3/8-inch sampling device.
b. Lower filter press valve with malleable iron pipe plug.
c. A 1 ½-inch upper filter press valve with malleable iron pipe plug.
d. Standard 4-inch bolted round pipe flange with gasketed cover plate for attaching the Company's vacuum valve and hose. The flange shall be located on the corner farthest from the

upper filter press valve to ensure that oil does not enter the Company's vacuum system.

e. A shut-off valve shall be provided on each end of the connection piping to the main tank.

I. Gas Detector Relay

Transformer shall be equipped with a gas detector relay with seal in coil, mounted in the control cabinet. Gas detector relay shall be EMB Buchholz Type BF80-10, twin float relay DR80, Model 09-236 with form C contacts wired out to a seal-in relay panel (Qualitrol model 909-300-01 AC/DC Seal-In relay). Seal-in relay panel shall be mounted in the control cabinet.

J. Online Dissolved Gas (DGA) Monitor.

Transformer shall be equipped with a Morgan Schaffer Callisto 2 Hydrogen, Carbon Monoxide, and moisture in oil monitor. Calisto 2 shall be mounted such that the display is unobstructed by transformer equipment. Calisto 2 communication connections and alarm relay outputs shall terminate in the control cabinet.

K. Fall Protection

Transformer shall be equipped with the following fall protection equipment:

a. Brackets for mounting of 2-inch diameter pipes for use as safety rails shall be provided at the top of the transformer. Design and fabricate brackets to meet OSHA-required lateral loads at the top of the safety rail. Brackets shall be spaced a maximum of 4 feet apart, with one on each corner of the transformer. See Appendix 2 for details.
b. Unique Concepts Ltd. weld-on base, Part Number 10816, shall be installed by the Supplier for attachment of a portable fall arrest system provided by the Company. Weld-on bases shall be installed on the transformer cover within 3 inches of each manhole.

L. Nameplates

Nameplate information shall be per the IEEE-C57.12.00 requirements. All nameplates shall be inked and engraved stainless steel.

a. Nameplates shall be attached with a minimum of four (4) bolts or rivets. Mounting holes shall be provided with rubber grommets or equivalent to decrease vibration noise.
b. Nameplates shall be located to be accessible and readable from grade level with an unobstructed view of the nameplate.
c. A temperature relay nameplate shall be supplied and shall

give the recommended temperatures at which the first set of cooling equipment shall be started, the second set of cooling equipment shall be started, and the temperature at which an alarm shall be actuated. All of these shall be calculated based upon operation at 65°C winding temperature rise. This information shall also be provided on the wiring diagram. The nameplate shall be mounted on or near to the temperature indicator(s).

d. On-load tap changer nameplates shall be provided and shall include make and model information. These nameplates shall be mounted next to the main nameplate or the information may be incorporated into the main nameplate.

23. Insulating Liquid

Insulating oil shall be Type II and shall meet IEEE C57.106 requirements. It shall be free of PCB's, chemically stable, free from acidity or other corrosive ingredients, and shall contain a suitable oxidation inhibitor. Maximum oxidation inhibitor content shall be 0.3% by weight and transformer nameplates shall indicate that the oil is inhibited. Insulating oil shall be completely tested in accordance with ASTM standards, including ASTM 1275 Method B for corrosive sulfur. Certified test reports verifying compliance with this specification shall be supplied with each tanker of oil at the time of delivery. Failure to provide certified test reports at the time of oil delivery may result in rejection of the oil.

TESTING

Testing requirements are defined in Appendix 4.

DELIVERABLES

Deliverable requirements are defined in Appendix 1.

PROPOSAL DATA REQUIREMENTS

Supplier shall provide proposed equipment data in accordance with Appendix 2.

SITE CONDITIONS

Site conditions are defined in Appendix 6.

QUALITY ASSURANCE

QA/QC requirements are defined in Appendix 3.

PACKAGING STORAGE & SHIPPING

Packing, shipping storage requirements are defined in Appendix 5.

MATERIALS & WELDING

PERFORMANCE GUARANTEES

See Appendix 6 for MPT performance requirements and guarantees.

SOUND CONTROL REQUIREMENTS

Sound Levels shall be in accordance with Appendix 6.

INSTRUMENTATION & CONTROL REQUIREMENTS

See Specification Section “Auxiliary Equipment and Accessories” for I&C requirements.

CLEANING, PAINTING & COATING

See Specification Section “Transformer Tank” for cleaning, painting and coating requirements.

SPARE PARTS

Supplier-recommended commissioning spares shall be provided with the equipment.

APPENDICES TO SPECIFICATION

1. DELIVERABLES
2. REFERENCE MATERIALS
3. QA/QC
4. STARTUP, TESTING, AND COMMISSIONING
5. PACKAGING, SHIPPING, AND STORAGE
6. MPT TRANSFORMER DETAIL SHEET

APPENDIX 1

DELIVERABLES

Manufacturer Drawings/Documentation:

1. Shipping layout drawings
2. Installation instructions/details including rigging information and equipment loadings
3. Transformer dimensioned outline drawings (English dimension units)
4. Transformer foundation plans/details
5. Transformer nameplate drawings
6. Bushing outline drawing and electrical data
7. Surge arrestor outline drawing and electrical data
8. Current transformer saturation curves
9. Control panel layout, schematics and wiring diagrams
10. Transformer energization authorization letter
11. Manufacturer's QA/QC Inspection and Test Plan

Test data:

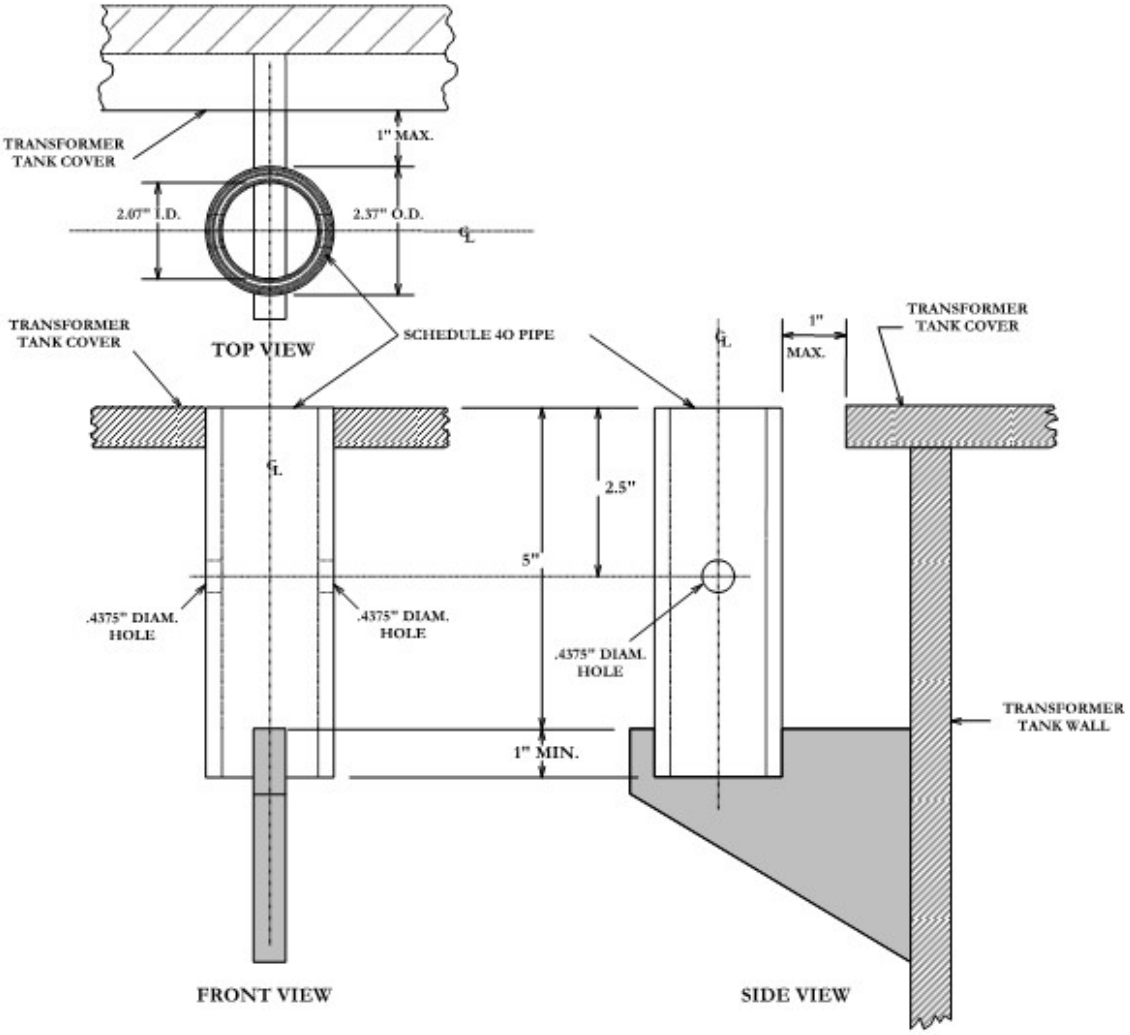
1. Factory and field test data/test reports. See Appendix 4 for details.

Operation and Maintenance (O&M) Manuals:

1. O&M manuals shall include the following minimum information
    a. Installation instructions
    b. Operating instructions
    c. Maintenance instructions
    d. Nameplate data
    e. Manufacturer drawing/documentation
    f. Bill of Material with vendor part numbers
    g. Cut sheets and brochure data for all transformer auxiliary equipment
    h. Recommended spare parts list
    i. Certified (final) test reports
    j. Storage and Handling instructions
    k. Special tools required for installation, operation and/or maintenance
    l. Warranty information

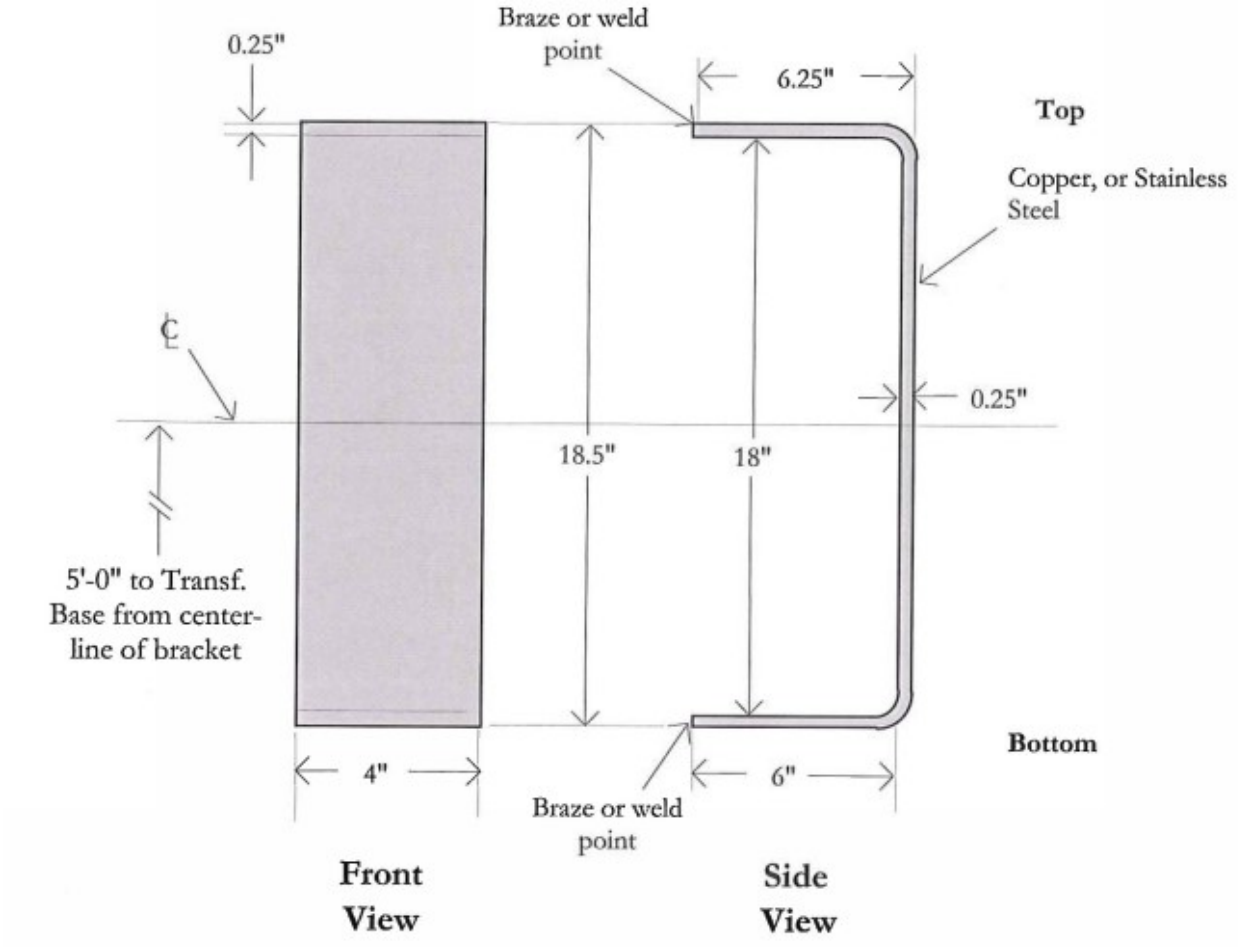
APPENDIX 2

REFERENCE MATERIALS



Safety Rail Pocket Detail

Personal Protective Grounding Bracket Detail



APPENDIX 3

QA/QC

QA/QC

1. Supplier shall have a quality assurance program that meets the requirements of ISO 9000. Documents demonstrating the Supplier has met these requirements shall be part of the bid documents.
2. Supplier shall submit their standard Inspection and Test Plan (ITP) for approval.
3. Compliance and suitability of QA/QC procedures for this product shall be evaluated by means of factory acceptance trips, self-evaluations, and other methods as deemed appropriate by Company.

APPENDIX 4

STARTUP, TESTING AND COMMISSIONING

1. Transformers shall be tested in accordance with ANSI/IEEE C57.12.00 and ANSI/IEEE C57.12.90.

2. The following tests shall be performed and certified by the Supplier for each transformer:

a. Resistance measurements on all windings. The test report shall indicate how windings were connected, either series or parallel.
b. Ratio tests on the rated voltage connection and on all tap connections.
c. Polarity and phase relation test on the rated voltage connection.
d. No load loss and exciting current at rated frequency and voltage and at maximum raise and lower tap position.
e. No load loss and exciting current at rated frequency at 90% rated voltage (0.9 PU).
f. No load loss and exciting current at rated frequency at 110% rated voltage (1.10 PU).
g. Auxiliary losses shall be verified by actual test measurements.
h. Impedance volts at rated current and at maximum raise and lower tap positions.
i. Load loss at rated current and at maximum raise and lower tap positions.
j. Temperature rise test made at the transformer self-cooled KVA rating at rated current.
k. Applied voltage test.
l. Induced voltage test for Class II power transformers with radio influence voltage (RIV) for partial discharge measurement.
m. Impulse tests. The neutral current method of fault detection shall be employed and oscillograph or digital records of all impulse tests shall be furnished with the test report.
n. Core insulation resistance test.
o. Factory Sweep Frequency Response Analysis (SFRA):
    i. Doble M5300 V5.2 (or latest version) shall be used.
    ii. SFRA testing shall be performed as follows:
        1. Company bushings installed
        2. Oil installed
        3. Core Ground Solidly Grounded
        4. Core Demagnetized
        5. H0 connection floating as specified in test setup
        6. OLTC tap position with highest number of OLTC winding turns in the circuit and OLTC tap position with no OLTC windings in the circuit. See Note 1.

iii. SFRA pre-shipment testing shall be performed as follows:
1. Doble M5300 V5.2 (or latest version) shall be used
2. Shipping Bushings installed (shipping bushings to remain installed during shipment)
3. Oil drained
4. Core Ground Solidly Grounded
5. H0 connection floating as specified in test setup
6. OLTC in 16R Position (Full OLTC winding included in SFRA test).

p. SFRA testing at rail siding shall be performed prior to off-loading from rail car as follows:

i. Doble M5300 V5.2 (or latest version) shall be used.
ii. Shipping Bushings installed
iii. Oil drained
iv. Core Ground Solidly Grounded
v. Core Demagnetized
vi. H0 connection floating as specified in test setup
vii. OLTC in 16R Position (Full OLTC winding included in SFRA test).

q. SFRA test shall be performed following installation on final foundation and with units in a ready-to-be energized condition as follows:

i. Doble M5300 V5.2 (or latest version) shall be used.
ii. Company Bushings installed
iii. Oil installed
iv. Core Ground Solidly Grounded
v. Core Demagnetized
vi. H0 connection floating as specified in test setup
vii. OLTC tap position with highest number of OLTC winding turns in the circuit and OLTC tap position with no OLTC windings in the circuit. See Note 1.

r. Transformer noise frequency spectrum analysis (under no load and full load conditions).
s. Insulation power factor test.

3. The certified test report shall indicate all impedance values (positive, negative, and zero sequence); oil test reports, which include all tests indicated in ANSI C57.106.

4. Copies of all factory power factor tests or equivalents shall be furnished with the certified test reports. Certified test reports shall be prepared and submitted to the Company following completion of the testing and prior to transformer shipment.

Note 1:

SFRA Test 1: 16R Tap Position (Highest voltage rating of transformer, OLTC at 16 positions (+10%) above nominal voltage rating of transformer. This test is intended to include the highest number of winding turns available in the circuit being tested.)

SFRA Test 2: N Position (Nominal voltage rating of transformer, OLTC tap position at center tap position. This test is intended to test the transformer winding with the OLTC winding not included in the circuit being tested.)

APPENDIX 5

PACKAGING, SHIPPING AND STORAGE

PACKAGING, SHIPPING AND STORAGE

Supplier shall prepare equipment for shipment following successful completion of factory testing and resolution of QA/QC non-conformances (see Appendix 5 for additional details.

Supplier shall prepare equipment to withstand any possible damage or loss due to rough handling or exposure to weather during transit or extended outdoor storage (up to two (2) years).

Supplier shall install all required covers to protect equipment from rain, hail, wind, dust, snow and environmental conditions detrimental to the equipment.

Equipment shall be adequately sealed and protected during shipment to prevent corrosion, foreign matter egress and freeze damage which could result from the presence of residual water.

Lifting points and centers of gravity shall be clearly marked on the shipped equipment.

Shipping structural bracing shall be installed as required to allow for field handling, skidding and hoisting.

Equipment supplied with space heaters shall have heater leads accessible without requiring disassembly of shipping containers.

Threaded outlets shall have plugs or caps installed prior to shipping.

Ancillary materials which are “shipped loose” shall be in separately boxed and re secured to the main equipment containers.

Supplier shall provide the following minimum unloading/handling information:

- Shipping weight and dimensions of each article
- Pick points
- Rigging requirements
- Weight distribution
- Center of gravity
- Sensitivities
- Hazards

A QA/QC inspection certification signed by the Supplier shall be issued to the company prior to shipment. A copy of this certificate shall be included with the Bill of Lading

Shipping documentation shall include the following minimum information:

- Company Destination (Plant, Unit)
- Company Agreement number
- Supplier's order number
- Date shipped
- Shipping origin
- Company equipment tag information
- Supplier's equipment identification information
- Shipment tracking information
- Shipment description
- Shipment quantity
- Gross weight
- Special handling requirements
- Identification of spare equipment
- Barcode, RFID, or similar material control information

Supplier shall coordinate all deliveries with Company prior to shipment. Coordination shall include resolution of QA/QC non-conformances, delivery schedule, unloading/handling requirements, and storage requirements

Transformers shall be shipped under positive dry air pressure.

Supplier shall install and ship impact recorders on rail cars transporting the transformers. The impact recorders shall be installed at the factory to provide a permanent record of the magnitude of axial, transverse, and vertical forces to which the transformer was subjected while in transit (via truck, rail, and/or shipping vessel).

The transformer shall be designed to withstand transportation-related mechanical loadings generated by impacts, swaying, yawing, fatigue and vibration. The minimum design limits for impact loading with respect to the transformer shall be: 5 g longitudinal, 3 g vertical and 1 g transverse directions. The transformer shall be designed to allow transportation via rail and truck, (and via sea vessel as applicable).

[NTD: An Appendix 6 sheet must be completed for each transformer and the example sheet on page 34 of this specification removed.

Note that the MVA rating and voltage ratings of the transformers follows the following criteria

1. No more than 150 MW of capacity shall be directed through any single main step-up transformer. For Project's with a nameplate capacity exceeding this threshold, the Project shall incorporate parallel main step-up transformers in either 100 MW, 125 MW or 150 MW increments, where each such transformer is identical and interchangeable (mechanically and electrically). Load from each Collection System Circuit shall be split evenly across each transformer. Example: a 270-MW project shall incorporate two (2) identical 150 MW main step-up transformers with approximately 135 MW on each unit.

2. The standard transformer MVA rating for a transformer carrying 100 MW of generation is 75/100/125 MVA with an impedance at 75 MVA of 9%. The standard transformer MVA rating for a transformer carrying 125 MW of generation shall be 94/125/156 MVA with an impedance at 125 MVA of 10 percent. The standard transformer MVA rating for a transformer carrying 150 MW of generation is 113/150/187 MVA with an impedance at 113 MVA of 10 percent.

3. The main power transformer high side voltage rating shall coordinate with the transmission line voltage. The transformer nominal high side voltage rating shall match ANSI standard C84.1 voltage ratings. The nominal high voltage rating shall typically be either 115,000; 161,000; 230,000; or 345,000 volts.

4. The main power transformer low side voltage rating shall be 34,500 volts.

For Current Transformer (CT) requirements, review against the site M&R diagram requirements & prior projects. Also consider interconnecting Utility Metering CT requirements if their CT input is from the Xcel collection system substation.

Metering CT's on the transformer should be extended range, high accuracy rated CT's.]