Specification – Substation Power Transformer

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** Must be the Process Owner and is the person assigned authority and responsibility for managing the whole process, end-to-end, which may extend across more than one division and/or functions, in order to deliver agreed business results.*

*** Frequency period is dependent upon circumstances– maximum is 5 years from last issue, review, or revision whichever is the latest. If left blank, the default must be 1 year unless otherwise specified.*

Revision Control		
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1	20/11/2020	Updated from comments provided
0	17/08/2015	Initial Document

STAKEHOLDERS The following positions shall be consulted if an update or review is required:	
Manager Engineering and Project Services	Project Directors
Manager Assets Services	EPCM Contracts Manager
Manager Systems & Network Planning	Asset Managers
Manager Power Systems Operations	

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1 SCOPE

This Specification covers Horizon Power's technical requirements for the design, manufacture, factory testing, delivery to site, unloading, site testing and pre-commissioning of three-phase transformers with a primary winding up to and including 220 kV and a rating from 1.25 MVA up to and including 160 MVA.

Power Transformers as per this Specification shall be delivered as defined in the Tender contract terms, of which this technical Specification forms an integral part.

Tests prescribed will evaluate the performance of transformers and such tests shall be as prescribed in this Specification.

Approval in terms of this Specification shall be obtained by one or a combination of the following:

a) successful completion of the appropriate tests required by this Specification by an independent and accredited test authority.

b) provision of test certificates from an independent and accredited test authority based upon an alternative specification, with test requirements at least equivalent to this specification.

NOTE: Verification of accreditation of the test authority shall be provided by NATA.

2 NORMATIVE REFERENCES

2.1 Standards

The following documents contain provisions that, through reference in the text, constitute requirements of this specification. At the time of publication, the editions indicated were valid. All standards and specifications are subject to revision, and Suppliers are encouraged to investigate the possibility of applying the most recent editions of the documents listed below. Information on currently valid national and international standards and specifications can be obtained from SAI Global – Standards On-Line data base or equivalent standards database.

The order of precedence for standards shall be, in order of highest first: Horizon Power standards, Australian standards, IEC standards, ISO standards, then British standards.

Table 1 – Relevant Horizon Power Standards

STANDARD	DESCRIPTION
HPC-9CA-01-0002-2012	Numbering and Titling Specification
HPC-9EJ-01-0001-2013	Horizon Power Environmental Conditions
HPC-9AJ-01-0001-2014	Coating and Colour Coding

Table 2 – Relevant Australian Standards

STANDARD	DESCRIPTION
AS 1111	ISO metric hexagon bolt and screws
AS/NZS 1170.0	Structural Design Actions – General Principles
AS/NZS 1170.2	Structural Design Actions – Wind Actions
AS/NZS 1170.4	Structural Design Actions – Earthquake Actions
AS 1243	Voltage Transformers for Measurement and Protection
AS 1252	High strength steel bolts with associated nuts and washers for structural engineering
AS 1307.2	Surge arresters - Metal-oxide surge arresters without gaps for a.c. systems
AS 1319	Safety Signs for the Occupational Environment
AS 1359	Rotating Electrical Machines - General Requirements - Introduction
AS 1554	Structural Steel Welding
AS 1627	Metal Finishing
AS 1767	Insulating Liquids
AS 1789	Electroplated zinc (electrogalvanized) coatings on ferrous articles (batch process)
AS 1796	Certification of Welders and Welding Supervisors
AS 1891	Industrial fall-arrest systems and devices
AS 2067	Substations and high voltage installations exceeding 1 kV a.c.

STANDARD	DESCRIPTION
AS/NZS 2312	Guide to Protection of structural steel against atmospheric corrosion by the use of protective coatings – Paint coatings
AS 2374	Power transformers
AS/NZS 3000	Australian/New Zealand Wiring Rules
AS 3111	Approval and test specification - Miniature overcurrent circuit-breakers
AS 4041	Pressure piping
AS/NZS 4680	Hot-dip Galvanized (Zinc) Coatings on Fabricated Ferrous Articles
AS/NZS 5000	Electric Cables - Polymeric Insulated
AS/NZS ISO 9001	Quality management systems
AS 60034.22	Rotating electrical machines – AC generators for reciprocating internal combustion (RIC) engine driven generating sets
AS 60044.1	Instrument transformers - Current transformers
AS 60044.2	Instrument transformers – Inductive Voltage transformers
AS 60060.3	High voltage test techniques – Definitions and requirements for onsite testing
AS 60068	Environmental testing
AS 60076	Power Transformers
AS/NZS 60076	Power Transformers
AS/NZS 60137	Insulated bushings for alternating voltages above 1,000 V
AS 60214	Tap changers – Performance requirements and test methods
AS 60270	High Voltage test techniques - Partial discharge measurements
AS 60422	Mineral insulating oils in electrical equipment
AS 60529	Degrees of protection provided by enclosures (IP Code)
AS 60947	Low Voltage Switchgear and controlgear
AS 61000.4	Electromagnetic compatibility (EMC; Testing and measurement techniques (All sections)
AS 62271.301	High voltage switchgear and controlgear - Dimensional standardization of terminals

Table 3 – Relevant International Standards

STANDARD	DESCRIPTION
IEC 60034	Rotating electrical machines.
IEC 60044:- 6	Instrument transformers.— Part 6 Requirements for protective current transformers for transient performance.
IEC 60060	High-voltage test techniques
IEC 60068-1	Environmental testing — Part 1 Cold
IEC 60068-2	Environmental testing — Part 2 Dry Heat
IEC 60068-30	Environmental testing — Part 30 Damp heat, cyclic (12h + 12h cycle)
IEC 60076-1	Power transformers — Part 1 General
IEC 60076-2	Power transformers — Part 2 Temperature rise
IEC 60076-3	Power transformers — Part 3 Insulation levels and dielectric tests
IEC 60076-5	Power transformers — Part 5 Ability to withstand short circuit
IEC 60076.7	Power transformers — Part 7 Loading guide for oil-immersed power transformers

STANDARD	DESCRIPTION
IEC 60076-8	Power transformers — Application Guide
IEC 60076-10	Power transformers — Part 10 Determination of sound levels
IEC 60076-18	Power transformers — Part 18 Measurement of frequency response
IEC 60085	Thermal evaluation and classification of electrical insulation
IEC 60137	Insulating bushings for alternating voltages above 1 000 V
IEC 60156	Insulating liquids – Determination of the breakdown voltage at power frequency
IEC 60185	Current transformers
IEC 60214	On-load tap-changers
IEC 60255-5	Electrical relays. — Part 5 Insulation coordination for measuring relays and protection equipment
IEC 60255-21	Electrical relays. — Part 21 Vibration, shock, bump and seismic tests on measuring relays and protection equipment (All sections)
IEC 60255-22	Electrical relays. — Part 22 Electrical disturbance tests for measuring relays and protection equipment (All sections)
IEC 60270:1981	Partial discharge measurements
IEC 60354	Loading guide for oil-immersed power transformers
IEC 60751	Industrial platinum resistance thermometer sensors
IEC 60947	Low-voltage switchgear and controlgear
IEC 61850	Communication networks and systems in substations

Table 4 – Relevant British Standards

STANDARD	DESCRIPTION
BS EN 1011	Welding. Recommendations for welding of metallic materials. General guidance for arc welding
BS EN 1011-4	Welding. Recommendations for welding of metallic materials. Arc welding of aluminium and aluminium alloys
BS EN 1092	Flanges and their joints. Circular flanges for pipes, valves, fittings and accessories, PN designated.
BS 1872	Specification for electroplated coatings of tin
BS EN ISO 2081	Metallic and other inorganic coatings. Electroplated coatings of zinc with supplementary treatments on iron or steel
BS EN ISO 2082	Metallic coatings. Electroplated coatings of cadmium with supplementary treatments on iron or steel
BS 3523	Specification for granular desiccant silica gel impregnated with cobalt chloride
BS 6435	Specification for unfilled enclosures (cable boxes) for the dry termination of HV cables for transformers and reactors
BS 7371	Coatings on metal fasteners
BS 7371-12	Coatings on metal fasteners. Requirements for imperial fasteners
BS 7668	Weldable structural steels. Hot finished structural hollow sections in weather resistant steels. Specification
BS EN 10025	Hot Rolled products of structural steels

BS EN 10029	Hot-rolled steel plates 3 mm thick or above. Tolerances on dimensions and shape
BS EN 10113	Hot-rolled products in weldable fine grain structural steels
BS EN 10210	Hot finished structural hollow sections of non-alloy and fine grain steels. Technical delivery requirements
BS EN 13601	Copper and copper alloys. Copper rod, bar and wire for general electrical purposes
BS EN 60076-3	Power transformers. Insulation levels, dielectric tests and external clearances in air
BS EN 62271-106	High-voltage switchgear and controlgear. Alternating current contactors, contactor-based controllers and motor-starters

Where Equipment offered has only been tested for compliance in accordance to International Standards, Suppliers shall state in the Proposal (with supporting documentation) whether it complies with the equivalent Australian Standards.

2.2 Definitions and Abbreviations

For the purposes of this specification the following definitions apply:

2.2.1 Definitions

1) **Approved and Approval:** means approved or approval granted by the Horizon Power / Horizon Power Representative in writing.
2) **Equipment:** means all the equipment, accessories, terminations and other components required to form a transformer to meet the intent of this Specification.
3) **Horizon Power:** REGIONAL POWER CORPORATION ABN 57 955 011 697 (trading as Horizon Power) a statutory body established under section 4(1)(d) of the Electricity Corporations Act 2005 (WA).
4) **Horizon Power Representative:** means an individual or an officer of Horizon Power designated by title.
5) **Manufacturer:** means a firm or body corporate or unincorporated that manufactures transformers.
6) **Technical Specification or Specification:** – shall mean this document and all related Drawings and other documents referenced within this document.
7) **Unitised:** means comprising of inseparable units (switchgear functions).
8) **Supplier:** means the Tenderer whose tender has been received by Horizon Power and shall include the Supplier's legal personal representatives, successors and permitted assigns.

2.2.2 Abbreviations

1) ac: Alternating Current
2) AS: Australian Standard
3) BS: British Standard
4) CB: Circuit Breaker
5) CT: Current Transformer
6) dc: Direct Current
7) EN: European standard
8) IAC: Internal Arc Classification
9) IEC: International Electrotechnical Commission

10) ISO: International Organisation for Standardization
11) kV: kilo Volts (1,000 Volts)
12) LED: Light Emitting Diode
13) LV: Low Voltage <1000 Volts ac
14) MV: Medium Voltage >1000 V; <35 kV
15) HV: High Voltage ≥ 35 kV
16) MVAr: Mega Volt Amp reactive (1,000,000 Volt Amp reactive)
17) MW: Mega Watts (1,000,000 Watts)
18) pf: power factor
19) pu: per unit
20) rms: Root mean square, a practical average value for quantities with periodic waveforms
21) SCADA: Supervisory Control and Data Acquisition
22) Um: Highest voltage for equipment (as defined in AS/NZS 60076.3)
23) Un: System nominal voltage (line-to-line), e.g. 33 kV, 66 kV
24) VT: Voltage Transformer

3 REQUIREMENTS

3.1 General

Notwithstanding the requirements specified herein, any material or manufacturing method giving results at least equivalent to those specified may also be considered.

The Supplier shall detail in a proposal any departure from this Technical Specification in the Equipment offered. Any departure found, but not detailed as such, shall provide grounds for rendering the proposal as non-conforming.

Following tender award, no departure from the agreed item shall be undertaken by the Supplier without written approval from Horizon Power's Representative, for the term of the contract. Should the Supplier wish to supply Equipment that does not fully comply with the Specification, or differs from that which was agreed, a concession request must be made by the Supplier and approval by Horizon Power prior to delivery of the Equipment.

The Equipment shall comply with the item descriptions detailed in Schedule A in Appendix C of this Specification, the relevant Australian Standards and the following requirements. Suppliers may offer their standard equipment but any variation to this Specification must be clearly stated in the Supplier's proposal.

Where a description specifies a particular brand and reference number, only that specified product will be acceptable.

Where the Supplier proposes to supply proprietary goods the Supplier shall specify in Schedule B the Brand and Manufacturer's catalogue reference number of the Equipment the Supplier proposes to supply. Failure to specify such information shall provide grounds for rendering the proposal as non-conforming.

3.2 General Service Conditions

This specification gives detailed requirements for transformers for use under the following general conditions:

a) Environmental Conditions

Reference shall be made to Horizon Power's Environmental Conditions Standard HPC-9EJ-01-0001-2013.

b) Using ambient air temperatures as per the Environmental Conditions:

- temperature rise in windings 55 °C
- top oil temperature rise 50 °C

NOTE: — Due to high ambient temperatures, winding temperature rises / top oil temperature rises shall not exceed 55 °C / 50 °C respectively. As a result, the above temperature limits differ from those specified in AS 60076.2.

c) Symmetrical three-phase supply voltages (negative and zero phase sequence voltages less than 2 %);

d) Life expectancy at rated conditions shall be at least 40 years.

3.3 Ratings and operating conditions

3.3.1 Power

The values of rated power specified in Schedule A are the continuous ratings in MVA, at which each of the windings of the transformer can operate on all tappings at a voltage equal to the appropriate nominal system voltage (Un), without exceeding the temperature rise limits specified in this specification. (The power rating of the transformer shall be 100 % throughout entire tapping range).

Where mixed-cooled transformers are specified, (see clause 4.14.1 – Type of cooling required and ONAN rating), the naturally-cooled rating (ONAN) of each of the main windings shall be at least 0.70 pu (per unit) of the rated power of these windings.

If a tertiary winding is specified, this shall be capable of operating under the naturally-cooled condition at any loading up to the rated power specified in Schedule A in Appendix C, provided that the loading in the input winding does not exceed its naturally-cooled rating.

3.3.2 Current

Power transformers shall have overloading capabilities in accordance with AS/NZS 60076.7 Table 4. Also refer to clause 5.2 Transformer Tests, for Type Test requirements.

3.3.3 Voltage

3.3.3.1 Maximum continuous voltage on any tapping (Over flux)

Over excitation shall be limited to 5 % at full load and 10 % at no-load respectively. The maximum flux density shall be limited to 1.72 T at 50 Hz. Taking the frequency variation as specified in clause 3.3.4.1 Network frequency into account the flux density shall not exceed 1.79 T at 48 Hz.

3.3.3.2 Maximum temporary over voltage

Under switching conditions, the power frequency line voltage may exceed the highest voltage for equipment (Um as defined in AS/NZS 60076.3). Transformers shall be designed to withstand without damage the system overvoltage profile specified in Horizon Power's Technical Rules and specifically the following over-voltages.

a) 1.1 Um for continuous;

b) 1.2 Um for 200 s;

c) 1.5 Um for 0.2 s; and

d) 1.6 Um for 0.02 s.

3.3.4 Network

3.3.4.1 Network frequency

The transformer shall be designed for a rated frequency of 50 Hz ± 2 Hz.

The frequency variations may be sustained for 25 minutes.

3.3.4.2 Power factor

Permissible range for power factor shall be as per Table 5.

Table 5 – Permissible Power Factor Range

Supply Voltage (nominal)	**Power factor range (half-hour average, unless otherwise specified by the Network Service Provider)**
220 kV	0.96 lagging to unity
66 kV / 132 kV	0.95 lagging to unity
<66 kV	0.9 lagging to 0.9 leading
33 kV / 22 kV / 11 kV	0.8 lagging to 0.8 leading

3.4 Ability to withstand abnormal electrical conditions/loadings

3.4.1 Short-circuits

Notwithstanding the over current limits tabulated in AS 60076-5, the transformer with the standard minimum percentage impedances given in of this specification, shall be capable of withstanding the thermal, mechanical and other effects using the following criteria for calculating the short circuit withstand condition:

a) Pre-fault voltage of 1.1 Um;

b) Source impedance shall be assumed to be infinite;

c) Fault duration of 1 s;

d) The inner winding shall be designed to withstand the free buckling criteria. However, the specific stress (average) of the inner winding shall not exceed 50 % of the copper conductor yield strength. Whenever a reasonable application of Epoxy Bounded CTC is possible, this would be the preferred solution;

e) The yield strength that shall apply to the conductor of the outer winding shall be 80 % of the copper conductor yield strength;

f) All material used for winding cylinders shall be pre-dried and pre-impregnated with oil prior to use;

g) The blocks which are used to apply the axial compression shall be pinned to the clamping system.

The purchaser reserves the right to apply a short-circuit test to one transformer of any batch on site or elsewhere where convenient, before taking over the batch, in order to prove the short-circuit strength of the windings. Such tests will follow the guidelines laid down in AS 60076-5. Should the test fail the Supplier (manufacturer) shall be liable for all costs (redesign is mandatory).

The calculation of the short circuit design shall be verified during the purchaser's design review.

3.4.2 Additional Loadings on Transformers

The transformer windings and leads shall be mechanically braced in order to cater for all additional loadings. The specific requirements and provisions shall be evaluated during the transformer design review.

3.4.2.1 Seismic disturbances

The Equipment and associated fittings shall be designed to withstand without failure or operation of trip and alarm devices the effects of shock waves and earth movements resulting from earthquakes.

The Supplier shall provide calculations in accordance with AS 1170.4, which show the force, applied to the Equipment and its fittings under earthquake conditions as follows:

a) Overturning and sliding forces;

b) Bending moments at base of bushings;

c) Force on cooler and conservator support structure and strength of structure;

d) Stability of all alarm and trip contacts;

e) Force on bracing between core and main tank and strength of bracing;

f) Details of fixing main tank to concrete plinth and strength of fixing.

3.4.2.2 Wind loads

Equipment and associated fittings shall withstand 3 second gust wind speeds of 171 km/h. A provisional extra cost shall be provided for withstanding 348 km/h.

3.5 Standard tapping ranges

All on-load regulated transformers shall have on-load taps from +5 % to -15 % of the HV voltage in 16 equal steps of 1.25 % each.

When an off-circuit tap switch is specified, the range shall be +5 % to -5 % of the HV voltage in 4 steps of 2.5 % each.

3.5.1 Zero sequence impedance

Where specified in Schedule A in Appendix C, the zero sequence impedance of one unit of each rating and type shall be measured as detailed in clause 5.2 – Transformer Tests, in this specification.

3.6 Acoustic noise

The transformer, tap changing equipment and supplementary cooling equipment shall comply with the values stated in Table 6 – Audible sound levels for oil-immersed power transformers and be verified in accordance with AS 60076.10.

Table 6 – Audible sound levels for oil-immersed power transformers

Equivalent two-winding transformer rating (MVA)	Average Sound Level, (dBA)			
	Primary voltage 66 kV and below		Primary voltage greater than 66 kV	
	ONAN	ONAF	ONAN	ONAF
5	65	66	67	68
10	68	69	70	71
20	71	72	73	74
40	74	75	76	77
80	77	78	79	80
160	80	81	82	83

NOTES:

For ONAF ratings, the sound levels are with the auxiliary cooling equipment in operation

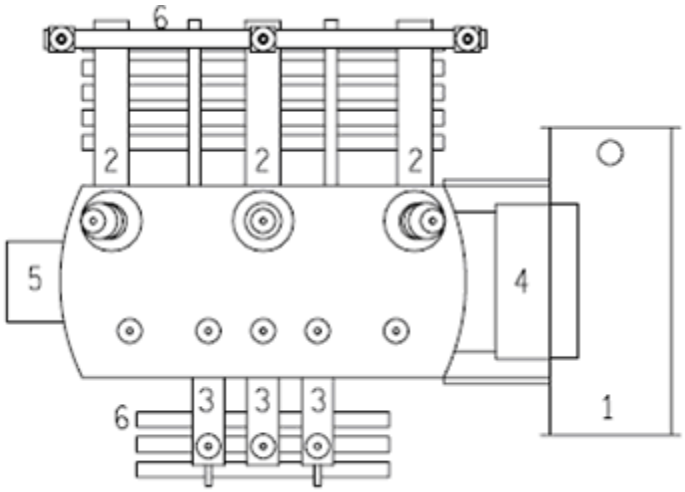
Where the design of the power transformer is required to allow installation in a noise enclosure, bushing turrets shall be provided.

Bushing turrets are to be designed as close to the vertical from the main tank lid as possible to minimise stresses and loadings on turrets and bushing flanges.

3.7 Clearances in air

When assembled with connections as in service, electrical clearances in air shall be adequate to withstand the assigned impulse withstand test voltages. This shall be demonstrated by the impulse voltage routine tests specified in clause 5.2 – Transformer Tests, during the performance of which all relevant fittings shall be in position as for service conditions.

Care shall be taken to ensure that fittings are located so as not to interfere with the external connection to the bushing terminals, and the clearances to such connections shall not be less than the appropriate values given in AS 2067 –



1. CONSERVATOR TANK
2. HV S/ARR BRACKET
3. MV S/ARR BRACKET
4. ON LOAD TAPCHANGER
5. MARSHALLING KIOSK
6. RADIATORS

Figure 1 – Typical Transformer Layout

Substations and High Voltage Installations exceeding 1 kV.

3.8 Physical arrangements

3.8.1 Bushings, cooler banks, conservator and maximum dimensions

Unless otherwise specified, the physical arrangement shall be such that:

a) Separately mounted cooler banks, if provided, shall be located to allow free withdrawal of the transformer in the direction of the minor axis; and

b) Preferable Maximum overall dimensions (excluding surge arresters) for power transformers with a highest voltage rating of 132 kV and below and ratings up to and including 160 MVA shall be as detailed in Table 7, unless specified otherwise by relevant project requirements.

c) No limitation in dimensions are specified for 220 kV power transformers as such limitations, if any, should be specified by relevant project requirements.

Table 7 – Maximum overall dimensions for two winding transformers (excluding auto transformers)

HV rating, Un	Height	Length	Width
132	5500	7800	5 000
66	5500	6800	5 000

NOTES:

a) The HV bushings should as far as possible be symmetrically arranged about the overall transverse center line of the transformer

b) The above dimensions exclude surge arresters and their mounting brackets

Table 8 – Maximum overall dimensions for two winding auto transformers

HV rating, Un	Height	Length	Width
132	6200	9800	6700

NOTES:

a) The HV bushings should as far as possible be symmetrically arranged about the overall transverse center line of the transformer

b) The above dimensions exclude surge arresters and their mounting brackets

3.8.2 Surge arrester brackets

The arrangement for surge arrester brackets shall be in accordance with clause 4.8.6.

3.9 Insulation, fault levels and creepage distance

3.9.1 Insulations levels

Insulation levels shall be determined in accordance with Table 9 and AS 2067.

Table 9 – Lightning Impulse Voltage and Clearances in Air

Rated Voltage (kV RMS)	Rated Lightning Impulse Withstand Voltage (kV RMS)	Phase to Earth (mm)	Phase to Phase (mm)
12	95	120*	185*
24	150	220*	325*
36	200	380*	440*
72.5	325	630	725
145	650	1300	1495
245	1050	1900	2185

***Refer to clause 4.4.3.6**

3.9.2 Creepage Distance

Creepage distance shall be determined for insulation levels in clause 3.9.1 and considering a heavy pollution level of 31 mm/kV as per clause 3.2(a) – Environmental Conditions.

3.9.3 Fault levels

Fault levels for design purposes are specified in Horizon Power's "Transmission Planning Criteria" (DM# 1838710). The values are summarised in Table 10.

Table 10 – Standard Terminal Station/ Zone Substation Plant Ratings

System Voltage	220 kV	132 kV	66 kV	33/22 kV	11 kV
Short Time Withstand Current (kA)	25	40	25	16	25
Short Time Withstand (s)	1	1	3	3	3

4 DESIGN AND CONSTRUCTION OF TRANSFORMERS

4.1 Transformer cores

4.1.1 Electrical continuity

Where the core laminations are divided into sections by insulating barriers or cooling ducts parallel to the plane of the laminations, one tinned copper bridging strip shall be inserted to maintain electrical continuity between sections. This bridging strip shall be as short as possible and as close to the core-cooling ducts.

4.1.2 Insulation of the core

The insulation between the core and the clamping structure, including core bolts and/or bands and buckles, shall withstand a test voltage of 2 kV ac or 3 kV dc for 60 seconds.

Designs requiring core bolts are not favoured by Horizon Power but if used this fact shall be clearly highlighted in the tender documentation and, if accepted, core bolts shall be of non-magnetic material to avoid local hot-spots and class F insulation sleeves shall be used.

4.1.3 Earthing

4.1.3.1 Core

The core shall be earthed to the core clamping structure at one point only, through a removable external link suitably situated, and protected to allow testing after installation of the transformer.

4.1.3.2 Core clamping structure

The bottom core clamping structure shall be in electrical contact with the top core clamping structure through the tie bars, by way of the tank, or by means of a connection placed on the same side and end of the core as the removable core earthing link.

If a copper earthing connection is used between the core clamping structure and the tank, it shall be flexible, (e.g. laminated, stranded or braided), tinned at the ends, and shall be located on the same side and end of the core clamping structure as the removable core earthing link.

Care shall be taken to ensure that contact resistance between mechanical members that form part of any intentional current paths, be it circulating or to earth, is not detrimentally affected by any painting.

There shall be no sparking, that may upset Dissolved Gas Analysis (DGA) monitoring of the transformer, between bolted mechanical members during inrush or other transient conditions.

A drawing detailing the specifics of the earthing design is required as part of the transformer manuals and shall also be made available during the transformer design review. The Supplier shall inform the purchaser of changes to the design prior to construction.

4.1.3.3 Cross-sectional area of earthing connections

No core earthing connection shall have a cross-sectional area smaller than 80 mm², with the exception of the connections inserted between laminations which may be reduced to a cross-sectional area of 20 mm², where they are clamped between the laminations.

4.1.4 Mechanical construction

4.1.4.1 Materials

All materials used for equipment shall be new, unused and free from defects.

The use of the following materials or chemicals is strictly prohibited:

a) Poly Chlorinated Biphenyl (PCB)

b) Asbestos

c) Radioactive material

d) Know carcinogenic substances

e) Imported packaging timber not treated and certified free from insect infestation

4.1.4.2 Lock nuts

The core and core clamping structure shall be of adequate strength to withstand, without damage, the stresses to which they may be subjected during handling, transportation, installation and service.

All nuts shall be effectively locked using locking plates, standard machined lock nuts or other approved means. Peining of bolt-ends and/or threads alone or the use of tempered pressed steel nuts will not be acceptable. Nuts and bolts of insulating material shall be fixed by glueing or other approved means.

4.1.4.3 Mechanical supports

Where the core and winding assembly is attached to the transformer cover plate, it shall also be supported by the tank bottom. Hand holes shall be provided in the attachment to the cover plate, for regulation of the mechanical distances.

Members to support the cover or side walls during vacuum shall be adequate to withstand transport movements without damage.

Special parts for the above functions that are removed after vacuum or transport shall be considered part of the transformer and shall be handed over to the purchaser. Drawings detailing the designs of these parts as well as a description of their use shall be included in the transformer manuals.

4.1.4.4 Bolting and Tie Rods

Unless otherwise approved in writing, continuous (i.e. not jointed) vertical tie rods or plates shall be provided between the top and bottom core clamping structures.

4.1.4.5 Lifting facilities

Lifting lugs or other means shall be provided for lifting the core and windings and, when lifting, no undue stress shall be imposed on any core bolt or its insulation or on the tank cover plate.

4.1.5 No-load losses and current

All core, shunts and construction parts shall be designed to withstand the fluxing conditions resulting from the continuous and temporary over voltage conditions as well as frequency deviations, as specified.

The no-load losses and the no-load current of each transformer shall be measured as specified in clause 5.2 – Transformer Tests, as well as at an agreed overflux condition to demonstrate compliance with this specification.

4.2 Windings and connections

4.2.1 Winding arrangement

For all two winding transformers the winding arrangement (reference from the transformer core) shall be MV winding, HV winding and Regulating winding.

For auto-transformers the winding arrangement (reference from the transformer core) shall be Tertiary winding, Common winding, Regulating winding & Series winding.

4.2.2 Winding Insulation

The paper used shall be of the thermally upgraded type. The axial spacers for disk windings shall be at least 3 mm.

4.2.3 Bracing of windings

All winding insulation shall be processed to ensure that there will be no detrimental shrinkage after assembly.

Windings shall be provided with clamping arrangements that will distribute the clamping forces evenly over the ends of the winding. Unless otherwise approved, winding clamping arrangements shall permit adjustment of the pressure and the taking up of shrinkage that may occur in service.

The bracing of the windings and connections shall be such that these parts shall safely withstand the cumulative effects of stresses that may occur during handling, transportation, installation and service, including line-to-line and line-to-ground faults.

Full details of the winding clamping arrangements, and their adjustment in or out of the tank, together with relevant drawings and values, shall be submitted for approval and shall form part of the transformer manual. The Supplier shall inform the purchaser of any changes to this design prior to construction.

4.2.4 Methods of making winding connections

All connections shall be rounded off to prevent sharp edges.

4.2.4.1 Soldered and brazed connections

Soft solder shall not be used in making winding connections.

If brazed connections are used all traces of acidity shall be eliminated on completion of the process.

4.2.4.2 Welded connections and joints in winding body

All welded copper connections shall be made by the metal-inert gas method or other specifically approved method. This applies particularly to conductor joints in the body of windings. All such joints shall be properly controlled by an approved quality control procedure.

4.2.4.3 Bolted connections

The mating faces of bolted connections shall be appropriately finished and prepared for achieving good, long lasting, electrically stable and remake able contacts.

All nuts shall be locked by standard machined lock nuts, or by using approved locking plates.

4.2.4.4 Crimped connections and other methods

Connections made by “compression” and “cold-welding” techniques may be used where the particular method has been approved by Horizon Power.

All compression fittings shall be the correct size for the conductors and the correctly sized compression dies shall be used.

4.2.5 Winding terminations onto bushings

Winding termination interfaces with bushings shall be designed to allow for repeatable and safe connection under site conditions without jeopardising the in-service integrity of the transformer.

The winding-end termination, insulation system and transport fixings shall be so designed that the integrity of the insulation system is not easily compromised during repeated work in this area.

Allowances shall be made for accommodating up to 100 mm tolerances on bushing axial dimensions and the fact that bushings may have to be rotated to get oil level inspection gauges to face in a direction that allow easy inspection from ground level. In particular, rotation or straining of insulated connections shall be avoided during the fastening of conductor pads from the winding onto the termination surfaces of the bushing.

Suitable inspection and access facilities into the tank shall be provided to minimise the possibility of creating faults during the installation of bushings.

4.2.5.1 Surge protection of non-earthed HV neutral of YN-.-.connected transformers

The neutral ends of the HV windings of all YN- - connected transformers with partially graded HV winding insulation (220 kV, 132 kV and 66 kV HV windings) shall have surge arrester protection in cases where their neutral terminals are not earthed (see note in clause 4.2.5.2 below).

4.2.5.2 Arrester rating

The following information shall appear on the rating and diagram plate and shall bear the following cautionary instruction:

"HV winding insulation partially graded. HV neutral shall be solidly earthed or protected by a ..... kV r.m.s. continuously rated (MCOV) metal oxide surge arrester with a ..... kV peak residual voltage (10 kA)".

The continuous voltage rating and residual voltage (10 kA) of the required surge arrester shall be inserted as per the information in Schedule A of Appendix C.

> **NOTE:** — This reduction in insulation has been adopted in order to effect a worthwhile saving in the cost of these transformers, whose neutrals would generally be earthed but may occasionally be unearthed.

The insulation levels chosen are adequate to meet the voltages impressed on the neutrals of these transformers during the tests, but may be inadequate when transformer neutrals are unearthed during service. An example of this situation is when simultaneous voltage surges enter the star windings from two or more HV line terminals. For this reason, provision is made for surge arrester protection.

4.3 Oil for transformer and tap-changer

4.3.1 Type and quality

Only new naphthenic-based mineral oils, which must be certified as such prior to filling, shall be used.

Where the first filling of virgin oil is to be supplied by the contractor, the oil shall at least be as specified in AS 1767, without any additive. The moisture content of the oil shall not exceed the applicable values from AS 60422.

Under no circumstances shall poor quality oil be filled into the transformer and subsequently bringing up to specification by circulation within the transformer.

4.3.2 Dielectric strength

The power frequency dielectric breakdown strength of the oil in any part of the transformer and on-load tap-changer shall not be less than 60 kV / 2.5 mm for virgin oil prior to filling, and not be less than 50 kV / 2.5 mm at time of take over.

Dielectric strength shall be determined in accordance with the method prescribed in IEC 60156.

4.3.3 Moisture content

The moisture content of the oil before filling the transformer and on-load tap-changer shall not exceed 10 ppm. At time of takeover, the moisture content of the insulating oil shall not exceed 20 ppm in the main tank and the on-load tap-changer compartment. The requirements in clause 4.3.4 – Oil sampling and testing shall be met and if not achieved, drying / filtering of oil needs to be undertaken.

It shall be demonstrated that the moisture content in the paper insulation body of the transformer is less than 1 %. The test to verify the moisture content must be to internationally accepted standard methods for determining the moisture in paper.

4.3.3.1 Degree of polymerisation

After dry out, the manufacturer is to provide the degree of polymerisation (DP) value of the paper. Minimum value is 950 DP.

The paper used shall be thermally upgraded paper.

4.3.4 Oil sampling and testing

a) Units with a highest voltage of 40 kV and above

One sample is required in each of the following cases:

i. during testing in the factory:

a particle test shall be performed before and after each filling of the transformer for factory testing. The particle count in oil shall be less than 1000/10 ml for particles less than 2 µm.

ii. at time of take over:

all units delivered to site without oil, at least 7 days after in-situ oil processing has been completed, to test for dielectric strength, dissolved gas analysis (DGA), and acidity (A), but with the main emphasis on water content. Samples taken sooner will not necessarily reflect the correct water content (WC).

b) Units with highest voltages below 40 kV

Routine oil sampling and DGA of transformers in this group is normally not required, but this will be done at the discretion of the user (i.e. sampled on a “need only” basis). However, one sample to test for DS and WC, is required for acceptance purposes; before despatch from the manufacturer, or before commissioning on site. Records of the oil sample results shall be kept for future reference purposes.

c) On-load tap-changer diverter switches (all voltage categories)

A sample, to test for WC and DP only, shall be taken before commissioning and thereafter annually. This sample shall be taken from the tap-changer diverter conservator or diverter drain valve.

4.3.5 Oil-filling/impregnation under vacuum

When a transformer is designed to be oil-filled under vacuum, an instruction to this effect shall feature prominently on the rating-and-diagram plate or on a separate plate mounted adjacent to it.

All transformers installed in vacuum-proof tanks shall be oil impregnated and filled under vacuum.

Oil impregnation or drying under vacuum shall be done with the transformer and oil at a temperature of at least 60 °C.

The duration of the treatment shall be such that is results of the in moisture content is as specified in clause 4.3.3 – Moisture content.

Procedures shall be submitted for approval and full instructions shall be included in the transformer manual.

4.3.6 Preservation system

See clause 4.10.9 for the detail requirements of the conservator systems.

4.3.7 Poly Chloride Biphenyls (PCB) content

All oils used in the transformer and its accessories shall be free of PCBs (zero ppm).

A formal test certificate to this effect shall be included in the transformer manual.

4.3.8 Contact with bare copper

Bare copper in contact with transformer oil shall be minimised by using appropriate paper covering or painting.

4.4 Main terminals and Bushings

4.4.1 Position of open terminals

4.4.1.1 HV/MV terminals

The high-voltage bushings shall be approximately parallel to the major axis of the transformer;

The intermediate-voltage bushings, or for two-winding transformers, the low-voltage bushings shall be approximately parallel to the major axis of the transformer, and symmetrical with the high voltage bushings.

All terminal groups shall be arranged so that when viewed in the direction of power flow, the neutral terminal shall be on the left, followed by the line terminals in alphabetical order, as shown in Figure 2.

The power shall always be assumed to flow from the winding with the highest voltage rating towards all other windings.

4.4.1.2 Tertiary terminals

Tertiary winding terminals shall be on the right-hand end of the transformer when viewed from the HV side.

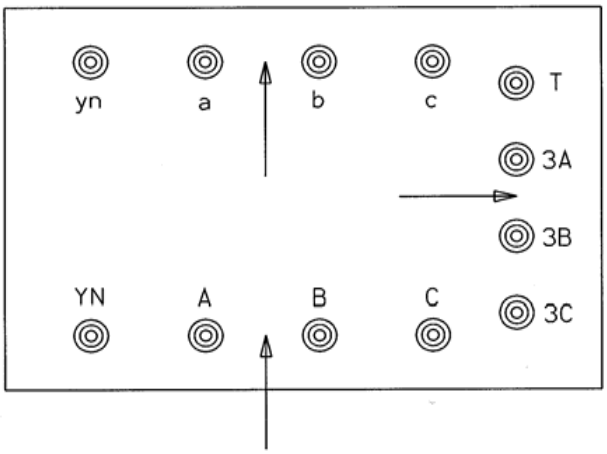


Figure 2 – Position of terminals for system transformers

4.4.2 Terminal markings

The terminal markings on the diagram plate shall be as specified in IEC 60076-8.

Terminals shall be positioned as indicated in clause 4.4.1.

Terminal markings characters shall be in relief, adjacent to their appropriate terminals.

The characters may be of brass, steel or other acceptable metal and shall be permanently fixed to the tank by means of brazing or welding.

4.4.3 Bushings

4.4.3.1 Terminals

Unless otherwise specified in Schedule A in Appendix C, air-side bushing terminals shall be solid copper or copper alloy cylinders of the diameter and length specified in Table 11. They shall be electro-tinned in accordance with BS 1872, Classification Cu/z/Sn/10/b without subsequent heat treatment or machine cleaning being necessary.

Suppliers shall also provide, a costed option to provide plug-in cable bushings (Pfisterer, Euromold or similar) as an alternative to the air-side bushing terminals.

> **NOTE:** — Suppliers providing the plug-in cable bushing option shall include the short circuit ratings (Current, RMS symm kA for 3 seconds, Peak asymm kA and Voltage Um kV) and contact type for the interface bushing.

Table 11 – Dimensions of open air bushing terminals

Bushing Type	Diameter (mm)	Length (mm)
Primary	26	125
Primary Neutral	26	125
Secondary/Tertiary	38	125
Secondary/Tertiary Neutral	38	125
NOTE: - Dimensional tolerances shall be as specified in *BS EN 13601*: Neutral terminals shall be fitted with terminal connectors and bolted clamping plates, all tinned or plated, and suitable for connecting two undrilled 50 mm x 3 mm flat copper bars.		

4.4.3.2 Continuous and overload currents

Bushing conductors shall be capable of safely carrying the currents implied by the short term and emergency overloading requirements in clause 3.3.2 – Current, without exceeding the temperature rise and hot spot limits specified in AS/NZS 60137.

4.4.3.3 Short-time current

Bushing conductors shall be capable of safely carrying, for 3 s, the short-circuit currents resulting from the faults detailed in clause 3.4 – Ability to withstand abnormal electrical conditions/loadings. This time factor allows for the possibility of having repetitive system short-circuits in quick succession.

4.4.3.4 Insulation levels and creepage distances

All bushings shall be able to withstand 10 % more test voltages than those determined as per clause 3.9.

The protected creepage distance, to be given in Schedule A in Appendix C, is the value of creepage distance in the rain shadow at an angle of precipitation of 90 degrees to the bushing axis. This value shall not exceed 50 % of the total creepage.

4.4.3.5 Bushing types

4.4.3.5.a Outdoor immersed bushings

Unless otherwise stated in Schedule A (in Appendix C) of an enquiry document, all open bushings shall be outdoor immersed bushings.

4.4.3.5.b Completely immersed bushings

Connections from winding leads into cable boxes or oil filled disconnecting chambers shall be effected using completely immersed bushings.

4.4.3.5.c Capacitance graded bushings

Capacitance graded bushings shall be supplied for all applications with nominal voltages of 66 kV and above in accordance with this specification.

4.4.3.5.d Resin impregnated bushings

Resin impregnated paper bushings shall be supplied with silicon rubber housings.

4.4.3.5.e Non-fluid bushings

Non-fluid filled capacitance graded bushings will only be accepted with specific approval.

4.4.3.6 Tertiary bushings — minimum voltage ratings, stems and spacing

For three winding auto transformers the low-voltage (tertiary) bushings shall, despite their actual operating voltage, have at least an insulation level corresponding to a nominal system voltage of 33 kV. These bushings shall have a minimum metal-to-metal phase spacing of 520 mm.

4.4.3.7 Minimum insulation, spacing and terminals for bushings on transformers rated up to 33 kV

For all transformers of in this specification, with a secondary voltage of 33 kV and below, the line-end bushings shall have a minimum insulation level corresponding to the nominal system voltage as per AS 2067. These shall also be of the capacitance graded type if Partial Discharge (PD) testing is specified.

These bushings shall have the same terminals and spacing in accordance with clause 4.4.3.6 and Table 11.

4.4.3.8 Test tappings

Pressure contacts against the outer earth layer of the bushing condenser are not acceptable.

The test tap contact and earthing system shall be adequately designed so as not to be damaged by repetitive fast transient currents during the life of the bushing.

Test tappings of approved design and materials shall be provided on all capacitance graded bushings.

4.4.3.9 Safe mounting height

For compliance with safety regulations, open bushings shall be arranged and mounted on the transformer in such a manner that the minimum vertical working clearances listed in AS 2067 are provided from finished ground level to live metal.

4.4.3.10 Mechanical forces

The minimum withstand values of cantilever load that may be applied to the external bushing terminals of standard transformers shall be not less than the values specified in AS/NZS 60137.

4.4.3.11 Gaskets

Gaskets shall be of nitrile rubber (medium hardness nitrile rubber bonded cork gasket) material or better material. All gaskets or O-rings shall be replaced after they have been disturbed but designs shall nevertheless be such as to be forgiving should this not be done. The manufacturer shall provide details of proposed gasket materials.

No metal shall bear directly on porcelain.

4.4.4 Cable sealing boxes and disconnecting chambers

4.4.4.1 General

Cable boxes shall be supplied as specified in Schedule A in Appendix C. Cable boxes shall be air insulated; be constructed to the requirements of BS 6435 (unfilled enclosures for dry terminations) and shall be suitable for use with heat-shrink cable connection systems. Appropriate drainage/ventilation of air insulated cable boxes shall be provided to ensure moisture does not accumulate. Insect screens shall be placed over the drainage/ventilation holes. Silica gel breathers are not acceptable on cable boxes.

Cable boxes shall be fitted with windows to allow for in-service thermography. Number and location of windows shall be such that all cable connections are visible. Thermography windows shall be constructed of a suitable material for the environment and shall incorporate a cover to protect the window from damage.

Cable boxes shall be complete with all the fittings necessary for attaching and connecting the cables specified in Schedule A in Appendix C.

Provision shall be made to isolate the transformer from the Cable/Bushing connections for testing purposes.

The gland plates shall be made from aluminium and be detachable from the boxes. They shall be of sufficient thickness to support the weight of cables without undue deflection. Gland plates shall be earthed directly to an earth bar provided in the cable box for earthing of high voltage cable screens.

Suitable cable support brackets shall be fitted to the main tank. These shall provide full support for cables so as to remove any terminal loading on the MV/LV bushings and eliminate cable slump when cables are disconnected from the bushings.

Flexible laminations and bolts shall be provided to enable the connection of appropriate cables sizes and quantities specified. ‘Keeper plates’ shall be supplied with to spread the applied pressure on the laminations.

Suppliers shall also provide, a costed option to provide plug-in cable terminations (Pfisterer, Elastimold or similar) as an alternative to the air insulated cable boxes.

4.4.4.2 Construction of cable-box shells

Cable box shells shall be constructed to minimise the danger of fragmentation under internal arcing fault conditions: cast metal construction is not acceptable. Where mild steel is used, the thickness of metal shall not be less than that specified in Table 12.

Table 12 – Minimum thickness of mild steel plate for cable box shells

Part	Thickness (mm)
Shell	3
Gland Plate	3
Cover Plate	3
Bushing Plate	8

4.4.4.3 Cable-entry and connections

Unless otherwise specified, cables shall enter cable boxes vertically from below. Where cable stands are provided, these shall be equipped with suitable cable saddles vertically aligned with the cable gland positions on the cable boxes and spaced to suit the cable manufacturer's recommendations, but in any case not more than 1 metre apart.

Copper strip used for the laminae of flexible connections shall not exceed 0.5 mm in thickness.

4.4.4.4 Armour cable clamps

Cable boxes for armoured cables shall be provided with suitable armour clamps.

4.4.4.5 Single-core cables and cables with insulated sheaths

Suitable 10 mm earthing terminals fitted with all required washers, nuts, lock nuts and removable copper earthing links shall be provided on the cable boxes and on the insulated cable glands required for single-core cables, for the purpose of bridging the gland insulation.

Stud holes shall not break through the metal of the gland or cable box to the inside.

Notwithstanding the requirements of BS 6435; where a higher insulation level is required for the glands for cables having anti-electrolysis finish, the gland insulation shall withstand a test of 5 kVdc for 60 seconds.

4.4.4.6 Interchangeability

For identical transformers, the cable boxes and disconnecting chambers shall be jig drilled and fabricated so as to permit interchangeability of the transformer.

4.4.4.7 Corrosion proofing and colour

Surfaces shall be treated and finished to correspond with the transformer in all respects.

4.4.4.8 Sealing during transport and storage

All apertures giving access to the interior of cable boxes, ventilation and drainage holes, and cable glands shall be sealed during transport and storage, to exclude the ingress of water and foreign matter.

4.5 Current transformers

Current transformers shall be installed for Over Current, Earth fault, Restricted Earth Fault (REF) protection and Winding and Oil Temperature measurement purposes. All other protection and metering functions requiring current transformers shall be either transformer bushing CTs or using external post CTs. The Supplier shall specify in Schedule A in Appendix C, the kind of CT arrangement for the transformer.

4.5.1 Number and location

The number, ratings and location of current transformers associated with each power transformer, shall be as specified in Table 13, Table 14, Table 15, and Table 16.

4.5.2 Applicable standard

Current transformers shall comply with the requirements AS 60044.1 and shall be “Class - PX Type” for protection purposes.

4.5.3 Transformer short-circuits and overload

Current transformers shall be capable of mechanically and thermally withstanding the same over currents and overload, for the same periods, as the associated windings of the power transformer.

4.5.4 Insulation levels and short-circuiting for testing

Current transformers (including the neutral bushing CT’s on partially graded neutrals) shall withstand all dielectric tests applied to the power transformer windings, and shall be in position and in circuit during the power transformer voltage withstand and impulse tests.

Open circuits shall be avoided during testing of the transformer.

All current transformers shall be shorted and earthed in the factory and delivered to site in that condition.

4.5.5 Tests

Current transformers shall be tested as specified in clause 5.2 – Transformer Tests.

Type test certificates shall be provided which match the current transformers specified.

Results from routine tests shall quote the current transformer by serial number, and provide all information stated in clause 4.5.8.

All results and certificates shall submitted electronically. Information (as stated in clause 4.5.8) shall be in table format in a spreadsheet, and quote e each current transformer by serial number.

4.5.6 Connections

4.5.6.1 Terminals and locknuts

Current transformer secondary terminals, where applicable, shall comply with the requirements of clause 4.7.4 and they shall be indelibly marked for identification as indicated in clause 4.5.8.1 and Figure 3. All current transformer terminals inside the power transformer shall be of the stud type and all connections shall be securely locked using lock nuts or locking plates. Steel lock washers are not acceptable.

4.5.6.2 Secondary connection wiring and termination

The beginning and end of each secondary winding and all secondary tappings shall be wired to terminals in a terminal box accessible from ground level and thence to the free standing marshalling box, all as specified in clause 4.7.3.

4.5.6.2.a Termination of leads

Particular attention shall be paid to the termination of leads inside the transformer tank with a view to ensuring secure connection of current carrying lugs, and the elimination of all possible tension in the leads (see clause 4.7.3.6).

4.5.6.2.b Conduit or armour

Where a current transformer's secondary leads are taken through conduit or armoured cables, all leads from one winding shall be included in one particular conduit or armoured cable.

4.5.7 Protection current transformers

4.5.7.1 Type

Protection current transformers shall be of the low-reactance type for all ratios.

4.5.7.2 Ratio

The nominal ratios for protective current transformers are specified in Table 13, Table 14, Table 15, and Table 16.

4.5.7.3 Turns compensation

Protective current transformers shall not be turns compensated.

4.5.7.4 Required data

The following information relating to protective current transformers shall be submitted for approval:

a) magnetization curve;

b) secondary winding resistance; and

c) secondary winding leakage reactance.

4.5.7.5 Designation

Where more than one protective current transformer is provided in any one phase, the current transformer designated "main protective current transformer" shall be located furthest from the transformer windings. In addition, protective current transformers together with current transformers in general, shall be given designations as indicated in Figure 3 and Figure 4.

4.5.7.6 Current transformers for delta-connected windings

The arrangement of protective current transformers associated with delta-connected power transformer windings, is indicated in Figure 3 and Figure 4.

4.5.7.7 Winding temperature indication for delta windings

Where the current transformer for a winding temperature indicator is associated with a delta connected winding, it shall be located inside the delta so that it can detect all over-current conditions of the delta winding, including those circulating current conditions resulting from external earth faults on the associated power systems.

4.5.7.8 Type and accessibility

Current transformers shall preferably be of the bushing type for transformer CTs. Separately mounted CTs shall be located above the core and winding assembly and be provided with adjacent hand-holes in the tank side or cover of a size adequate for their removal and replacement.

4.5.8 Data for rating and diagram plates

Where current transformers are built into the transformer, the combined rating and diagram plate shall provide full details of the location of each current transformer, its polarity, secondary terminal markings and also all the information required by AS 60044.1, with the provision that no information is duplicated.

The following symbols may be used on rating and diagram plates:

a) IL = Secondary insulation level (3 kVdc)

b) Hz = Rated frequency

c) Ith = Rated short-time current and rated time kA-s;

d) RS = Secondary winding resistance at 75 °C;

e) N = Turns ratio

f) Vk = Kneepoint voltage

g) Im = Magnetising current

h) Ip = Primary current

i) IS = Secondary current

j) VA = Output in (VA)

4.5.8.1 Terminal markings

The system of marking used to identify the terminals for current transformers supplied with power transformers, shown in Figure 4 shall indicate:

a) the polarity of the primary and the secondary terminals, or, where no primary terminals exist as such, the orientation of the current transformer; and

b) the current transformer designation, viz.

- the connection in which it appears (e.g. a phase or neutral connection);
- the sequence relative to other current transformers appearing in the same connection.

The current transformer winding (primary and/or secondary) and its polarity shall be denoted by the letter P and/or S and the numerals 1 and 2 as specified in AS 60044.

The convention used shall always place P1 (and/or S1) nearer the external terminal of the transformer and P2 (and/or S2) nearer the winding.

The winding alpha-numeric and the polarity alpha-numeric shall be prefixed by letters denoting the phase or neutral connection (see Figure 3) in which the current transformers appear and these alphanumeric shall be prefixed by numerals giving the sequence of the current transformers relative to other current transformers in the particular phase or neutral connection, as indicated in Figure 3.

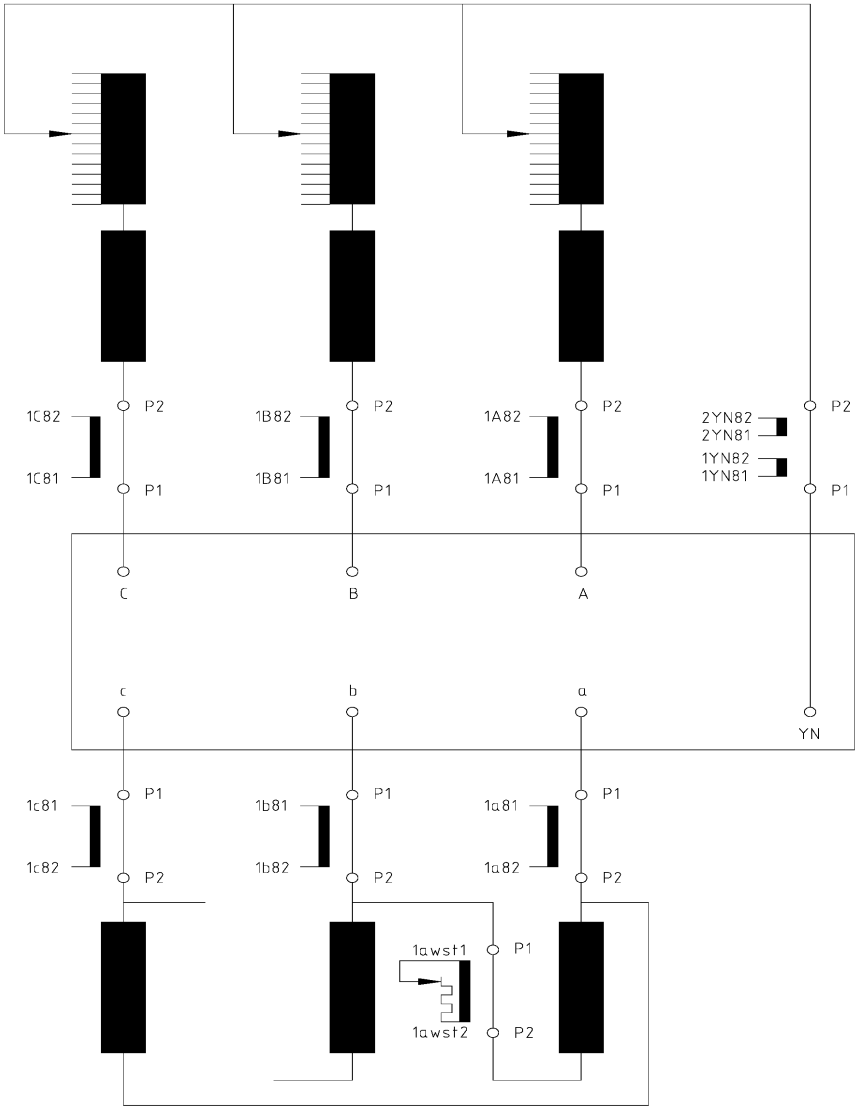


Figure 3 – Current transformer terminal markings

NOTES to Figure 3

c) Current transformers with a wound primary shall be shown on the rating-and-diagram plate as exemplified by current transformers 1YN and 2B.

d) Ring type current transformers with an integral bar primary shall be shown in the same way as current transformers 1-3B and 1B.

e) Ring type current transformers mounted on bushings or positioned over an independent connection shall be shown as exemplified by current transformers “1a”, “1b” and “1c”

These numbers shall be counted in the case of star-connected windings, from the power transformer external terminal towards the neutral point connection, and, in the case of delta-connected windings, in a direction from the external terminal through the particular phase winding towards the junction with another phase.

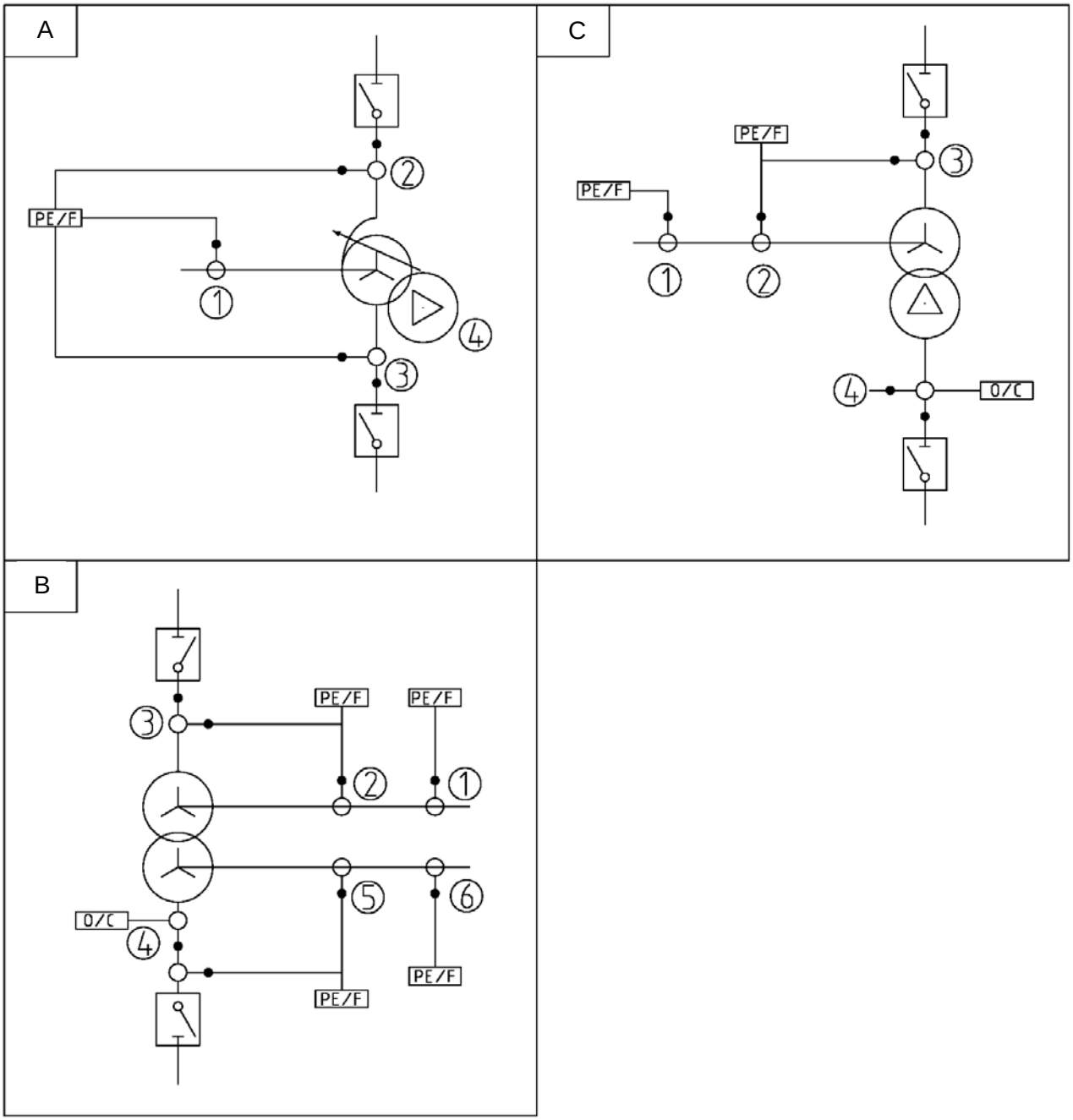


Figure 4 – In-built current transformers

See Table 13, Table 14, Table 15, and Table 16 for CT particulars.

Table 13 – In-built current transformers for Figure 4(A) (Auto transformers)

Transformer		In-built Current Transformer Cores	
Voltage (kV)	**Power (MVA)**	**Cores 1, 2, 3**	**Core 4**
132/66	160/20	2400/1	800/1
	80/10	1000/1	400/1
	40/10	800/1	400/1
	20/5	400/1	200/1

Table 14 – In-built current transformers for Figure 4(B) (Star/Star transformers)

Transformers		In-built current transformer turns ratio				
kV	**MVA**	**Core 1**	**Cores 2,3**	**Core 4**	**Core 5**	**Core 6**
220/66	80	200/1	300/1	1200/1	1200/1	1200/1
	40	200/1	300/1	1200/1	1200/1	1200/1
132/11	40	200/1	300/1	2400/1	2400/1	2400/1
	20	200/1	300/1	1200/1	1200/1	1200/1
66/22	40	200/1	400/1	1200/1	1200/1	1200/1
	20	200/1	300/1	600/1	600/1	600/1
66/11	40	400/1	400/1	2400/1	2400/1	2400/1
	20	200/1	200/1	1200/1	1200/1	1200/1

Table 15 – In-built current transformers for Figure 4(C) (Star/delta transformers)

Transformer		In-built current transformer turns ratio		
kV	**MVA**	**Core 1**	**Cores 2,3**	**Core 4**
132/66	80	300/1	500/1	800/1
	40	200/1	300/1	600/1
132/33	40	200/1	300/1	800/1
	20	200/1	300/1	400/1
	10	200/1	300/1	200/1
132/22	80	300/1	500/1	2400/1
	40	200/1	300/1	1200/1
	20	200/1	300/1	600/1
	10	200/1	300/1	300/1
132/11	40	200/1	300/1	2400/1
	20	200/1	300/1	1200/1
	10	200/1	300/1	600/1
66/22	40	200/1	400/1	1200/1
	20	200/1	300/1	600/1
	10	200/1	300/1	300/1
	5	200/1	100/1	200/1
66/11	20	200/1	300/1	1200/1
	10	200/1	300/1	600/1
	5	100/1	100/1	300/1
	2.5	100/1	100/1	200/1

Table 16 – In-built current transformers (Class “TPS” specification core details)

Class “TPS” core specification			
Turns Ratio	**I_m (mA) (Max)**	**V_K (V) (min)**	**RS (Ω) (max)**
1/100	500	150	0.4
1/200	500	200	0.8
1/300	330	300	1.2
1/400	250	400	1.6
1/500	200	500	2.0
1/600	170	600	2.4
1/800	125	600	3.2
1/1000	100	650	4.0
1/1200	83	650	4.8
1/1400	71	650	5.6
1/1600	63	700	5.6
1/2000	50	700	8.0
1/2400	42	750	9.6

NOTES:

a) I_m = CT excitation current V_K = knee point voltage

b) The knee point of the excitation curve is the point where an increase of 10% of the secondary EMF results in a 100% increase in excitation current.

4.6 Voltage variation and control

4.6.1 Tapping ranges

For the standard tapping ranges refer to clause 3.5 – Standard tapping ranges.

For two winding transformers (Y-connected Primary) the tap changer shall be positioned on the neutral side of the primary winding.

Tap-changers shall be installed in the HV series winding (MV potential) at the line end of common winding (auto transformers only).

4.6.2 Off-circuit tapping switch

When specified, the transformer shall be provided with a ganged off-circuit tapping switch, operated by an external handle situated in an unobstructed position, not more than 1.5 metres above ground level.

The contacts shall be positively self-locating in each tapping position without constraint from the operating mechanism, which shall provide for padlocking in each position.

The tapping positions shall be indelibly marked to correspond with the data given on the rating and diagram plate and these markings shall be legible by a person standing at ground level.

4.6.3 On-load tap-changing equipment

On-load tap-changing equipment shall:

a) comply with AS 60214; and

b) designed to be maintenance free.

Maintenance free being defined as:

- Monitor the moisture content and dielectric of oil at intervals dictated by the supplier but excluding replacement of oil, filtering and un tanking
- Units smaller than 20 MVA shall be deemed maintenance free for 100 000 operations.
- Units having a rating of 20 MVA and above shall be deemed maintenance free for 300 000 operations.
- Transformer and tap-changer oil (Refer to clause 4.3)

4.6.3.1 Ratings

4.6.3.1.a Current ratings

The rated through current of the tap-changer, as defined AS 60214, shall not be less than that the maximum current through the tapping winding. (It shall be able to operate at the emergency and overload ratings of the transformer without damage (see clause 5.2 – Transformer Tests).

4.6.3.1.b Short-circuit currents

In addition to the requirements of AS 60214 for on-load tap-changers, tap-changing equipment shall be capable of carrying the same currents, due to external short-circuit, as the transformer windings with which they are associated (refer to clause 5.2 – Transformer Tests).

It is permissible that tap-changing be inhibited during transformer overload conditions above 1.5 pu.

4.6.3.1.c Insulation level

Notwithstanding the requirements of AS 60214, on-load tap changing equipment, including all insulating and barrier boards, shall withstand the impulse and dielectric test voltages applicable to the part of the transformer windings with which they are associated, as specified in clause 3.9.

If any specific critical phase-to-phase insulation situations exist in the transformer it should be noted that the purchaser's surge arresters will only limit incoming surges on a phase-to-earth basis and that phase-to-phase insulation will therefore be protected by two arresters in series. This particularly applies to three-phase line end tap-changers and their leads, as well as the leads of single-phase tap-changers.

The transformer design shall cater for this situation.

4.6.3.1.d Tie-in Resistor

Should a tie-in resistor be used on the selector switch, the value of the tie-in resistor shall be provided in Schedule A in Appendix C. The schematics on the rating and diagram plate as well as the schematics on the transformer manuals shall show the position and value of the tie-in resistor.

4.6.3.2 Design of the tap-changer

4.6.3.2.a Replacement of current switching contacts

The current breaking contacts of diverter switches shall be easily replaceable.

4.6.3.2.b Diverter and selector switch compartments

Drop-down tanks that necessitate the provision of pits in the foundations, are unacceptable.

Each diverter and selector switch compartment shall be provided with an oil drain valve or plug.

Care shall be taken to close the drain valve or plug of the diverter compartment before operating the tap-changers on load in the factory or after installation. Failure to do so will require full reprocessing of the oil in the transformer at the contractor's cost.

Current breaking switches (e.g. diverter and selector switches as distinct from tap selectors and change-over selectors) shall not operate in the insulating oil of the main transformer.

The insulating oil for these switches shall be completely segregated in an oil and gas-tight compartment separate from that in the main transformer tank and the oil conservator for maintaining the oil level in the compartments containing such switches, shall be separated from the main transformer oil conservator. Where a common conservator tank construction is employed to serve both the main tank and the tap-changer switching compartment, the two bodies of oil shall be segregated by an oil and gas tight steel partition. Each body shall have its own separate dehydrating breather and oil level indicator, that shall be clearly labelled to relate it to the corresponding oil body.

4.6.3.2.c Protective devices for diverter and selector switch compartments

Protective functions to be provided for diverter switch and selector switch compartments shall effect the tripping of the circuit-breakers controlling the transformer in the case of:

a) low oil level (may be omitted if a surge relay, that fulfils this function, is provided).

b) a surge of oil produced by a fault inside the compartment, or a rise in pressure or temperature resulting from such a fault, whichever one of these three is most appropriate to the design of the apparatus.

Transformers with ratings below 100 MVA, shall be equipped with one protective device.

Transformers with a rating of 100 MVA and above shall be equipped with two approved protection devices, or alternatively one device with two sets of contacts.

Where a pressure sensitive device is provided; its contacts shall close under a steady increase of pressure and at a value not less than 100 kPa or as recommended by the manufacturer, taking the head of oil into consideration.

4.6.3.2.d Breather

The oil in diverter switch and selector compartments shall only communicate with the atmosphere through a dehydrating breather containing a silica gel charge of at least 2 kg.

4.6.3.2.e Buchholz relay for selector compartment

Where tap selectors and change-over selectors are contained in compartments separate from current breaking switches, those compartments shall be protected by the Buchholz relay serving the main transformer tank, unless separate oil surge and low-oil level relays are provided. Provisions shall be made for filtering and draining the oil in those compartments.

4.6.3.2.f Alarm and tripping contacts for protective devices

These contacts shall comply with the requirements of clause 4.6.3.9.

4.6.3.2.g Strength of tap-changer compartments and insulating barriers

Tap-changer compartments and insulating barriers shall have adequate strength to resist, without suffering significant permanent distortion or damage of any sort, the forces resulting from the application of a full internal vacuum at sea level.

In the case of insulating barriers, the vacuum is unequalised (i.e. applied from one side only, against atmospheric and oil pressure on the other side), and applied internally from either side, with the following provisions:

a) in the case of tap-changers energised at voltages below 66 kV, the vacuum requirement applicable to the tap-changer compartment will be limited to that which produces a pressure differential between the tap-changer compartment and the atmosphere of not more than 65 kPa; and

b) where such insulating barriers serve tap-changers mounted wholly within the transformer tank, (e.g. diverter switch cylinder) the application of the vacuum or pressure may be equalised on both sides of a diverter switch compartment by interconnecting the two conservators.

4.6.3.2.h Sealing of tap-changer parts for transport

Where it is necessary to remove parts or the whole of the on-load tap changer for transport purposes, it shall be possible, unless otherwise approved, to complete erection on site with the transformer windings and terminal insulation covered with oil.

4.6.3.3 Driving mechanism, control and indicating equipment

4.6.3.3.a Enclosures of apparatus

The driving mechanism shall be enclosed in a ventilated, dust-proof, weather-proof and vermin-proof cubicle provided with an AC 240 V , separately fused, anti-condensation heater and switch (with a solid withdrawable link in its neutral lead), and, at its lowest point, with a 25 mm diameter gauze covered drain hole (see clause 4.8.3.2 for internal corrosion proofing).

Where a gland plate for cables is provided, ample space shall be allowed from the terminal strip for arranging the entry of the cable cores (see clause 4.7).

NOTE: — Unless specified to the contrary, the automatic and remote control panels and equipment for the on-load tap-changer will be supplied and installed by the purchaser.

4.6.3.3.b Design of driving mechanism: synchronism and limit stops

The driving mechanism shall be so designed that once a tap-changing operation has been initiated, the diverter switch or selector switch contacts will not remain in an intermediate position should the power supply for the driving unit fail.

The design shall include means to ensure that tap-changers fitted to three single-phase units, or units operating in parallel, remain in step. Mechanical stops shall be provided to prevent the mechanism from overrunning its end position.

4.6.3.3.c Manual operation

For maintenance and emergency operation of the tap-changing equipment, a readily detachable handle shall be provided for manual operation. Adequate provision shall be made to prevent the diverter switch or selector switch contacts being left in an intermediate position when operated manually.

To prevent power operation with the handle in position, a normally closed contact in the control or motor circuits shall be provided that opens when the handle is inserted (Figure 5).

The tap-changer shall be accessible from ground level (±1.2 m from base plate), i.e. all operating inspection points shall not be positioned higher than 1.8 metres as to ensure that the operator does not have to leave ground level.

4.6.3.3.d Electrical operation

Clauses 4.6.3.3.d.i to 4.6.3.3.d.xi are the minimum equipment requirements and these shall be mounted in the driving mechanism enclosure or other suitable kiosk, mounted near the transformer (see also Figure 5, Figure 6 and Table 17). The following points shall be complied with:

a) Control relays shall only respond to control initiation pulses of 150 ms duration or longer.

b) The rating of control relay contacts shall be in accordance with clause 4.6.3.9.

c) All contactor operating coils and trip coils shall be rated at 110 Vdc.

The tap-changer shall be accessible from ground level (±1.2 m from base plate), i.e. all operating inspection points shall not be positioned higher than 1.8 metres as to ensure that the operator does not have to leave ground level.

4.6.3.3.d.i Tap-changer drive motor

See motor “a” on Figure 5.

A tap-changer drive motor rated at: 415 Vac, three-phase, 50 Hz shall be fitted.

4.6.3.3.d.ii Tap-in-progress indication

A terminal shall be provided for the neutral of the 415 Vac supply and one terminal of the motor shall be connected to an external terminal for a "tap-in-progress" lamp. (Refer to Figure 5).

Or alternatively, a "tap-in-progress" indication contact similar to contact 'A' of 4.6.3.3.d.viii, shall be provided.

4.6.3.3.d.iii Circuit-breaker for motor protection

See "b" on Figure 5.

a) For a three-phase drive motor, a circuit-breaker fitted with three-phase thermal overload protection and single-phasing protection and a separate DC shunt trip coil shall be provided. The trip coil shall be provided with a contact to break its own current if the coil rating exceeds 50 W. The trip coil rating in watts shall be stated on the OLTC drive schematic diagram.

b) Where "raise" and "lower" contactors are fitted, both the circuit-breaker and the DC shunt trip coil shall be provided.

4.6.3.3.d.iv Protection of tap-changer during system faults

A self-resetting contactor shall be provided in the motor circuit for overcurrent blocking of the tap-changer drive under system fault conditions. The contactor shall be fitted with a DC operating coil, and normally closed contacts capable of interrupting motor starting currents. Contactors with normally open contacts that require the coil to be continuously energised are not acceptable.

4.6.3.3.d.v Local control

"Raise" and "Lower" push-buttons or a control switch for the local control, mechanically or electrically interlocked, shall be provided (see "d" on Figure 5).

As shown in Figure 5, these raise/lower control devices shall be connected to separate terminals for use in the purchaser’s control scheme. They shall not be connected for direct control of the OLTC drive.

4.6.3.3.d.vi "Raise and Lower" motor-operating contactors

Direct-current operated "Raise" and "Lower" contactors for controlling motor direction shall be provided (see "e" on Figure 5).

4.6.3.3.d.vii Completion of tap-change operations

Auxiliary contacts shall be provided for sealing "Raise" and "Lower" contactors and mechanism contact "A" for controlling the sealing of the "Raise" and "Lower" contactors (see "f" and "g" in Figure 5) (see 4.6.3.3.d.iv).

4.6.3.3.d.viii Step-by-step and parallel operation

See "h" and "i" on (Figure 6 and Figure 5). The manufacturer shall provide and install all the appropriate equipment and circuitry inside the driving mechanism i.e. contacts, relay(s) etc. in order to perform within the mechanism box the full step-by-step function (see Figure 6 step-by-step typical circuit).

For operation of step-by-step relay(s) and single or two contacts shall be provided. When single contact is used this must close in either “Raise” or “Lower” direction, when two contacts are used, one contact shall close only when the drive moves in the "Raise" direction and the other shall close only when the drive moves in the "Lower" direction.

These contacts may take the form of mechanism contacts or, alternatively, auxiliary contacts on the "Raise" and "Lower" contactors may be used.

In the latter case an additional mechanism contact, similar to 'A' in 4.6.3.3.d.vii above shall be provided for the step-by-step circuit if the 'A'-contact is the normally open type, i.e. if the mechanism contact through which the "Raise" and "Lower" contactors are sealed is the type that is open in the rest position and closed during operation.

The essential features of the contacts provided for the step-by-step circuit are that they shall not operate the step-by-step relays before the "Raise" and "Lower" contactors have had time to seal themselves in, and that they shall remain closed throughout a tap-change operation, and, preferably, also throughout a transition step. If they do not remain closed throughout a transition step, then a spare mechanism contact shall be provided and wired to separate terminals.

4.6.3.3.d.ix Tap position indication, supervision and monitoring

Two sets of coded, voltage free contacts shall be provided (see Figure 6).

Tap position switch for use in parallel checking circuit. This switch may take the form of either a change-over switch that changes its position at the end of each tap-change operation or a multi-position rotary switch with as many contacts as there are taps on the transformer. These switches shall be of the break-before-make type. (see “l” on Figure 6).

4.6.3.3.d.x Limit switches

See “n” on Figure 5.

Limit switch contacts, to prevent the tap-changer from overrunning the end positions, shall be provided.

These contacts shall be provided where indicated in the initiating circuits and shall preferably be provided in the motor circuits as well if, in the case of single-phase motors, motor contactors are provided.

NOTE: — The preceding clauses list the purchaser’s minimum requirements, but if the contractor wishes to add further relays (e.g. for step-by-step control), this is acceptable though not desirable.

4.6.3.3.d.xi Approval of components

All contactors, switches, circuit-breakers, relays and contacts incorporated in the electrical control of tap-changers, shall be subject to the purchaser’s approval.

4.6.3.4 Mechanical tap position indicators

An externally visible mechanical tap position indicator shall be provided on the driving mechanism.

The tap-changer shall be accessible from ground level (±1.2 m from base plate), i.e. all operating inspection points shall not be positioned higher than 1.8 metres as to ensure that the operator does not have to leave ground level.

4.6.3.5 Maximum and minimum tap position indicators

Maximum and minimum tap position indicators arranged for manual resetting shall be fitted to the driving mechanism to register the operating range encountered in service.

4.6.3.6 *Operation counters*

Externally visible mechanical counters (e.g. cyclometers) shall be provided to register the number of tap-change operations. These recorders shall have at least five digits, and shall have no provision for resetting. These counters shall be of suitable quality for at least 1 000 000 operations. This shall be supported by a type test certificate.

The tap-changer shall be accessible from ground level (±1.2 m from base plate), i.e. all operating inspection points shall not be positioned higher than 1.8 metres as to ensure that the operator does not have to leave ground level.

4.6.3.7 *Drawings and technical data*

4.6.3.7.a *Details on transformer outline drawings*

The main features of tap-changers, including the fittings and protective devices specified, shall be indicated on the transformer outline drawings.

4.6.3.7.b *Schematic diagrams*

Transformer on-load tap changer drive schematic diagrams showing the rating in watts of the DC shunt trip coils fitted to the driving motor circuit breakers, shall be supplied. The contractor shall indicate on this diagram which of the requirements, detailed in clause 4.6.3.3.d above, each device will fulfil.

4.6.3.7.c *Timing charts*

A diagram or chart showing the relative timing of all contacts during both a regular tapping step and a transition step shall be provided.

4.6.3.8 *Tap position numbering*

For both off-circuit and on-load tapping arrangements the tap position shall be numbered so that an increase in tap position number represents an increase in the controlled or outgoing voltage.

Controlled secondary voltage is defined as the voltage that is changed as a result of the change in tappings. In the case of interconnection or coupling transformers involving power flow in both directions the controlled voltage will be specified in Schedule A of an enquiry document.

NOTE: — Transition steps that give the same outgoing voltage should all take the same tap position number, distinguished in each instance by a lower case letter; e.g. 9(a), 9(b) and 9(c) where there are three transition steps.

4.6.3.9 *Alarm, control and tripping contacts*

Alarm and tripping contacts shall be provided with electrically independent and unearthed circuits and shall be insensitive to vibration and earth tremors. This insensitivity shall not depend on the method of mounting, but shall be an inherent feature of the contact assembly.

Auxiliary relays shall not be used.

4.6.3.9.a Alarm and control contacts

Contacts providing alarm output shall be rated as follows:

a) Make and carry for 200 ms: 5 A @ DC 110 V

b) Carry continuously: 2 A @ DC 110 V

c) Break (inductive L/R = 40 ms): 30 W or 0.2 A @ DC 110 V

4.6.3.9.b Tripping contacts

Contacts providing trip outputs shall be rated as follows:

a) Make and carry for 200 ms 30 A @ DC 110 V

b) Carry for 1 s: 10 A @ DC 110 V

c) Carry continuously: 5 A @ DC 110 V

d) Break (Inductive L/R = 40 ms): 30 W or 0.2 A @ DC 110 V

4.6.3.9.c Tests

Devices fitted with alarm and tripping contacts shall be tested as specified in clause 5.2 – Transformer Tests.

4.6.3.10 Standard on-load tap-changer control schemes: minimum requirements for driving mechanisms:

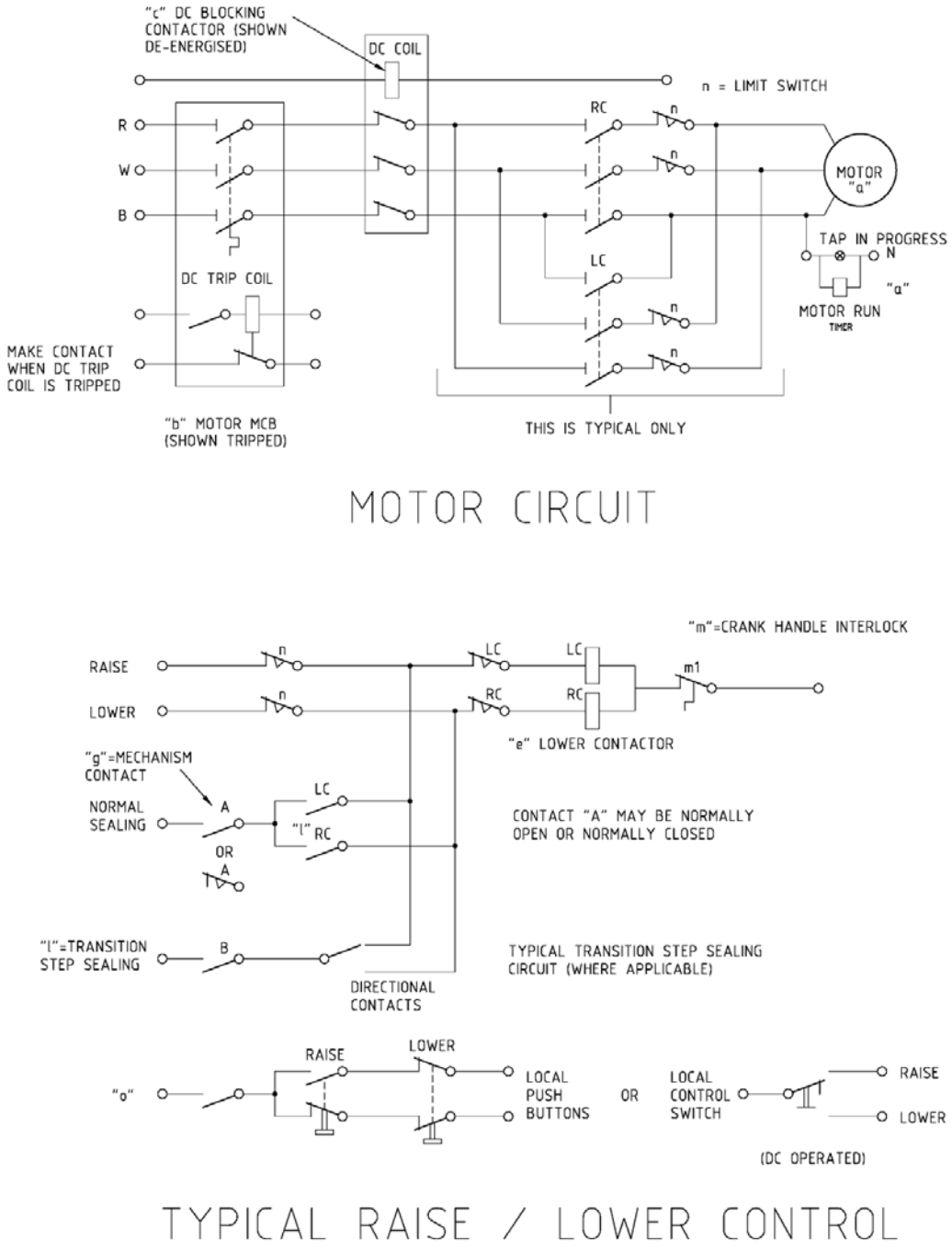


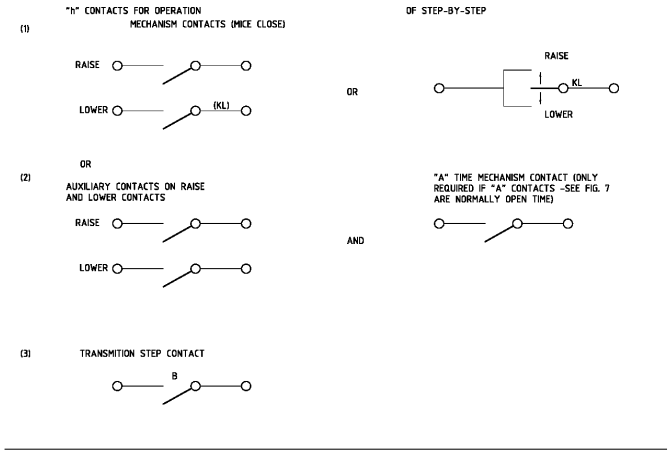
Figure 5 – Control circuits for three-phase OLTC motor drives

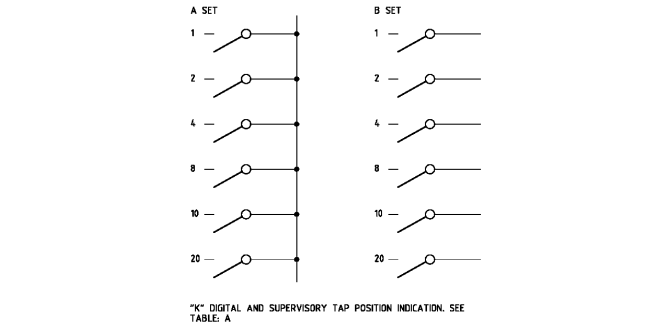
NOTES to Figure 5

a) If the motor is continuously rated for the stalled condition, the thermal overload protection may be omitted.

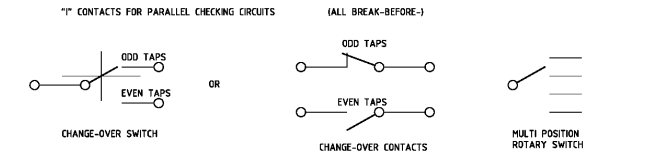
b) Where 'raise' and 'lower' contactors are not provided and the motor current does not exceed 5 A when starting or running, the separate DC shunt trip coil may be omitted.

c) In the case of single-phase motors continuously rated for the stalled condition and with a motor current not exceeding 5 A when starting or running, the circuit-breaker may be omitted entirely, provided no 'raise' or lower' contactors are fitted.

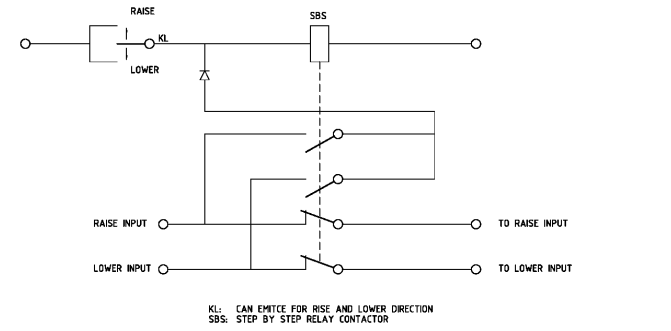




TAP POSITION INDICATOR CIRCUITS



PARALLEL CHECKING CIRCUITS



STEP BY STEP CIRCUIT (TYPICAL)

Figure 6 – Common circuits for OLTC control

Table 17 – Contact state at each tap position

Position	20	10	8	4	2	1
1	0	0	0	0	0	1
2	0	0	0	0	1	0
3	0	0	0	0	1	1
4	0	0	0	1	0	0
5	0	0	0	1	0	1
6	0	0	0	1	1	0
7	0	0	0	1	1	1
8	0	0	1	0	0	0
9	0	0	1	0	0	1
10	0	1	0	0	0	0
11	0	1	0	0	0	1
12	0	1	0	0	1	0
13	0	1	0	0	1	1
14	0	1	0	1	0	0
15	0	1	0	1	0	1
16	0	1	0	1	1	0
17	0	1	0	1	1	1
18	0	1	1	0	0	0
19	0	1	1	0	0	1
20	1	0	0	0	0	0
21	1	0	0	0	0	1
22	1	0	0	0	1	0
23	1	0	0	0	1	1
24	1	0	0	1	0	0
25	1	0	0	1	0	1

Position	20	10	8	4	2	1
26	1	0	0	1	1	0
27	1	0	0	1	1	1
28	1	0	1	0	0	0
29	1	0	1	0	0	1
30	1	1	0	0	0	0
31	1	1	0	0	0	1
32	1	1	0	0	1	0
33	1	1	0	0	1	1

4.7 Auxiliary supplies, marshalling cabinets, terminal boxes, wiring and cabling

4.7.1 Auxiliary supplies

The auxiliary power supply shall be rated at AC 415 V 50 Hz three phase for auxiliaries (e.g. cooling fans, tap changer) and 240 V 50 Hz single phase for control, GPO, lighting and anti-condensation heaters. The unearthed DC supply shall be 110 Vdc for alarm and trip contacts and 24 Vdc for remote control and indication.

4.7.2 Marshalling cabinets / Terminal boxes

4.7.2.1 Marshalling cabinets and terminal boxes

All equipment shall be arranged such that it is accessible from the front of the cabinet/box. Any divisions between compartments within the cabinet/box shall be perforated to assist natural air circulation.

Where applicable, access to equipment from the rear shall be provided subject to the purchaser's approval.

NOTE: — hinged panels are acceptable.

4.7.2.1.a Marshalling cabinets

Marshalling / local control cabinet shall have ingress protection rating of IP56. Adequate sun shielding shall be provided on all sides of the control cubicle (including the doors) to maintain the temperature within the enclosure to below the maximum allowable operating temperature of any equipment housed in it. The local control cabinet shall not include any glass viewing windows (to minimise temperature rise).

The cabinet door shall, in addition to a gasket seal, be provided with a double-curved flange along the top edge and sides. The door opening in the cabinet shall have a double-curved flange around its entire perimeter, the outer face of which shall form the gasket joint. Cabinet doors and access covers shall be fitted with integral handles, be easily opened and not secured by bolts or nuts.

4.7.2.1.b Terminal boxes and covers

Terminal boxes shall have ingress protection rating of IP56 with easily removable covers of the slip-on type, fixed by not more than two screws. Covers in a vertical plane shall, in addition to a gasket seal, be provided with a double-curved flange along the top edge and sides. The top of the box shall be made to overhang the cover, except in the case of slip-on covers. These shall be double-curved and fitted with drip ledges to prevent internal corrosion.

4.7.2.2 Venting and draining

Marshalling boxes and terminal boxes, arranged in a vertical plane, shall be provided with a 25 mm vent and drain hole, each covered by a fine mesh of non-corrodible wire, fitted at the lowest point. This mesh shall be of a design that prevents entry of termites and 'Singapore' ants (monomorium destructor). This fitting shall be flush inside to allow total drainage.

4.7.2.3 *Wiring terminals*

All control wiring terminal strips shall be of the moulded type with recessed clamp terminals and shall be sized to suit incoming cabling. The terminals shall be of vibration proof type terminals (spring loaded) Weidmuller WDU or Horizon Power Representative approved equivalent (Supplier shall include full details of any alternative terminals offered).

The terminals shall be grouped according to the circuit voltages with dividers or spaces between each group.

Provision shall be made to short and earth the winding temperature, line-drop compensator and metering CTs in the control cubicle by bridging terminals, though sliding link terminals for CT connections are not to be used.

All exposed 110 Vdc (or higher) and 415/240 Vac terminals where access may be gained whilst the equipment is live shall be fitted with shrouds. This includes fuse holders and relay terminals and any terminals exposed by opening hinged panels on other access doors (no equipment other than wiring and terminals shall be mounted behind hinged access panels).

Shrouding of terminals is to be shown on all appropriate drawings.

4.7.2.4 *Earthing terminal*

An earthing terminal consisting of a boss with a M16 stainless steel or brass bolt shall be provided in each terminal box and marshalling box on both the inside and outside.

4.7.2.5 *Spare terminals*

Each marshalling box shall be provided with at least 25 spare terminals for future cable terminations from external locations unless otherwise agreed.

4.7.2.6 *Incoming auxiliary circuits*

To prevent entry of water, the auxiliary wiring from the gas- and oil-actuated relay, current transformers and other auxiliary apparatus, shall be arranged for side or bottom entry into the marshalling box. If bottom entry is adopted, the gland plate used shall be independent of that provided for the purchaser's outgoing cables.

4.7.2.7 *Provision for outgoing cables*

The marshalling box shall be provided with a separate, removable, undrilled 4 mm thick brass gland plate to take the purchaser's cable glands, mounted at least 100 mm below the bottom of the terminal blocks, or other equipment, in such a manner as to facilitate the entry of the purchaser's cables.

The gauze covered drain and vent hole may be fitted to this gland plate.

4.7.2.8 *Contactors*

Contactors shall not be mounted directly on the back plate of winding temperature or oil temperature indicators, as vibration can cause these indicators to read incorrectly.

4.7.3 Wiring

Wiring shall conform to AS 3000 and AS 2067 (AS 2067 shall take priority in cases of duplication or disparity).

All equipment and wiring shall be laid out in such a manner that changing of fuses, removal of links, changing of lamps, removal of switches, changing of lamps, operation of switches, resetting of relays and fault finding can all be carried out conveniently without danger of accidental contact with live 240/415 V wiring.

All wiring shall be ferruled at both ends with white cable marking ferrules having the identifying numerals and/or letters engrave and filled with a non-deteriorating black paint corresponding with the identification on the drawings. All terminals and labels shall be easily accessible after wiring and cabling has been completed.

Ferrules shall be of the ‘gripping’ type i.e. it shall not be necessary to strip the cable insulation for installation. 'C' type or saddle type clip on ferrules shall not be used. Critchley type Z or Grafoplast ferrules are preferred.

CT wiring shall be continuous, with no intermediate connections (e.g. inline crimps) between the CT secondaries and the first terminal strip.

4.7.3.1 Insulation

Wiring insulation shall be oil- and moisture-proof, and, where affected by temperatures above that of the ambient air, shall have thermal characteristics at least equal to class 'A' of IEC 60085.

4.7.3.2 Insulation test voltage

All auxiliary circuits shall withstand a test voltage of 2 kV r.m.s. to earth and to all other secondary circuits.

4.7.3.3 Type of conductor

All wiring shall be of single core, unsheathed multi-stranded, PVC insulated with copper conductor type. Wiring that will be outside sealed metallic enclosures shall also be nylon sheathed for the purpose of protection against termites and ants.

4.7.3.4 Protection of external wiring

Wiring shall be neatly loomed or installed in ducts. The Supplier shall state their standard method of installing small wiring in their Proposal.

Where wiring is installed in ducts, a maximum of 80 % of the duct volume shall be used. This is to allow for future additional wiring.

External wiring shall be either, in ducts, in a metal protective channel or in the form of armoured cable. Mineral insulated copper sheathed cables shall not be used.

Horizon Power shall approve (at Horizon Power’s complete discretion) the workmanship and detailed arrangement of cable looms and ducts. This approval shall be granted at the factory acceptance test, and any defects raised shall be rectified prior to shipping.

4.7.3.5 Multicore Cabling

4.7.3.5.a General

All cables used for interconnections between terminal boxes, temperature and other devices and the marshalling box shall be unarmoured black PVC.

Cables used for CT/VT secondaries and protection circuits shall be screened. All cables shall terminate on a gland plate. Cables with metallic screens shall use metal glands to allow for screen earthing (at both ends). All other glands shall be nylon with weatherproof shrouds fitted.

Glands shall be of a design that prevents entry of termites and 'Singapore' ants (monomorium destructor).

All cabling on the transformer shall be mounted off the tank surface and be adequately supported. This may be via cable trays using metallic saddles or by steel (or PVC coated stainless steel) ties. Nylon or PVC ties are not acceptable.

Cables shall have cores identified by ferrules as per clause 4.7.3 – Wiring. Cabling which cannot be left intact for dispatch shall be made up at the Contractor's work in correct lengths, complete with necessary support brackets, fixings, trays, terminal markings, identification labels.

4.7.3.5.b Responsibility for cabling by Horizon Power

Horizon Power (or third parties) will supply, install and connect up to the control cubicle all control, alarm and power cables from the control room.

This will include the following:

- A three phase and neutral 415 V supply to the control cubicle;
- 110 V and 24 Vdc supplies for alarm and control circuits (if applicable); and
- Any cables between transformers for paralleling.

4.7.3.6 Termination of wiring

Insulated crimp type lugs shall be used for all flexible wiring. Double bootlace lugs are not acceptable.

Where wires are required to be terminated in the one terminal, lip blade lugs (Utilux or equivalent) shall be used back to back. However, the preferred method is to use bridged terminals with each terminal having one wire.

All terminal blocks shall be as per clause 4.7.2. For stud type terminals e.g. at CT terminal box, complete circular eye type connectors shall be used complete with flat and spring washers.

Spare cores of multicore cables shall be parked in terminals and ferruled as "SPARE".

4.7.3.6.a Connections

Where insulation is stripped from the wires in order to make connections, the conductors shall be left clean and undamaged. Only the required minimum length of insulation shall be removed, preferably with a thermal stripping device.

4.7.3.6.b Termination of internal wiring and terminal boxes

All wiring connected to the terminals of auxiliary apparatus within the transformer tank shall be terminated at the terminals of a terminal box on the tank wall or cover plate.

These terminals, or tags permanently attached to them, shall be indelibly marked with the terminal marking of the corresponding terminal of the internal apparatus and also its wiring designation (see clause 4.5.8.1).

The terminal marking tags, where used, and the terminals themselves shall be so fixed to their respective bushings or barrier board that there is no possibility of the internal connection or the terminal slackening, or of the removal of the terminal marking tag during the process of applying or removing the external connection.

4.7.3.6.c Termination of external wiring

All wiring from alarm and tripping contacts, current transformer secondary terminal boxes or any other apparatus on the transformer requiring connection to external circuits, shall be terminated in a marshalling box situated on the transformer at a height approximately 1.5 metres above ground level.

4.7.3.7 Identification of wiring

All equipment boundary/interface terminals and the equipment wires connected to those terminals shall have a unique wire/terminal number in accordance with Horizon Power's drawings, see Table 18, Table 19 and Table 20.

The wires shall be marked with black letters impressed on a white background or black letters on a yellow background providing that the colour selected is consistent throughout the panel and/or suite of panels and is to the purchaser's approval.

4.7.3.8 Marshalling interface box

A marshalling interface box (MIB) with a standard terminal layout that includes all transformer terminals and tap change drive terminals for transformers with ratings up to 160 MVA shall be provided. The MIB shall consist of a single box that houses at least 116 terminals and shall be mounted on the side of a transformer. The manufacturer of the transformer shall supply and terminate a cable between the tap-change drive and the MIB to transfer the tap change functions, as specified in the MIB layout to the MIB. All normal transformer functions as specified in the MIB layout shall also be cabled to the MIB either directly or through a transformer terminal box.

Spare terminals may be used by the manufacturer to terminate any extra functions that will not normally be used in a Horizon Power application. He may however not deviate from the prescribed terminal allocation. Terminals indicating functions that are not provided by the manufacturer shall be left open.

The manufacturer shall fit partitions between terminals X1.26, X1.27, X1.28, X1.29, X1.30, X1.31, X1.32, X5.1, X5.2, X5.3, X5.4, X5.5, X5.6, X6.1 and X6.2.

Horizon Power will supply and terminate four 19-core 2.5 mm^2, one 4-core 4.0 mm^2, 4-core 16 mm^2 and two 10-pair twisted pair telephone cables between the MIB and the transformer protection and tap change control cabinet in the substation control room.

Table 18 – Standard layout for marshalling interface box fitted to transformers (cooling-related signals)

Device	Abbrev-iation	Terminal Number	Wire Marking	Application
Gas and oil relay	G.O.R.	X1.1 - XU X1.3-X1.4	X1.1 -X1.2 X1.3-X1.4	Trip Alarm
Pressure relief valve	P.R.V	X1.5-X1.6 X1.6 - X1.7	X1.5 -X1.6 X1.6-X1.7	Normal open contact Normal closed contact
On Load Tap Change Protection	O.L.T.C. Prot	X1.8 - X1.9 X1.9 - X1.10	X1.8 -X1.9 X1.9-X1.10	Normal open contact Normal closed contact
Oil temperature indicator	O.T.I	X1.11-X1.12 X1.13-X1.14	X1.11 -X1.12 X1.13-X1.14	Trip alarm
HV Winding temperature indicator	H.V.W.T.I	X1.15-X1.16 X1.17-X1.18	X1.15-X1.16 X1.17 -X1.18	Trip alarm
MV Winding temperature indicator	L.V.W.T.I	X1.19-X1.20 X1.21-X1.22	X 1.19 - X 1.20 X1.21 - X1.22	Trip alarm
Tert Winding temperature indicator	T.W.T.I	X1.23-X1.24 X1.25-X1.26	X1.23 - X1.24 X1.25 - X1.26	Trip alarm
Oil level indicator	O.LI	X1.27-X1.28	X1.27 - X1.28	Oil level alarm (High/Low)
Tap-change oil level indicator	O.L.T.C.O. LI	X1.29-X1.30	X1.29-X1.30	Oil level alarm (High/Low)
Cooler abnormal		X1.33-X1.34	X1.33 - X1.34	Common alarm for cooler
Fans/Pumps Thermometer		X1.35-X1.38	R, S, T, N	3 Φ Control supply
Fans/Pumps		X1.39-X1.41	X1.39+ - X1.40 - X1.41	110/220 Vdc Cooler stop and thermometer supply
MIB Heater Thermometer failure		X1.42-X1.43 X1.48-X1.49	X1.42 - X1.43 X1.48-X1.49	AC supply for MIB heater Thermometer failure alarm
Analogue output – Oil temperature		X150-X1.51	X1 50+ - X1.51-	Analogue output 4- 20 mA / 0-10 Vdc (IDC Terminals)
Analogue output - HV Winding temperature		X1.52-X1.53	X1.52+ - X1.53-	Analogue output 4- 20 mA / 0-10 Vdc (IDC Terminals)

Device	Abbrev-iation	Terminal Number	Wire Marking	Application
Analogue output - MV Winding temperature		X1.54-X1.55	X1.54+ - X1.55-	Analogue output 4- 20 mA / 0-10 Vdc (IDC Terminals)
Analogue output – Tertiary Winding temperature		X1.56-X1.57	X1.56+ - X1.57-	Analogue output 4- 20 mA / 0-10 Vdc (IDC Terminals)

Table 19 – Standard layout for marshalling interface box fitted to transformers (protection CT wiring)

Device	Terminal number	Wire Marking	Application
HV "A" phase CT	X2.1 -X2.2	1AS1 - 1AS2	Protection
HV "B" phase CT	X2.3 -X2.4	1BS1 - 1BS2	Protection
HV "C" phase CT	X2.5-X2.6	1CS1 - 1CS2	Protection
MV "a" phase CT	X2.7 -X2.8	1aS1 - 1aS2	Protection
MV "b" phase CT	X2.9 -X2.10	1bS1 - 1bS2	Protection
MV "c" phase CT	X2.11-X2.12	1cS1 - 1cS2	Protection
HV neutral CTs	X2.13-X2.14 X2.15-X2.16	1YNS1 - 1YNS2 2YNS1 - 2YNS2	Protection Protection
MV neutral CTs	X2.17-X2.18 X2.19 - X2.20	1ynS1 - 1ynS2 2ynS 1 - 2ynS2	Protection Protection
Tertiary "a" Phase CT	X2.21 - X2.22	1-3AS1 - 1-3AS2	Protection
Tertiary "b" Phase CT	X2.23 - X2.24	1-3BS1 - 1-3BS2	Protection
Tertiary "c" Phase CT	X2.25 - X2.26	1-3CS1 - 1-3CS2	Protection
HV "A" phase CT	X2.27 - X2.28	2AS1 - 2AS2	Protection
HV "B" phase CT	X2.29 - X2.30	2BS1 - 2BS2	Protection
HV "C" phase CT	X2.31 - X2.32	2CS1 - 2CS2	Protection
MV "a" phase CT	X2.33 - X2.34	2aS1 - 2aS2	Protection
MV "b" phase CT	X2.35 - X2.36	2bS1 - 2bS2	Protection
MV "c" phase CT	X2.37 - X2.38	2cS1 - 2cS2	Protection

Table 20 – Standard layout for marshalling interface box fitted to transformers (control and other wiring)

Device	Terminal number	Wire Marking	Application
	X3.1 -X3.4	x	3 Φ Motor supply
	X3.5-X3.6	L,N	1 Φ Heater and encoder supply
	X4.1 -X4.2	+, -	Tap change control DC supply (When required)
	X4.3 -X4.4	X4.3 -X4.4	Parallel check for even taps
	X4.5-X4.6	X4.5-X4.6	Parallel check for odd taps
	X4.7 -X4.9	X4.7 -X4.9	Local control Switch (7 Com, 8 Raise, 9 Lower)
	X4.10-X4.11	X4.10-X4.11	Seal In for raise operations (When required)
	X4.12 - X4.13	X4.12 - X4.13	Seal in for lower operations (When required)
	X4.14	X4.14	Initiate raise operation
	X4.15	X4.15	Initiate lower operation
	X4.16-X4.17	X4.16 - X4.17	Energise O/C block contactor (Negative may be commoned)
	X4.18-X4.19	X4.18 - X4.19	Trip motor supply MCB (Negative may be commoned)
	X4.20 - X4.21	X4.20 - X4.21	Motor supply MCB has tripped
	X4.22 - X4.23	X4.22 - X4.23	Indication for tap-change in progress
	X5.1 -X5.6	X500, X501, X502 X504, X508, X510	Binary coded decimal output to tap position indicator
	X5.7 -X5.12	X600, X601, X602 X604, X608, X610	Binary coded decimal output remote indication
	X6.1-X6.2		(Spare)

Interlocking "slip-on" types of ferrules are preferred and shall match the size of wire onto which they will be fitted.

For heavy conductors and very light wiring (telephone type) where the preferred type of marking ferrules is not available, other methods may be approved.

Ferrules shall be arranged to read upright on cable terminal strips and to read from terminal to insulation in the case of relay apparatus and instrument connections.

4.7.4 Secondary terminals

4.7.4.1 General

All terminals and associated mounting rails and markers used for connection of external circuits shall be in accordance with Horizon Power policy, subject to approval. Not more than two conductors shall be connected to any side of a terminal. The size of all terminals shall be suitable for the termination of two external cables of 4 mm² each.

The standard terminal block shall be the 10 mm screw clamp insertion type. Terminal blocks bearing Insulation Displacement Connectors (IDC) in one side shall be applied for interfacing with twisted pair telephone wires, as indicated in Table 18.

An appropriate stud-type terminal shall be applied for heavy duty supplies (e.g. cooler fan supplies).

4.8 Tanks

4.8.1 Component approvals

The components and fittings associated with transformers covered by this specification shall be subject to the purchaser's approval. Samples, technical literature, drawings, test reports and lists of the names of the principal users, with experience gained, shall be supplied on request. The burden however, is on the contractor to only submit components for approval to the purchaser if the components have been approved by the manufacturer for use on this transformer. Standardised, approved components already used by the purchaser are preferred to minimise spares holdings.

4.8.2 Materials and welding

Unless otherwise approved, metal plate, bar and sections for fabrication shall comply with BS EN 10025-1:2004, BS EN 10025-2:2004: Welding shall comply with AS 1554. Welds exposed to the atmosphere shall be continuous.

4.8.3 Corrosion protection and paint finish

4.8.3.1 General

Prior to corrosion protection, dye penetrant testing shall be done as described in clause 5.4.1.3. The interior and exterior surfaces of the tank, the tank cover and (when fitted) the conservator shall be either abrasive blast-cleaned or pickled, rinsed and dried, both in accordance with the procedures set out in AS/NZS 2312, AS 1627 and, immediately, prior to coating, shall be free from rust, grease, oil and moisture.

Abrasive blast cleaning shall only be used where the thickness of the steel plate is 3 mm or greater.

Special attention shall be given to the surface preparation of the welded areas of the covers and tank rims of sealed transformers. All spatter, slag and flux shall be removed and the areas cleaned back to bare metal immediately.

NOTE: - Recommendation: After the surfaces have been blast-cleaned, a coating be applied before contamination or oxidation of the surfaces can occur. For guidance, a coating should be applied not later than 4 hours after blast-cleaning.

4.8.3.2 *Coating of interior surfaces*

The interior surfaces of the tank, the cover and the cooling equipment shall be clean and dry immediately prior to filling the transformer with oil. Interior surfaces (other than those of cooling tubes and headers) above a line that lies at least 50 mm below the oil level that corresponds to an oil temperature of 20 °C shall be corrosion-protected by varnishing, priming or painting, using materials that are not affected by, or will not adversely affect the electrical or chemical properties of, the insulating oil.

NOTE: - Temporarily protect the remainder of the interior surfaces from corrosion (by varnishing, oiling or applying a corrosion preventative) until the transformer is filled with oil.

4.8.3.3 *Coating of exterior surfaces*

All transformer tanks and accessories (excluding radiators) shall be coated in accordance with Horizon Power's Standard for Coating and Colour Coding – HPC-9AJ-01-0001-2014.

All external surfaces, with the exception of the oil conservators shall be finished with an outer coat of enamel of colour in accordance with Cloud Grey.

The conservators shall be finished with an outer coat of colour in accordance with Horizon Power requirements.

4.8.3.4 *Nuts and Bolts*

Bolts shall comply with either AS 1111 or AS 1252 but only one grade bolt shall be used throughout the Contract. Nuts shall conform to either AS 1112 or AS 1252. The grade of nut shall be compatible with the bolt. Each bolt is to be supplied with a plain flat or tapered washer as applicable and a locking device. Split, star and other types of locking washers are not acceptable.

High strength bolts shall conform to AS 1252. Tightening shall be by the part turn of nut method. At the time of tensioning, each bolt shall be clearly marked to indicate that it has been correctly stressed.

All nuts, bolts and pins shall be locked in position in an approved manner. Wherever possible, bolts shall be fitted in such a manner that, in the event of the nut working loose and falling off, the bolt will remain in position.

If bolts and nuts are placed so that they are inaccessible by means of an ordinary spanner, a suitable special spanner shall be provided.

On outdoor applications, all bolts, nuts, studs, motor shaft and washers are to be hot dipped galvanised or stainless steel. Projection of bolts or studs through their nut(s) shall be more than one thread but less than four threads. All studs are to be welded into position.

The use of iron and steel shall be avoided in instruments and electrical relays wherever possible. Steel screws, when used, shall be electroplated, or when plating is not possible owing to tolerance limitations, shall be of corrosion-resisting steel. All wood screws shall be of dull nickel-plated brass or of other approved finish.

Instrument screws (except those forming part of a magnetic circuit) shall be of brass or bronze. Springs shall be of non-rusting material, e.g. phosphor bronze or nickel silver, as far as possible.

4.8.4 Tank construction

4.8.4.1 Shape

The shape of the transformer tank and fittings, including the under base shall be such that no water can be retained at any point on their external surfaces. Furthermore the lid on the inside shall be shaped to ensure that all free gas generated inside the transformer escapes to the conservator by way of the gas and oil actuated relay.

4.8.4.2 Cooling corrugations

Corrugated tanks will not be accepted unless approved in writing.

4.8.4.3 Guides for core and winding assembly

Guides shall be provided inside the transformer tank to correctly locate the core and winding assembly in the tank.

4.8.5 Tank strength and oil tightness

4.8.5.1 Rigidity

Transformer tanks and their associated components shall have adequate mechanical strength and rigidity to permit the complete transformer, filled with oil, to be lifted, jacked and hauled in any direction, and to be transported without structural damage or impairment of the oil tightness of the transformer, and without the necessity for the special positioning of sliding rails in relation to the tank.

Tank stiffeners shall not cover welded seams, to enable the repair of possible oil leaks. The tank and transformer as a whole shall be suitable for transport by low-bed or beam wagon.

4.8.5.2 Internal pressure and vacuum

Transformer tanks, complete with all fittings and attachments normally in contact with the transformer oil, and filled with oil of the specified viscosity shall withstand the pressure and the leakage tests prescribed in clause 5.4.2 – Routine oil leakage test.

4.8.6 Brackets for surge arresters

The surge arrester brackets used to mount the Primary, Secondary and Tertiary surge arresters to the transformer shall comply with the following requirements:

a) The surge arrester mounting brackets shall be provided to suit the dimension shown in Figure 7 – Surge Arrester Bracket.

b) The outline and dimension drawings provided in terms of a contract, shall show the surge arresters mounted on the transformer with all necessary clearances and sizes dimensioned.

c) Universal surge arrester mounting details, fully dimensioned, shall be shown in an inset on these general arrangement drawings.

d) Refer to clause 4.8.13 for the earth continuity requirements of the surge arrester brackets.

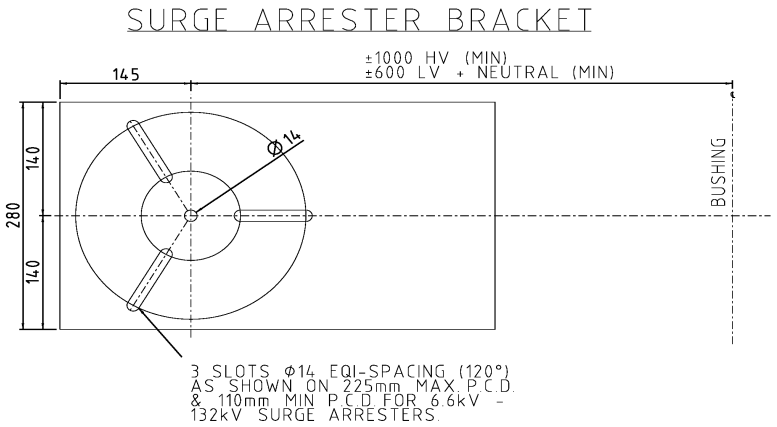


Figure 7 – Surge Arrester Bracket

NOTES:

a) All steel work shall be hot dip galvanized. No cutting. welding or drilling shall be done after the galvanizing process is completed.

b) Tolerance on dimensions shall be ± 2 mm

c) Tolerance on hole centres shall be ± 1 mm

d) Steel plate shall be 10 mm thick.

4.8.7 Magnetic flux effects

The tank and cover shall be designed so that local heating due to stray flux in any structural part shall not exceed the top oil temperature limit specified for the transformer, by more than 10 °C.

Heating, due to stray flux, shall also not cause local temperature elevations of more than 15 °C relative to the oil temperature at that level.

Thermometer pockets shall be located so as to avoid errors in temperature indication due to the heating effects resulting from stray flux.

4.8.8 Underbase

The underbase shall be suitable for the movement of the transformer in any direction, by sliding on greased rails, and shall be provided with four hauling eyes not less than 50 mm in diameter, as near as possible to the extremities of the length and width of the tank with not less than 100 mm working clearance above them.

Unless otherwise approved, transformer underbases shall have a thickness not less than that specified in Table 21. Fabricated bases shall not retain water. The position of the axial and transverse centre lines as shown on the dimension and foundation drawings shall be accurately stamped onto the tank at the base level, on both sides and at both ends, and indicated by means of a red enamelled mark at each point.

For foundation plinth tolerances refer to clause 4.23.2 – Foundation tolerances and site details.

Table 21 – Minimum thickness of transformer tank base plates – mild steel

Length of tank (m)	Minimum plate thickness (mm)
Fabricated bases not exceeding 2.5	10
Fabricated bases exceeding 2.5	12
Flat bases not exceeding 2.5	12
Flat bases over 2.5 m but less than 5 m	20
Flat bases over 5 m but less than 7.5 m	26
Flat bases exceeding 7.5 m	32

4.8.9 Jacking pads

Four suitably and symmetrically placed jacking pads shall be provided in positions accessible by typical means of jacking. Where jacking pads are not suitable for supporting the transformer during transit, they shall be suitably labelled (e.g. 'Not suitable for support while transformer in transit').

The position of the jacking pads shall be such that they do not restrict the direction in which the transformer could be moved (forward, backward and sideways) once off-loaded on site.

Each jacking pad shall be designed to support at least half of the total mass of the transformer filled with oil (with an adequate factor of safety).

Where jacking pads are suitable for supporting the transformer in transit, they shall meet the following requirements:

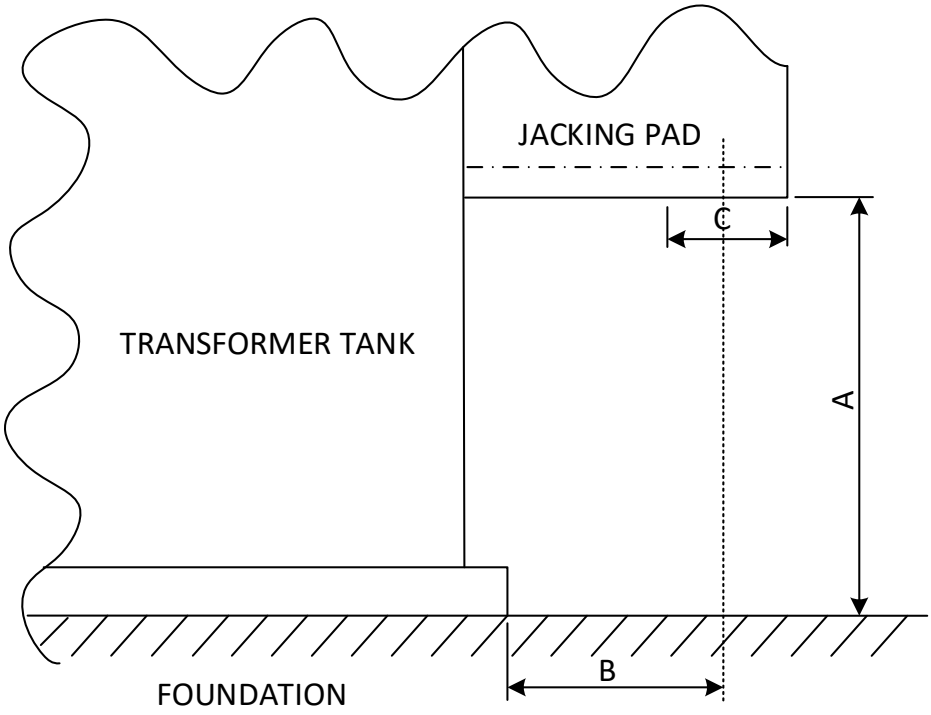
- Cyclical loading
- Design and factors of safety to allow for failure of one of the jacking points

Unless otherwise approved, the heights of the jacking pads above the bottom of the transformer base, and the unimpeded working surface of the jacking pads shall be as in Table 22 (read in conjunction with Figure 8).

Table 22 – Jacking pad dimensions

Transformer mass complete with oil (metric tons)	Min/max height of jacking pad above base "A" (mm)	Overhang to centre of jacking pad "B" (mm)	Unimpeded working surface of pad "C" (mm)	Width of symmetrical unimpeded access to jacking pad "D" (mm)
60 and below	460/530	115	170 × 170	230
Above 60	650/700	150	210 × 210	300
Access in direction 'E' shall be unrestricted.				

SIDE VIEW



TOP VIEW

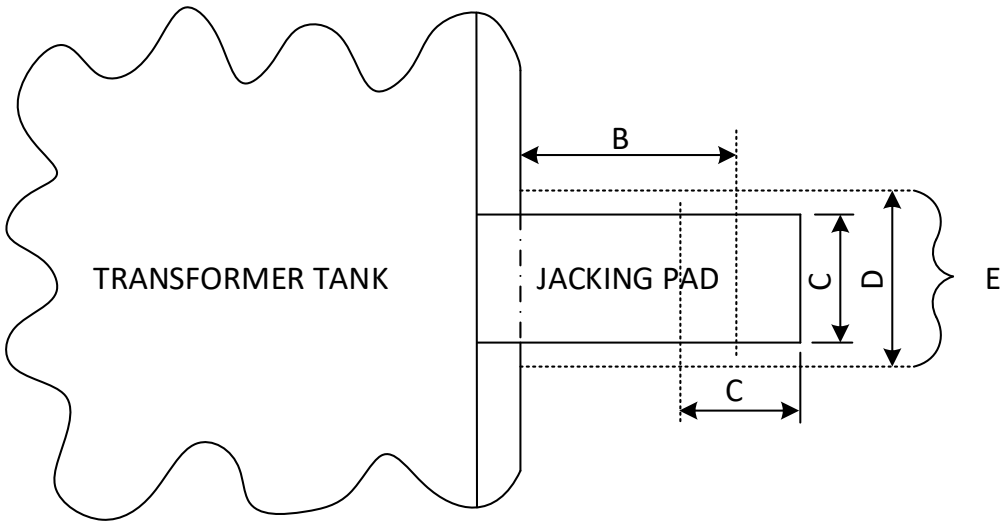


Figure 8 – Arrangement of jacking pads

4.8.10 Lifting lugs

Four symmetrically-placed lifting lugs shall be provided to allow lifting the complete transformer when filled with oil without structural damage to any part of the transformer. The lugs shall be designed with suitable safety factors to bear static load and dynamic load that may occur (e.g. shock, oil movement).

The lifting lugs shall be arranged and located to be accessible when the transformer is loaded on the transport vehicle, without damage to any transformer fittings or accessories.

4.8.11 Centre of Gravity

Centre of gravity shall be clearly visible and indicated on all sides of the transformer tank. This marking should not be degraded by the elements over time.

4.8.12 Pressure Relief Devices

Transformers rated below 100 MVA shall be equipped with one spring operated pressure relief device.

Each device shall:

a) Maintain its oil tightness under a static oil pressure equal to the static operating head of oil plus 20 kPa;

b) Attain its full opening in not more than 2.5 ms when subjected to an internal pressure impulse equal to the static operating head of oil plus 50 kPa;

c) Be capable of withstanding full internal vacuum at sea level;

d) Be fitted with a visual operation indicator plainly visible from ground level, and arranged for manual resetting;

e) Be equipped with normally open contacts that may be used to give electrical indication that the device has operated (see clause 4.6.3.9); and

f) Have an opening diameter of at least 100 mm.

Pressure relief devices shall be mounted so as not to entrap gases that may be generated or released inside the transformer. These devices shall be fitted directly to the side walls of the transformer tank at a level as near as possible to the top of the windings. Where one device is fitted it shall be positioned as close as possible to the centre phase. Where there are two devices they shall be arranged on opposite sides of the transformer, i.e. between 'A' and 'B' phases on one side and between 'b' and 'c' phases on the other. Alternative mounting positions, such as on the tank cover, may be considered if adequate mechanical protection can be provided to avoid inadvertent damage by erecting personnel. This shall be subject to approval by the purchaser.

A combined weather guard and oil deflector shall be fitted to ensure free deflection of the oil towards the ground and provide adequate protection from the environmental elements. Enclosed ducting shall be provided to channel any released oil down to ground level in the event of oil being released from the transformer during operation of the pressure relief device.

Because pressure relief devices are recognised to have a limited action for severe internal faults, alternative well proven devices to only detect pressure waves resulting from internal faults but not giving any pressure relief, may be submitted for consideration by the purchaser.

Despite any testing requirements in this specification the overpressure device shall not be influenced to generate invalid trip signals by tank vibrations and the magnetic fields generated during normal operation and through faults.

4.8.13 Provisions for Earthing

Provision shall be made for earthing the transformer and associated apparatus as follows:

a) Transformer tank earthing

At a height not less than 300 mm from the base of the transformer tank and near each end of each of the two major sides of the tank (i.e. in four positions).

These provisions shall take the form of earthing pads integral with the tank walls; where the pads are attached by welding, such welding shall be continuous around the perimeter of the pads. Earthing pads shall be stainless steel.

Provision shall be made for connection to the earthing pads of four galvanised steel straps (one per corner) each 80 mm x 6 mm, laid one upon another and clamped in position by a heavy clamping plate fastened by not less than two M12 studs or set screws with hexagonal heads and fitted with lock washers, spanning the width of the copper straps.

b) Transformer neutral(s) earthing (direct)

A stainless steel pad having the same clamping arrangement as the transformer earthing pads and integral to the transformer tank shall be provided for each transformer neutral terminal for earthing.

This pad shall be mounted as near as possible to its corresponding neutral terminal in order to ensure a short and steady connection to earth.

The manufacturer shall supply a suitably rated corrosion protected connection between the neutral bushing and the tank.

c) Transformer surge arrester earthing (line and neutral surge arresters)

The surge arrester mounting brackets shall be used as the earth path for surge arrester discharging to earth via the transformer tank (i.e. copper earth tails shall not be used for surge arresters).

Where brackets for phase and neutral surge arresters are to be fixed to the tank using tank mounted bolts, stainless steel pads (similar to the transformer tank earthing pads that form an integral part of the tank) shall be used. When these pads are attached by welding such welding shall be continuous around the perimeter of the pads.

Where brackets are not directly mounted onto the tank (on radiators) a separate suitably rated corrosion protected connection shall be provided to the earthing pad on the tank.

NOTE: - Bolted down surface contact areas of transformer surge arrester support brackets and earthing pads shall be free of any paint or metal spray coatings.

d) All tank attached apparatus, including cable marshalling boxes, tap-changer operating gear and mechanism boxes, and fan and pump motors shall be bonded to their supporting structures.

e) Earthing pads, as specified in clause 4.8.13(a), shall also be provided on each end of the supporting structures for all separately mounted cooler banks and oil conservators and on all free-standing cubicles, as well as any external earths.

f) No copper shall be used as connections for the purpose of earthing.

NOTE: - Integral pads to suit the fault levels indicated in Table 10.

4.8.14 Main tank covers

4.8.14.1 Shape

The main cover of the transformer tank may be flat, domed or of the "bell type".

Positive provision shall be made to guide any gas that may be developed toward the Buchholz relay.

This provision shall take into account the possible slopes of the plinth on which the transformer will be mounted.

The effectiveness of guiding gas in the transformer shall be tested by injection of a known quantity of gas into bottom drain valve furthest away from the Buchholz relay.

In order to avoid the undesirable and possible dangerous entrapment of gas in the transformer, this test shall be carried out prior to the final vacuum treatment of the transformer oil.

4.8.14.2 Lifting

Lifting lugs or eyes shall be provided, and the cover so arranged that it may be lifted and handled without permanent distortion.

4.8.14.3 Support

The cover may be supported from, but shall not support, the core and winding assembly (see clause 4.1.4.5 – Lifting facilities).

4.8.14.4 Gas venting

The transformer cover, and generally the internal spaces of the transformer and all relevant oil connections, shall be designed to provide venting of any gas in any part of the transformer to the gas and oil actuated relay.

Attention is drawn to the foundation tolerances specified in clause 4.23.2 – Foundation tolerances and site details and the testing requirement in clause 4.8.14.1.

4.8.14.5 Vacuum connection

All transformers with voltage ratings of 132 kV and above, with a minimum rating of 160 MVA shall have a 150 mm nominal diameter pipe flange, with bolted blanking plate and gasket, fitted at the highest point of the transformer cover plate, sufficiently clear of the latter to permit the manipulation of the nuts for the mating flange fixing bolts.

The position of the flange on the transformer cover plate shall provide easy access (e.g. between the transformer bushings) for the flexible vacuum pump tube.

The flange shall comply with the requirements of BS EN 1092, and with Table 16 of that standard.

The face of the flange shall always be in the vertical plane, and shall be suitably finished to provide an effective seal with an 'O'-ring housed in the mating flange.

4.8.14.6 Cover identification

The main tank cover shall have indelibly stamped into its edge below the "C"-phase bushing, the maker's serial number, which shall also similarly appear in the adjacent position on the edge of the main tank flange.

4.8.14.7 Thermometer pockets

A minimum of three thermometer pockets shall be provided including on fitted with a captive flanged screw plug and shall be suitably positioned for use with a thermometer to verify top-oil and winding temperatures.

Thermometer pockets shall be located so as to avoid errors in temperature indication due to the heating effects resulting from stray flux.

4.8.14.8 Currents flowing in tank cover and bushing turrets

To allow for the effect of induced loop currents and capacitive surge currents, the tank cover and bushing turrets shall be fixed to the transformer in such a way that good electrical contact is maintained around the perimeter of the tank and turrets.

Special care shall be taken in the vicinity of high current terminals.

4.8.15 Welding of cover

Joints, other than those that may have to be separated during transport or for maintenance in service, shall be welded.

The main tank/cover joint shall be welded. A fire-proof gasket shall be included to prevent foreign matter entering the transformer during welding.

The welded joint shall be designed to permit removal of the weld with minimum damage to the mating flanges and to leave them suitable for re-welding.

> **NOTE:** - Transformers small than 20 MVA may have bolted tank covers, provided bolts do not protrude directly into the tank and necessary gasket is in place see clause 4.8.16.

4.8.16 Gaskets: Types, material, re-tightening and welding

4.8.16.1 General

a) All gasketed joints shall be designed, manufactured and assembled to ensure long term leak and maintenance free operation.

b) Gasketed joints that need not be removed for normal maintenance or transport shall be welded in accordance with clause 4.8.15.

c) Details of all gasketed joints shall be submitted for approval.

4.8.16.2 Gasket Types

a) Bolt-on type tap-changers and selector tanks that require removal for transport or maintenance shall not use of O-ring type gasket joints. In these applications rectangular cord and groove joints where the nitrile rubber cord is not joined but passed twice around the perimeter with the loose ends at the bottom, are acceptable. Alternatively a flat nitrile rubber gasket with stoppers to prevent over compression will be acceptable.

b) All other gasketed joints shall be of the O-ring and groove type. The O-ring shall be manufactured from nitrile rubber or better.

Where approved non O-ring gaskets shrink and require re-tightening in order to avoid oil leaks, these shall be retightened in the second six months of service by the Supplier at no extra cost to the purchaser. The Supplier will be liable for all costs associated with leaks during the defects liability period.

4.8.16.3 Attachments to the transformer tank

Attachments to the transformer tank shall only be fixed by bolting them to the prepared flat surface of a flange facing, either integral with or welded to the tank and sealed by a gasket or O-ring to the mating flange of the attachment. Joints dependent on the sealing of screw threads, and direct welding of fittings to the tank will not be accepted.

4.8.16.4 Pipe joints

Oil pipes above 15 mm bore shall have flanged, gasketed and bolted joints. Flexible compression joints will not be accepted unless specifically approved. Joints dependent on the sealing of screw threads will not be accepted.

4.8.16.5 Drilling of pipe flanges

Except where otherwise stated, the drilling and bolting of pipe flanges and the mating flanges of fittings shall comply with BS EN 1092.

4.8.17 Access openings and covers

An appropriate number of suitably proportioned handholes and manholes shall be provided for easy access to the upper portions of the core and windings assembly, the lower ends of bushings, internal current transformers and the oil side of their terminal boxes (see clause 4.2.5).

4.8.17.1 Handles

Manhole covers shall be provided with stout handles to facilitate their removal.

4.8.17.2 Lifting lugs

Covers with a mass greater than 25 kg shall be provided with symmetrically arranged lifting lugs.

4.8.18 Fall restraint system

An appropriate fall restraint system shall be installed on top of the transformer tank, this may consist of either Maypole adaptor plates or stainless steel static line. The fall restraint system shall meet the requirements of AS 1891 and withstand a minimum load of 21 kN in any direction.

The fall restraint system may in no way impede the functionality of the transformer or access to any of the devices on the transformers or breach any of the required electrical clearances (see clause 3.7 and clause 3.9).

Construction of the fall restraint system shall be in-line with clauses 4.1.4, clause 4.8.2 and clause 4.8.3.

The Supplier shall specify in Schedule A in Appendix C, the kind of restraint system used and rated capacity.

4.9 Valves and oil sampling devices

All valves shall be stainless steel gate valves or stainless steel non-return valves complying with the requirements of AS 4041, unless otherwise approved. All valves shall be rated for 350 kPa working pressure at 120 °C.

Gate valves shall allow for the repacking of shaft seals while still in service.

Every valve shall be provided with an indicator to clearly show the position of the valve. Valves shall be installed so that indicators are clearly visible from the ground.

All valves shall be lockable in each position using standard 38 mm padlocks provided by Horizon Power.

4.9.1 Isolating valves

Suitably dimensioned isolating valves shall be provided:

a) at each point of connection to detachable cooling apparatus; and

b) at each point of connection to tap-changer compartments, cable disconnecting chambers and cable sealing boxes supplied from the transformer tank.

4.9.2 Filtering and drain valves

Not less than two 50 mm double-flange valves shall be provided. Where only two filtering valves are provided, one valve shall be located at the top of the tank adjacent to the oil conservator, and another at the bottom of the tank on the opposite end to give a cross current of oil during filtration (see clause 4.10.7).

The lower valve shall be a combined drain and filtering valve and, as such, shall be positioned so that it drains, as far as possible, all the oil from the transformer tank.

No valves shall be fitted by means of stud welding or welding to the main tank.

The tap-changer diverter chambers shall be fitted with 25 mm drain valves for maintenance purposes.

If inaccessible from ground level, they shall be piped down to 1.5 metre above ground level.

All drain valves shall be protected against mechanical damage. The means of mechanical protection shall be indicated on the general arrangement drawing.

4.9.3 Oil sampling devices

An oil sampling device consisting of a flange and drain plug (see Figure 9) or other approved device shall be provided in the following locations where applicable:

a) at the bottom of the transformer tank, bolted and fitted with O-rings to the free flange of the 50 mm drain valve specified in clause 4.9.2;

b) at the bottom of each separate tap-changer selector compartment;

c) on the free flange of the tap-changer diverter chamber; and

d) at the end of the main Buchholz relay sample pipe.

These points shall all be numbered on the sampling point with the number corresponding to the same point on the valve function plate (see clause 4.9.8).

All oil sampling devices to be accessible from ground level.

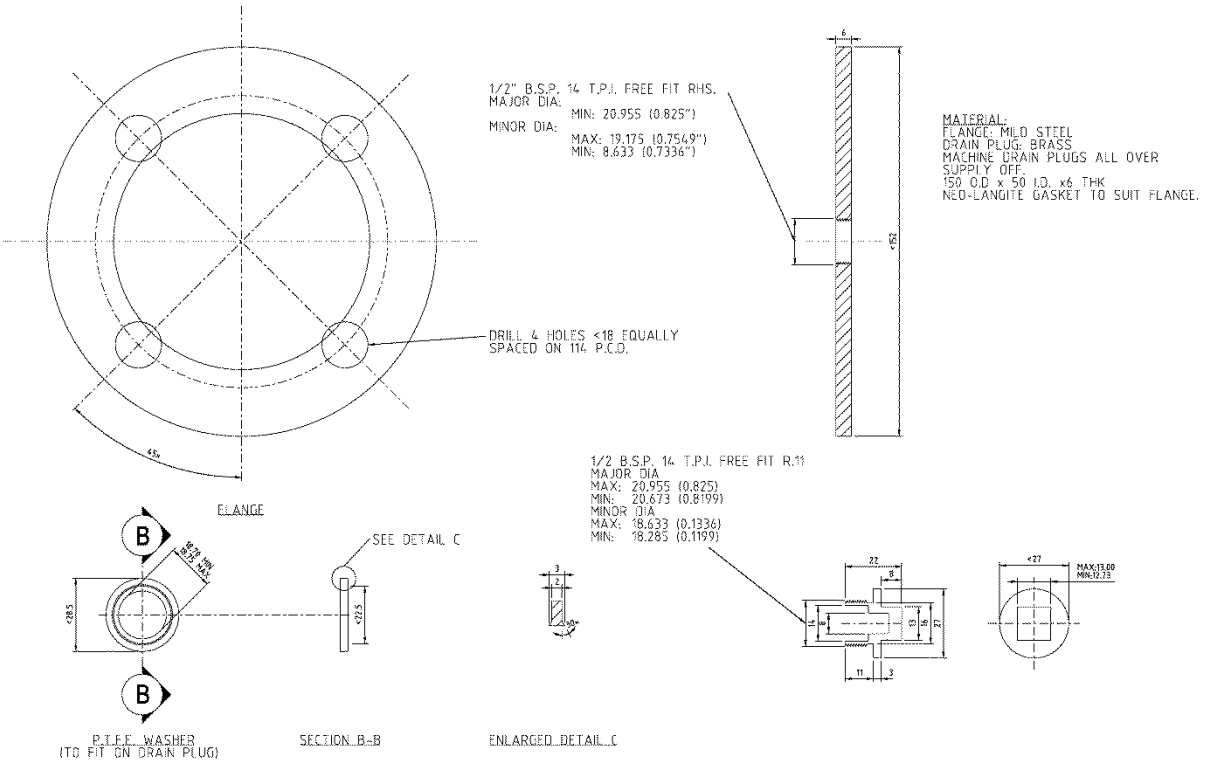


Figure 9 – Oil sampling flange interfaces

4.9.4 Strength and oil tightness

Valves and oil sampling devices shall be of adequate strength to withstand the hydraulic and mechanical loads imposed upon them during testing, processing and transporting of the transformer and in service. Pewter and similar low strength materials will not be accepted.

Valve discs, wedges, wedge facing rings, seats and seat rings, stems and spindles shall be of approved non-corrodible material. Valves and oil sampling devices shall withstand the tests specified in clause 5.4 – Transformer tank tests.

4.9.5 Valve stem seals

Valve stem seals shall be capable of adjustment in service without draining the transformer oil. In this connection, and generally, aluminium (or aluminium alloy) threads shall not mate with threads of brass valve stems.

4.9.6 Padlocking

Suitable means shall be provided for padlocking valves in both the open and closed positions.

4.9.7 Blanking plates

All valve entries communicating with the atmosphere shall be sealed using bolted and gasketed blanking plates, or captive screwed caps, or plugs as the case may be.

4.9.8 Valve function plate

A schematic diagram plate indicating all valves, vent plugs and sampling points shall be provided in the same manner as the rating and diagram plate (see 4.19 – Rating and diagram plates) indicating the position of each, the total number, the function and the required position during operation.

4.9.9 Valve position indication

The position of each valve, i.e. either fully open or fully closed, shall be clearly and unambiguously visible on inspection. Where this is not so, e.g. in the case of lever operated valves, the “open” and “closed” positions of the lever in relation to a clearly recognizable part of the transformer shall be depicted on the valve function plate specified in clause 4.9.8.

4.9.10 Labelling of oil sampling devices

All the oil sampling points, as specified in clause 4.9.3, shall be numbered the same as on the valve function plate with exception of the two routine sampling points that shall also be labelled as follows:

Table 23 Sampling Point Labels

Sampling point	Label
Main tank	MAIN TANK
Tap-changer compartments	TAP CHANGER
Tap-changer diverter chamber	TAP CHANGER DIVERTER
Buchholz relay	BUCHHOLZ

4.10 Oil conservator tank and connections

4.10.1 Capacity

The conservator for the main tank shall be designed to accommodate 120 % of the expansion volume of the oil between the average oil temperature range of 0 °C and 110 °C. Note also the requirements for the sump in clause 4.10.4.

Where the chamber of the tap changer containing the load making and breaking contacts requires it, an additional conservator shall be provided. This may take the form of an extension to the main conservator but two entirely separate compartments are to be formed. Under no circumstances shall the tap changer oil/gas be allowed to mix with the main tank oil.

The transformer shall nevertheless also be able to carry the overloads specified without overflowing.

4.10.2 Strength

The conservator shall be designed and tested to meet the requirements of clause 4.8.5.

4.10.3 Mounting

Oil conservators shall be mounted on the transformer tank.

Conservators shall be bolted on brackets to facilitate the complete removal of the conservator for whatever purpose.

The oil conservator shall fall in the direction of its main compartment drain valve by not less than 25 mm over the length of the conservator.

4.10.4 Sump

The connection to the transformer shall be positioned so that a level of oil not less than 10 % of the internal vertical dimension of the conservator with a minimum of 50 mm in the case of transformers with ratings up to and including 20 MVA and 75 mm for larger units, remains in the conservator after it has been drained to the transformer.

The conservator shall not have pockets that are not drained by the drain valve.

4.10.5 Removable end cover

The end cover of the conservator adjacent to the drain valve shall be attached by a bolted and gasketed external flange to facilitate internal cleaning of the conservator. In the case of a conservator that is partitioned to supply the tap-changer switch compartment(s), both end covers shall be removable.

These covers shall be provided with integral lifting lugs. The removal of these covers shall not be obstructed by pipework or fittings when the transformer is erected as in service.

4.10.6 Filling aperture

A filling aperture not less than 65 mm diameter, that is fitted with an air tight gasketed cover shall be provided at the top of each conservator.

4.10.7 Isolating/drain valves

a) A suitably dimensioned isolating valve shall be attached direct to the outlet of each oil conservator by a bolted and gasketed flange.

b) A 50 mm double-flanged valve shall be provided to fully drain each main tank conservator. This valve shall be mounted, on an extension pipe where necessary, approximately 1.5 metre above ground level.

c) A 25 mm double-flanged drain valve shall be provided to fully drain each tap-changer oil conservator.

d) Valves, flanges and flange facings shall comply with the relevant requirements of clause 4.9.

4.10.8 Pipework connections

Pipework connections shall be the correct size for their duty and shall be as short and direct as possible. Only radiused elbows shall be used. Pipework shall not obstruct the removal of tap-changers for maintenance.

The feed pipe to the transformer tank shall enter the transformer cover plate at its highest point and shall be straight for a distance not less than five times its internal diameter on the transformer side of the Buchholz relay, and straight for not less than three times its internal diameter on the conservator side of the relay. This pipe shall rise toward the oil conservator, through the relay, at an angle of not less than 5 degrees.

For transformers containing up to 10 000 litres of oil, the feed pipe diameter shall be not less than 50 mm, and for larger transformers it shall be not less than 75 mm.

Gas-venting pipes, as referred to in clause 4.8.14.4, shall be connected to the final rising pipe to the Buchholz relay as nearly as possible in an axial direction, and preferably not less than five pipe diameters from the relay, on the transformer side of the relay.

4.10.9 Sealed oil preservation system

Transformers of 40 MVA and above shall be equipped with a bagged main conservator. The materials, design and construction shall be subject to approval by the purchaser.

NOTE: - that the design and materials shall take the long life expectancy of the transformer into account.

High and low oil level alarm contacts shall be provided together with the oil level indication.

The bag or system shall not prevent or restrict the normal draining of the conservator or the flow of oil to the transformer.

The oil filling aperture shall be clearly marked to prevent oil filling into the bag.

The system shall be air tight.

The bag shall allow expansion without increasing the pressure or creating a partial vacuum over the full specified temperature range.

The rating and diagram plate shall bear a warning statement that the conservator is fitted with a bag.

The transformer manual shall give clear instructions on the operation, maintenance, testing and replacement of the bag.

4.11 Gas and oil actuated relays (Buchholz)

An approved gas and oil actuated relay suitable for operation in transformer oil as specified over the temperature range from 115 °C to –10 °C, shall be interposed in the connecting pipe between the oil conservator and the transformer tank in such a manner that all gas from the tank must pass through the relay as it rises to the oil conservator.

Contacts as specified in clause 4.6.3.9 shall be provided to close as follows:

a) the gas alarm signalling contacts shall be closed by the oil level falling to a predetermined point in the relay due, either to the deficiency of oil, or to the presence of gas in the relay;

b) the gas tripping contacts shall close on a further lowering of the oil level to a point before the gas escapes to the conservator. If this cannot be achieved the gas alarm signal shall be used for a gas trip signal in which case this arrangement shall be subject to approval by the purchaser;

the surge tripping contact shall close when there is a surge of oil through the relay towards the conservator with a rate of flow not less than that stated in Table 24.

Table 24 – Gas and oil actuated relays oil flow rates for closure of surge contacts

Transformer total oil content (kL)	Relay nominal size (mm)	Limits of minimum steady oil flow rate (mm/s)
Up to 1 kL	25	Between 700 and 1300
1.001 to 10 kL	50	Between 750 and 1400
10.001 to 50 kL	75	Between 900 and 1600
Above 50 kL	75	Between 1500 and 2500

The performance of the relay shall be demonstrated as specified in clause 5.4.22 – Routine oil leakage test.

4.11.1 Relay stability

In addition to the tests specified in clause 5.2 – Transformer Tests, the relay shall withstand the contact tests specified in clause 5.3 – Tests applied to devices with alarm and tripping contacts.

No mal-operation of the relay shall result from starting or stopping the transformer oil circulating pumps under any oil temperature conditions. Stability, in this regard, shall not be achieved by the use of pipe or relay aperture baffles to the impairment of sensitivity to oil surges as specified.

4.11.2 Magnetic influence

Despite the testing requirements of this specification, the relay shall not operate for through fault conditions or be influenced by the magnetic fields around the transformer under normal or external fault conditions.

4.11.3 Mounting and marking of relays

Pipe mounting flanges and relay lengths between flange facings shall, unless otherwise approved, comply with Figure 9 and preference will be given to relays that are, in these respects, interchangeable (see clause 4.10.8). Each relay shall bear clear indication as to which is the conservator end.

4.11.4 Windows

Unless otherwise approved, two graduated windows shall be provided in opposing sides of the relay and so arranged that the oil level in the relay may be clearly gauged. The internal surfaces of the relay shall be finished in glossy white, oil resistant enamel.

4.11.5 Gas release and oil sampling cock

An oil tight gas release cock, terminated in a threaded (6 mm) air connection fitted with a captive screw cap, and communicating by a small bore non-ferrous tube to the top of the relay body, shall be located approximately 1.5 metre above ground level. The tubing shall be protected against physical damage by appropriate routing, fastening and/or protective conduit.

4.11.6 In-situ testing

Each Buchholz relay shall have an internal test nozzle for simulating the gas alarm, gas trip and surge trip signals by injecting gas into this nozzle. The nozzle shall be piped down to a height of 1.5 metre above ground level in the same manner as the gas release cock specified in clause 4.11.6.

Alternatively, an approved mechanical device that operates the float mechanism and not just the switch contacts, may be provided.

4.11.7 Oil tightness and strength

The relay shall withstand the internal pressure and vacuum conditions specified in clause 4.6.3.2.c without damage and without leakage of oil, either externally or into its terminal box, and, in the case of the application of vacuum, without ingress of air.

4.11.8 Electrical connections, terminals and terminal box

In general, these shall comply with the requirements of clause 4.7. The gauze covered drain and vent hole in the terminal box on the relay (see clause 4.7.2.2) is, however, not required.

The terminal box cover gasket shall be confined to the perimeter of the cover where sealing is required, i.e. the central area of gasket material over the terminals shall be removed.

A suitable water-tight and weather resistant electrical conduit threaded cable entry shall be provided.

The alarm signalling and the tripping contacts shall be electrically separate and independent, and shall be externally connected as specified in clause 4.7.3.6.

4.11.9 Devices for the protection of relay contacts

Where the manufacturer deems it necessary to protect the relay contacts (see clause 4.6.3.9) from the effects of cable capacitance or electromagnetic relay inductance by means of resistor-capacitor snubber circuits or diodes, he shall provide and fit these items, preferably in the relay terminal box, or alternatively in the marshalling box on the transformer. Such designs shall be subject to the purchaser's approval.

4.11.10 Type and routine testing

The Buchholz relays shall meet the requirements of the tests specified in clause 5.4.22 – Routine oil leakage test.

A standard test card bearing the manufacturer's serial number for the relay shall be included with each of the operating instruction manuals supplied for each transformer.

4.11.11 Assembly, operating and maintenance instructions

Original and fully detailed instructions for assembly, operation and maintenance of the relay shall be included with each of the operating instruction manuals for the transformer.

4.11.12 Floats

The buoyancy of the floating elements shall be due to their specific gravity and shall not depend on the sealing of a hollow float. The materials shall not be affected by hot transformer oil.

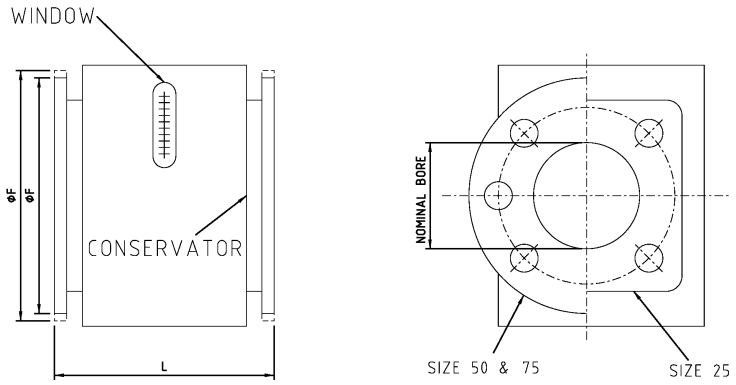


Figure 10 – Buchholz relay outline drawing and sizes

Table 25 – Buchholz relay dimensions

Relay Size & Nom. Bore (mm)	Length L (mm)	Flange Size – F (mm)	Bolt Holes		
			No	Size (mm)	PCD (mm)
25	127	Φ 75	4	Tapped M10	72
50	185	Φ 140	6	12	110
75	185	Φ 160	6	12	130

NOTES:

a) Flanges to be drilled off-centre to the vertical

b) All dimensions in millimetres

4.12 Dehydrating breathers

4.12.1 General

With the exception of oil-filled bushings and bushing mounted, tap-changer diverter switch compartments operating at line or tapping potential, the oil in conservators and other oil-filled compartments shall only be in contact with the atmosphere through a dehydrating breather approved by the purchaser.

No single breather shall carry a silica gel charge in excess of 12.5 kg. Where the required quantity exceeds this mass it shall be subdivided into a sufficient number of individual compartments arranged in series. A single atmospheric oil seal shall be provided to serve the entire breather group. The breather shall be carefully designed for easy and frequent changing of the silica gel charge by non-specialist maintenance personnel.

4.12.2 Type of breather

Unless otherwise approved, a desiccating breather using cobalt impregnated silica gel, complying with BS 3523, shall be provided.

The gel shall indicate blue when dry, and change colour to pink indicating saturation of moisture absorption.

Breather proportions:

The silica gel charges contained in the dehydrating breathers shall not be less than 0.3 kg per 1000 L of total oil content, with a minimum of 2 kg.

4.12.3 Diffusion of air through the desiccant

The silica gel charge shall be so supported and positioned that the air passing through the charge shall be diffused throughout the charge so as to contact all gel particles in the charge and, in particular, those that can be seen from the outside or through the window provided for this purpose.

4.12.4 Air intake during starting of oil circulating pumps

The positioning and proportions of the dehydrating breather shall be such that air inhaled during starting of oil circulating pumps shall receive adequate dehydration and shall be such that the oil in the atmospheric seal shall not be drawn into the breather unit(s) during this operation, nor blown out of the oil seal during the operation of stopping the oil circulating pumps.

4.12.5 Containing of the silica gel charge

The silica gel charge shall preferably be contained in a transparent and independent container of weatherproof, UV and heat resistant (up to 115 °C) material, that may be simply and easily removed and replaced without the use of special tools.

In the case of multi-unit breathers each separate charge shall be independently retained upon removal of the oil seal.

4.12.6 Visual inspection of the desiccant

Unless the container for the silica gel charge is transparent an inspection window, at least 50 mm wide, shall be provided to allow inspection of the colour and condition of the silica gel. The inspection window shall be positioned to make the desiccant visible at both ends and for the full length of each cartridge.

Windows or containers of heat resistant glass or other fragile material shall be protected using metal grids.

4.12.7 Seals

The breather desiccant shall not be in contact with the atmosphere unless the transformer is breathing, but shall be sealed by a device containing a quantity of transformer oil.

The designed oil level in this device shall be clearly marked. The seal shall preferably be constructed of heat-resistant glass.

All other seals on the breather shall be effected using oil-proof and air tight gaskets that shall be effectively retained when dismantling the breather for the purpose of changing the desiccant charge.

4.12.8 Castings

Where cast components are used they shall be high quality, non-porous castings.

4.12.9 Corrosion proofing

Corrosion shall be eliminated by the use, wherever possible, of non-corrodible materials, and by avoiding the contact of dissimilar metals.

The corrosion proofing shall be in accordance with clause 4.8.3.

4.12.10 Mounting and pipework connections

Dehydrating breathers shall be mounted approximately 1.5 metre above ground level.

Connection shall be made to a point in the oil conservator not less than 50 mm above the maximum working oil level (i.e. top oil temperature 115 °C), by means of a pipe with a minimum diameter of 20 mm in the case of breathers less than 10 kg in total mass, and a minimum diameter of 25 mm for units of 10 kg and above.

Breathers with a mass less than 10 kg may be supported by the connecting pipe, whereas units of 10 kg and above shall be supported independently of the connecting pipe.

Connecting pipes shall be securely cleated to the transformer, or other structure supplied by the manufacturer, in such a manner as to eliminate undesirable vibration and noise. In the case where a breather of less than 10 kg is supported by the pipe, there shall be a cleat directly above the breather flange.

Pipe connections shall comply with clause 4.8.16 unless otherwise approved.

4.13 Oil level indicators, alarm and signalling devices

4.13.1 General

The oil level in conservators and oil-filled chambers with a free oil level, shall be clearly indicated when viewed from ground level by approved weatherproof oil level indicators. The indicators shall be suitable for the design, i.e. free breathing or bag type conservators.

4.13.2 Range of indication

The oil level indication shall be continuous over the range of top oil temperature from -10 °C to +115 °C.

The level of oil in the conservator corresponding with the –10 °C index shall be not less than 25 mm above the transformer feed pipe entry.

4.13.3 Graduation of indicator

The oil level indicator on the oil conservator connected to the transformer tank shall bear the following markings:

If the indicator is the dial-type, the words “FULL” and “EMPTY”, shall be appropriately placed. (Dial type indicator pointers shall move from "Empty" to "Full" in the clockwise direction).

Graduations indicating the normal oil levels at oil temperatures of 15 °C, 30 °C, 45 °C, 60 °C, 75 °C and 90 °C.

4.13.4 Dial-type indicator

These shall be the magnetically operated type in which breaking the glass will not expose the oil to the atmosphere.

Floats used for the indicator shall comply with clause 4.11.13.

The vibration of the transformer shall not produce wear and damage to the mechanism of the indicator.

4.13.5 Gaskets

Gaskets shall be as specified in clause 4.8.16.

4.13.6 Mounting

Oil level indicators shall be arranged for front-end mounting without requiring access to the inside of the oil conservator or chamber.

4.13.7 Low and high level alarms

Transformers will have low and high level alarm contacts fitted, these contacts are to be paralleled.

A pair of circuit-closing, potential free, low oil level alarm signalling contacts shall be provided in each oil conservator. These contacts shall be set to close at the -10 °C point.

A pair of circuit-closing, potential free, high oil level alarm signalling contacts shall be provided in each oil conservator. These contacts shall be set to close before the oil is pushed into the breather pipe (see clause 4.12.10). Contacts shall comply with the requirements of clause 4.6.3.9.

4.14 Cooling arrangements

4.14.1 Type of cooling required and ONAN rating

Cooling arrangements shall be provided for the transformers as follows:

a) ONAN or

b) ONAN/ONAF cooling.

4.14.2 Hot oil connection point

Hot oil to the transformer oil cooling apparatus shall be drawn off, as far as practicable, from the highest point in the transformer tank to eliminate stagnant oil volumes below the cover-plate.

4.14.3 Electrostatic charging tendency (ECT)

The manufacturer shall guarantee that the transformer will be free of any deleterious electrostatic charging tendency throughout its life, under all operating conditions and in particular with all cooling and oil circulation systems simultaneously in operation. The purchaser will not accept any restrictions on the maximum number of cooling systems/pumps that may be operated simultaneously, irrespective of the cooling demand. Furthermore, the purchaser will not accept any restrictions in the type of oil that may be used in the transformer.

The manufacturer shall submit evidence or tests to prove that there is no electrostatic charging tendency in the design of his transformers.

4.14.4 Oil and Winding temperature measurement and settings

4.14.4.1 General Requirements

One or more digital-type thermometers, fully compensated for the effects of ambient temperature, shall be provided, catering for the measurement of the transformer “top-oil” temperature and the winding hot-spot temperature. Where possible, the oil and winding temperature measurements may be effected by a single instrument.

The device/s shall include mass storage of a complete database of all oil and winding temperature readings with an internal data RAM capable of storing six months of half hourly data. The database shall not be lost in the event of a loss of auxiliary supply to the instrument.

The instrument/s shall be rail mounted within the marshalling cabinet. The instrument/s shall employ PT100 sensors for temperature measurement in accordance with IEC 751.

The device/s shall include the following features:

a) Ethernet interface utilising a ST optical fibre connection and supporting the IEC 61850 networking protocol.

b) An USB interface of local communication to a personal computer.

c) An analogue output signal for each oil/winding measurement. The range shall correspond to -20 °C to +140 °C.

d) Windows based software.

e) Self-diagnostic functions, including a normally-open watchdog contact. The watchdog shall be opened in the event of a loss of auxiliary supply to the device, an internal device failure, or for a defective temperature sensor.

f) Dual rated auxiliary supply of 110 V dc and 220 V dc. The latter requirement may be achieved using a suitable dropping resistor together with the 110 V dc device.

g) The device enclosure shall be rated to IP56 or higher in accordance with IEC 60529.

NOTE: - Analogue thermometers are acceptable, though digital are preferred. Analogue thermometers shall provide alarm and trip voltage-free relay contacts and are to be installed in the marshalling cabinet.

4.14.4.2 Oil temperature measurement

The oil temperature thermometer shall provide local and remote indication of the transformer "top-oil" temperature. A typical overall measurement accuracy of ±1 °C is expected.

The instrument shall record the maximum oil temperature in a given time period, arranged for manual resetting, and with one alarm signalling and one tripping contact as specified in clause 4.6.3.9, that can be manually set to close at predetermined temperatures which, unless otherwise specified, shall be:

Alarm: 120 °C, Trip: 140 °C

The oil temperature instrument shall include a suitable hysteresis characteristic so as to avoid hunting/output contact jitter.

4.14.4.3 Winding temperature measurement

The winding temperature thermometer, fully compensated for the effects of ambient temperature, shall be provided and shall have a load-temperature characteristic approximately the same as the hottest part of the windings. The current transformer/s for operating the thermometer/s shall be built into the main transformer tank and shall be located so as to reflect the maximum hot-spot temperature of the respective windings.

This device shall provide local and remote indication of transformer winding temperature.

The hot spot temperature and transformer lifetime shall be calculated in accordance with AS 2374.7.

A separate winding temperature calculation shall be made for each loaded winding of the transformer, except in the case of two-winding transformers which shall be use a single winding temperature calculation arranged to provide a thermal image of the maximum overall winding hottest-spot.

The instrument shall record the maximum winding temperature in a given time period, arranged for manual resetting, and with alarm signalling and tripping contacts. An alarm contact, that can be set to close at a predetermined temperature, shall be provided in addition to a contact to be used for tripping purposes. Alarm and tripping contacts shall comply with the requirements of clause 4.6.3.9. The alarm contact circuits of all winding temperature measuring instruments shall be paralleled, and the trip contact circuits paralleled and each brought out to a pair of terminals. Unless otherwise specified, the alarm and trip settings shall be:

Alarm: 120 °C, Trip: 140 °C

Where supplementary forced cooling is provided, an additional pair of contacts, or an additional thermal or auxiliary relay shall be provided to automatically start the oil pump and/or fans for cooling the transformer. These contacts shall be self-resetting. Alternatively, the start signal may be derived from a current relay. The winding temperature instruments shall include suitable hysteresis characteristics to avoid hunting/output contact jitter.

Terminals shall be provided in the marshalling box or, where provided, the cooler controller cabinet for checking the output of the current transformer and/or the functioning of the heater coil by means of an external supply.

NOTE: - Digital temperature thermometers shall cater for programmable rated gradient, load current exponent and winding constant for up to 4 cooling groups. A device using the calculation methods of AS 60076.7 shall be used in preference to one using the IEC 60351 methods once such devices, acceptable to Horizon Power, become commercially available.

4.14.5 Construction details

The requirements of clause 4.8 shall, wherever they are relevant, apply equally to the cooling apparatus provided for the transformer.

Pipework and coolers shall be arranged to permit free access to oil conservators, tapping mechanism boxes, terminal and marshalling boxes and any items requiring inspection or maintenance in service.

In order to facilitate painting of non-detachable (non-galvanized) cooler tubes on site, a minimum of 80 mm shall be allowed between adjacent tubes and between these and the transformer tank.

All joints between tubes and the header shall be welded outside the header to reduce the possibility of corrosion in the seams.

4.14.6 Detachable radiators

Detachable radiators shall be provided with:

a) lifting lugs,

b) drain valves or plugs, at the lowest points,

c) vent plugs, at the highest points, and

d) flanged and bolted isolating valves at both points of attachment to the transformer tank or cooler bank.

4.14.7 Radiator corrosion protection

Radiators shall be coated by a system as specified in AS 2312, where radiator tubes of 1.6 mm thick walls are used, and the minimum coating thickness of hot dip galvanising is at least 100 microns.

4.14.8 Separately mounted cooler banks

Where separately mounted radiator (cooler) banks are provided, drawings shall indicate the maximum overall dimensions of the transformers including separate cooler banks.

It shall be assumed that separately mounted cooler banks will be mounted on separate plinths from the transformer tank and that the maximum relative movement between these plinths will not exceed 10 mm.

Expansion couplings, used in connection pipework between transformers and separate cooler banks, shall be subject to the purchaser's approval see clause 4.17.

The arrangement of the cooler banks shall comply with 3.8 Physical arrangements and the earthing provisions shall comply with clause 4.8.3.

A filtration valve (see clause 4.9.2) shall be provided at the top and bottom of each separately mounted cooler bank.

4.14.9 Forced cooling

4.14.9.1 Cooler control and settings

Forced cooling equipment for system transformers shall be designed for automatic operation by a winding temperature thermometer or current level contacts set at predetermined temperatures/currents. Generally the manufacturer's standard settings for the starting of fans and pumps shall be used, otherwise a setting of 65 °C or 0.6 pu current shall apply.

The cooler switches shall be suitably labelled.

4.14.9.2 Cooler control equipment

All the necessary automatic control, motor contactors, protective devices, and switches for the forced cooling equipment shall be housed in an IP56 rated cabinet. This cabinet shall be mounted on the transformer tank using approved anti-vibration mountings on the transformer tank. Hinged door(s), handle(s), locking facilities, a separately fused 240 V single-phase heater and switch, and a separately fused lamp with door switch shall be provided.

The heater shall be rated and located so that none of the apparatus in the cabinet will suffer damage due to prolonged operation of the heater at high ambient temperatures.

Tap-changer control equipment may also be housed in this cabinet.

4.14.9.3 The cooler control equipment shall include:

a) an isolating switch rated to carry and break full-load current for each group of fan and pump motors;

b) a "manual"/"auto" change-over switch;

c) a magnetic contactor for each group of fan and pump motors. Contactor coil leads shall be wired to the terminal board. A set of normally open contacts shall be provided to initiate an alarm circuit if the contactor is tripped by its overload element. All such contacts of the various groups shall be paralleled and wired to a pair of terminals in the control cabinet.

   Magnetic contactors shall maintain supply to motors at supply voltage down to 0.85 pu of the rated supply voltage at their terminals. Tripping shall only occur on a controlled basis and there shall be automatic restarting in the staggered mode if the voltage recovers while the transformer is in service; and

d) provision for disconnection of all cooling pumps and fans on the closure of a pair of contacts provided by the purchaser on the master tripping relay controlling the isolation of the transformer on the occurrence of a fault.

4.14.9.3.a The ratings of these contacts will be:

a) Make and carry continuously: 1250 W at maxima of 5 A and 660 V.

b) Make and carry for 0.5 s: 7500 W at maxima of 30 A and 660 V.

c) Break: 100 W resistive

d) 50 W inductive as defined in BS EN 60255-22-4: i.e. L/R = 40 ms.

The arrangement for disconnection of the oil pumps and fans shall not be self-resetting.

The cooler failure relay is to monitor all three phases and the cooler supply failure alarm to have a 4 s to 10 s timer fitted to prevent unnecessary signalling.

A change-over relay shall be provided in the control scheme. A contact of the trip relay, on the purchaser's protection panels will energise the operating coil of this change-over relay which in turn shall isolate the contactor control circuits. A reset push button shall be provided in the marshalling kiosk for resetting the change-over relay. The operating coil of the relay shall be continuously rated, or a make contact of it shall be wired in series with the operating coil and a break contact in series with the reset coil (see Figure 11 – Preferred cooler stop circuit Figure 11).

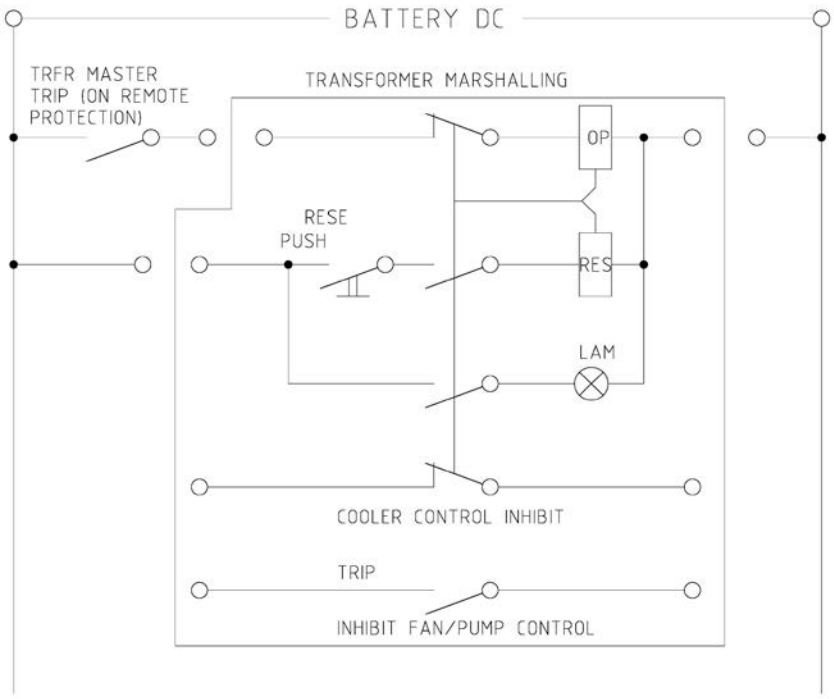


Figure 11 – Preferred cooler stop circuit

Where a contactor is supplied for this purpose, the operating coil shall be suitable for operation by way of the above mentioned contacts and shall operate and reset correctly between 80 % and 120 % of the DC auxiliary supply voltage specified in Schedule A of an enquiry document. The contactor shall have one set of normally closed contacts, which shall isolate the fan and/or oil pump motor control circuit(s). A N/O contact is to be provided for alarming purposes.

4.14.9.3.b Contactors shall comply with the provisions of AS 60947:

a) for staggering the starting times of oil pumps and fans or of individual groups of fans as required;

b) or overload and single-phasing relays;

c) for winding temperature and oil-temperature indicators, that shall be visible through a window in the door of the cabinet if installed in the same cabinet;

d) for links for testing winding temperature relay, and interposing current transformer;

e) for fuses, links and terminal boards (see clause 4.7) to make a complete assembly; and

f) for labelling of all apparatus, that shall be inscribed indelibly in black lettering on a white background and that will not discolour in long term service.

4.14.9.4 Fans

Fans and fan-motors shall not require concrete foundations.

Fan blades and fan ducting shall be of aluminium alloy, stainless steel, galvanized steel or other corrosion- resistant material and shall be designed to keep noise and vibration to a minimum. All fans shall be provided with galvanized wire-mesh guards. The rotation and air flow directions shall be clearly and indelibly indicated by appropriate arrows. Fans shall be mounted on anti-vibration dampers. Fan motors shall comply with AS 1359 and shall be 3 phase induction motors suitable for D.O.L. starting and continuously rated at 415 volts ± 10% 3 phase, 50 Hertz at an ambient temperature of 45 °C. The motor rating and frame size shall be selected from AS 1359.

Mesh guards shall be provided on all fans to prevent accidental contact with moving parts.

4.14.9.5 Motors

All motors shall be suitable for direct starting and continuous running from the 415 V supply voltage.

Three-phase motors are preferred but single-phase motors of 0.5 kW and less will be acceptable.

All motors shall comply at least with AS 1359 and shall be of the totally enclosed weather-proof type.

Three-phase motors shall be of the single-cage squirrel cage type. Bearings of all motors shall be of the ball or roller bearing type. With the exception of oil-pump motors, the bearings shall be grease lubricated.

Each motor shall be equipped with a terminal box arranged to accommodate the incoming cable provided by the manufacturer (see clause 4.7). If necessary, a suitable cable box shall be provided to terminate the cable.

Motors shall be provided with starters, overload protection (three-phase where applicable) and, in the case of three-phase motors, single-phasing protection.

All motors shall be labelled indicating kW and A ratings.

4.14.9.6 Maintenance

Fans/pumps/motors shall be installed to facilitate their easy removal in the event of failure. Although very low maintenance is desired, lubrication and servicing instructions, if required, shall be clearly stated in the transformer manual. If deemed necessary by the purchaser, labelling shall be provided at each pump or fan.

4.15 Quality and design review requirements

4.15.1 Quality

Where the tender conditions allow the purchaser to visit the supplier's facilities, this may be done to assess the manufacturer's capabilities and the quality of his products and processes.

Where the purchaser has specified 'Type 3' application of quality management in the contract, this specification is effective as the 'specified requirements'. Conformance with these requirements may be determined by the purchaser's inspection.

4.15.1.1 Quality Assurance Inspection Plan

The Supplier shall employ an established Quality Assurance Inspection Plan (QAIP) and shall submit a copy with the proposal. The QAIP shall be made available by the Supplier to Horizon Power at all stages of the manufacturing process, AND LOCATED AT THE WORK AREA.

The QAIP shall be to the approval of the Superintendent and shall as a minimum, include the following:

a) Indication of each inspection and test point and its relative location in the production cycle including incoming, packaging and site inspections.

b) Identification of the characteristics to be inspected, examined and tested at each point and specification of procedures and acceptance criteria to be used.

c) Indication of hold points, established by the Superintendent or his representative, which require approval and signature before further programmed work can proceed.

d) Reference to quality assurance procedures governing the work of the Supplier's subcontractors.

4.15.1.2 Quality assurance management system

For this Specification the required level of Quality Assurance Management System is:

a) The Supplier is required to have third party certification to ISO 9001; or

b) Alternatively, where the Tenderer has not yet achieved certification to the required standard the Tenderer will be required to:

- Demonstrate to Horizon Power's satisfaction that its executive management has the same commitment to the philosophy of quality as other principal functions of its organisation; and

- Provide detailed information concerning that part of its organisation charged with the responsibility of maintaining levels of quality and actions necessary should the work under the Contract fail to meet the specific quality standard; and
- Submit a detailed inspection and test plan that it will implement during the performance of the work under the Contract.

4.15.2 Technical Evaluation / Design Review

Technical Evaluation and Design Reviews will be conducted by Horizon Power at different stages of the procurement process for transformers.

The information given in Schedule A in Appendix C will be reviewed. Visits to the Supplier's (manufacturer's) works to inspect design, manufacture and test facilities may also take place.

The Design Review will commence after order placement, but before manufacturing commences.

The reviews will be more detailed and related to the specific design of the transformer on order. For this stage the design control element of ISO 9001 shall apply.

The scope of such a review shall include the following:

1) Core design
2) Winding and tapping design
3) Thermal design
4) Insulation co-ordination
5) Tank and auxiliaries
    a. Bushings
    b. Tap-changers
    c. Protective devices
    d. Oil preservation system
6) Corrosion protection
7) Processing and assembly
8) Testing
9) Sensitivity of specified parameters
10) Short-circuit withstand capability
11) Transient withstand capability
12) Noise
13) Overload capability
14) Operation capability beyond nameplate specification
15) RAM (Reliability, availability and maintainability)

16) Drawings:
    a. Outline
    b. Rating and Diagram Plate
    c. Wiring Diagrams
17) Manufacturing facility and capability

4.16 Drawings and manuals

All drawings, documentation, information, test reports, operating and maintenance instructions and other correspondence and like items shall be in the English language and SI Units.

The Preferred Supplier shall provide to Horizon Power within three (3) months from the date of the letter of acceptance:

1) An electronic files in DGN format containing detailed assembly and erection drawings showing, in detail, all parts and part numbers, and schematic and wiring diagrams.
2) An electronic file in DGN format depicting the rating and diagram plate (as described in clause 4.19), with all known details stated, and all unknown details (such as impedance which is measured after construction) marked 'TBC'
3) An electronic file in an ISO/IEC 29500 or ISO/IEC 26300 word processor format (DOCX or ODT) containing complete material lists for each assembly drawing.
4) An erection, commissioning and maintenance manual, and a parts manual showing the correct and complete description of all parts.
5) For each Equipment, a digital photograph in electronic JPG format.
6) Electronic versions (in DOC or Acrobat PDF format) of the Material Safety Data Sheets (MSDS) supplied with the Proposal.

4.16.1 Drawings

The Supplier shall supply the drawings as listed below with the tender for approval. When the electronic copies (DGN files) of manufacturer's standard drawings are supplied, they shall bear Horizon Power's drawing numbers as detailed in the standard *Numbering and Titling Specification* (HPC-9CA-01-0002-2012, DM# 9118921).

4.16.1.1 General arrangement

Outline and general arrangement drawing (fully dimensioned including overall dimensions), including the following details:

a) Position of MIB, tap changer, radiators, conservator, bushings and surge arrester brackets; (Figure 1 – Typical Transformer Layout)
b) Centre of gravity;
c) Details of underbase and jacking points to permit the design of plinth and off-loading facilities;
d) Indication of all auxiliary equipment;
e) Numbered legend;
f) Drawing shall show plan, side and front elevation

4.16.1.2 Rating and diagram plate

Refer to clause 4.19 – Rating and diagram plates.

4.16.1.3 Valve location plate

Refer to clause 4.19 – Rating and diagram plates.

4.16.1.4 MIB mechanical layout

Refer to clause 4.7.3.8 – Marshalling interface box.

4.16.1.5 MIB electrical layout

Refer to clause 4.7.3.8 – Marshalling interface box.

4.16.1.6 On Load Tap Changer

Schematic and if applicable, wiring diagrams for on-load tap changer circuits, including a diagram of the complete timing cycle for the tap changer giving:

a) Time in seconds for normal tap changer operation stepping in:

- raise direction after previous raise; and
- lower direction after previous raise.

b) Time in seconds for normal tap changer operation stepping in:

- raise direction after previous raise; and
- lower direction after previous raise.

c) The schematic drawing shall include:

- motor power and control circuits; and
- lower direction after previous raise.

4.16.1.7 Cooling circuit

- Cooling control circuit arrangement (if applicable)
- Cabling drawings for fan motor

In addition to the standard drawings, the following drawings shall also be supplied with the tender:

a) diagrammatic arrangement of windings and tappings;

b) sectional drawings of core and windings which shall clearly indicate the methods of coil clamping;

c) shipping and transport drawings including manufacturing drawings for all transport blanking plates;

d) outline drawings of bushings.

e) The same device references shall be used on schematic, wiring and cabling drawings.

4.16.2 Instruction manuals

Two hard copies and one electronic copy of approved instruction manuals shall be supplied for each transformer. The manuals shall be complete with all approved drawings that shall be sufficient to enable the equipment to be assembled, checked and overhauled.

Only original documentation, especially from sub suppliers, shall be provided.

A complete set of all drawings submitted during the contracting stage shall also be included in the manual.

4.16.2.1 Each manual shall bear on the front cover the:

a) the substation name;

b) the order number;

c) the manufacturer's serial number; and

d) the rating and ratio.

4.16.2.2 The following information shall be included:

a) a completed copy of the purchaser's order specification (Schedules A and B) in an electronic format (spreadsheet or delimited text file);

b) the checking and erection procedures at site;

c) the mechanical operation of tap-changers and cooling apparatus;

d) the electrical control of tap-changers, fan motors, pump motors etc.;

e) the assembly, adjustment and routine maintenance procedures for on-load tap-changers and cooling apparatus;

f) drawings of tap-changer circuit diagrams including the tie-in resistor with its value (if used);

g) drawings of oil-filled bushings and outlines of HV, MV, tertiary and neutral bushings;

h) full details for the calibration of oil and winding temperature thermometers;

i) a set of A5-sized colour photographs of the specific transformer completely assembled showing all details on the sides and the top;

j) the specification sheets, and setting and testing guides for the winding and oil temperature thermometers and gas and oil actuated relays;

k) the serial number of the transformer unit;

l) details of permissible vacuum and site processing (drying-out procedures);

m) a copy of the certificates of all tests carried out by the manufacturer, including the results of winding and core insulation resistance tests;

n) an internal arrangement of the core and windings, showing lead supports and winding clamping arrangements;

o) details of core and core clamping;

p) a sectional arrangement drawing of the windings showing sufficient details of the conductors and insulation for local maintenance purposes; and

q) a list of manufacturers recommended spares for normal maintenance purposes.

The manual shall be designed from a user's point of view. It shall be organised in a logical sequence and all maintenance instructions shall additionally be collected from the relevant subsections and presented in a simplified/summarised format for the transformer as a complete unit, while maintaining reference to subsections that may contain more details.

These instructions shall refer to specific maintenance time periods, e.g. 3 months, 6 months, 12 months, 3 years, 6 years, etc., for the life of the unit.

The Contractor shall supply a priced list, with full description, of the spare parts required for normal maintenance of each transformer within two months of Contract award. The list shall be supplied electronically in a spreadsheet format. The list shall be detailed, and each item shall include the following information:

a) The manufacturer's part number

b) A clear and concise description of the part

c) The price for each recommended part or set of parts delivered into Horizon Power's store at site

d) Delivery periods for the part

e) Specific attention shall be paid to bushing installation, transport, tap-changer maintenance, processing and site tests.

f) For all projects a fifth copy shall accompany the transformer to site and shall be handed over to the Site Manager.

4.17 Component approvals

The components and fittings associated with transformers covered by this specification shall be subject to the purchaser's approval. Technical literature, drawings and tests reports shall be supplied electronically. Samples and lists of the names of the principal users, (with experience gained), shall be supplied on request.

The Supplier shall submit components for approval to Horizon Power only after such components have already been approved by the Supplier for use in the transformer.

Horizon Power has a preference for standardised and approved components already in use in order to minimise spares.

4.18 Condition monitoring/assessment equipment

4.18.1 Provision for installation

The transformer shall be designed to accommodate the installation or retrofitting of modern on-line condition monitoring equipment. Unless specified otherwise, the transformer manufacturer shall propose monitoring equipment and detailed constructional designs for approval. Guidance shall be provided on the required facilities and fittings for interfacing, installation or retrofitting of such monitors.

On-line gas monitoring connected into remote indication or alarm facilities is of particular interest.

All proposed condition monitoring equipment shall be capable of IEC 61850 communication.

4.19 Rating and diagram plates

4.19.1 General

Rating and diagram plates shall comply with the requirements of AS 60076 except where otherwise stated in this specification. The rating and diagram plates shall be provided electronically as described in clause 4.16.

4.19.2 Materials and methods of marking

Rating and diagram plates shall be of stainless steel not less than 1.2 mm in thickness.

The required information shall be engraved on the plate or etched with a glossy black, baked enamel.

Other arrangements shall be specifically approved.

4.19.3 Mounting

The rating and diagram plates shall be mounted on the door of the marshalling interface box, finished in accordance with clause 4.8.3 situated in an accessible position not less than 1.5 metre above ground level, and secured by stainless steel screws.

4.19.4 Information to be displayed

The minimum information to be displayed on the rating and diagram plate shall be in accordance with the requirements of AS 60076.1 with addition of the following as detailed in Figure 12:

a) the tapping current values shall be shown for HV, MV and tertiary terminals for all tapping positions;

b) the capability of the transformer (including bushings and tap-changers) to carry overloads in accordance with the emergency duties detailed in AS 60076.7 shall be shown;

c) the system fault levels in kA for which the transformer is designed (as specified in Table 10);

d) the zero sequence impedances in the case of three-winding auto transformers;

e) the current transformer data detailed in clause 4.5.8 shall be shown;

f) a statement that the manufacturer deems it necessary for the transformer to be oil-filled under vacuum;

g) a statement that the transformer will withstand full vacuum at sea level;

h) Horizon Power's reference number shall appear on the rating and diagram plate;

i) values for all relevant parameters used by the digital temperature gauge for the winding hot-spot and transformer lifetime calculations as per AS 2374.7 or AS 60076.7 as applicable in clause 4.14.4.2 – Oil temperature measurement.

j) the temperature probe hole diameter/s and depths.

k) a blank space for the purchaser's asset number shall be provided;

l) the type, make and designation numbers of all bushings, to enable full identification (relating to stock spares) while the transformer is energised;

m) the valve and oil sampling point functions and positions;

n) a warning statement that the conservator contains a bag or other sealing systems if it is the case; and

o) the type of corrosion protection: Corrosive or low corrosive.

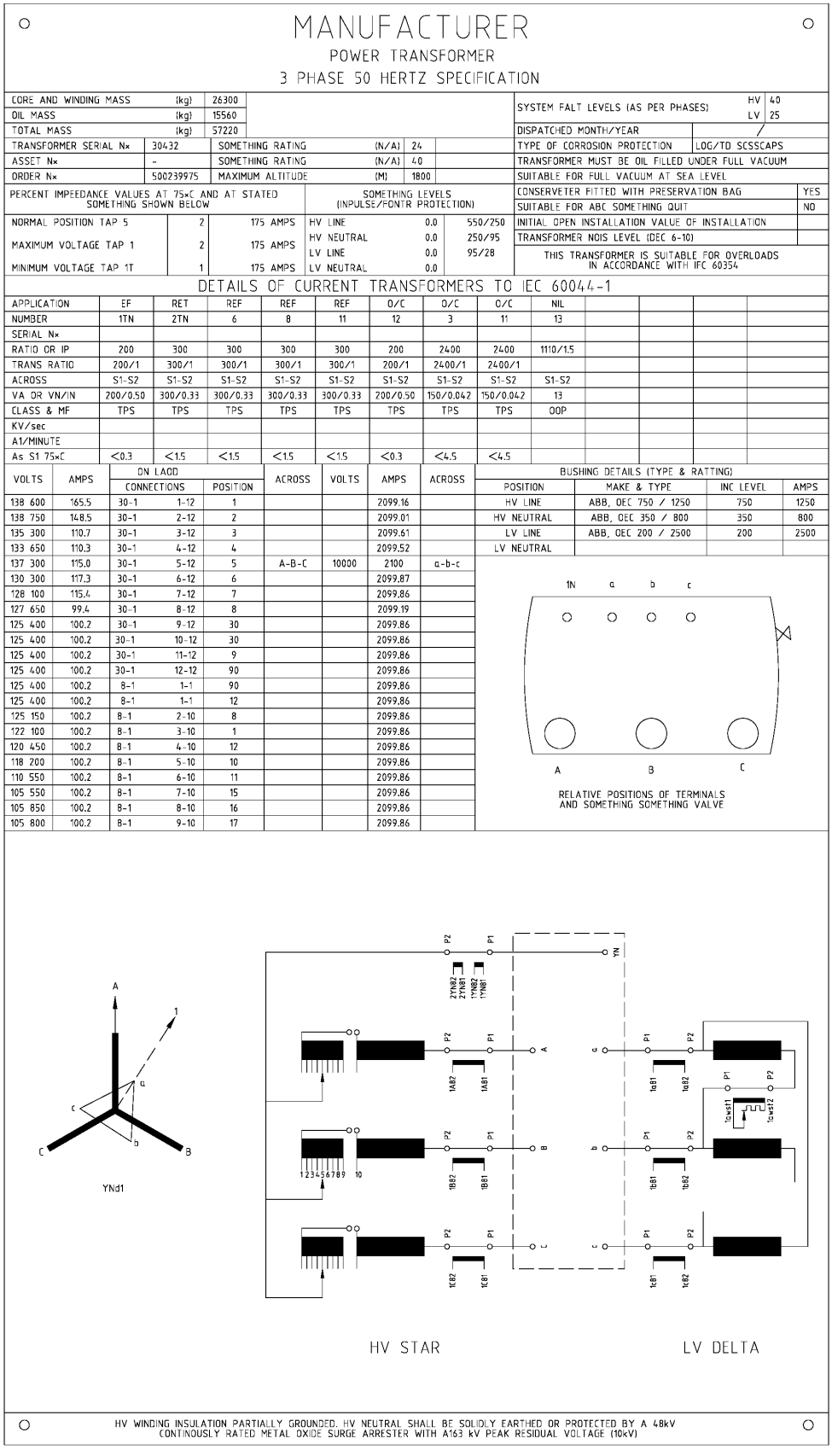
p) Initial DP value

q) Tie-in resistor schematic and value (if used).

r) Horizon Power Specification number, Specification Item number and Contract Order number.

Whilst a single plate is preferred, separate plates mounted adjacent to the main plate are acceptable for the information required by items (f), (g), (h), (m), (n), and (o).

Exposed auxiliary equipment and link connections shall have labels denoting their purpose and making the user aware of any special precautions that are required (such as core earthing links and tertiary winding test links).



MANUFACTURER

POWER TRANSFORMER

3 PHASE 50 HERTZ SPECIFICATION

CORE AND WINDING MASS	(kg)	26300				SYSTEM FALT LEVELS (AS PER PHASES)	HV 40 / LV 25
OIL MASS	(kg)	15560				DISPATCHED MONTH/YEAR	/
TOTAL MASS	(kg)	57220				TYPE OF CORROSION PROTECTION	LOG/TD SCSSCAPS
TRANSFORMER SERIAL N×	30432	SOMETHING RATING	(N/A)	24		TRANSFORMER MUST BE OIL FILLED UNDER FULL VACUUM	
ASSET N×	-	SOMETHING RATING	(N/A)	40		SUITABLE FOR FULL VACUUM AT SEA LEVEL	
ORDER N×	500239975	MAXIMUM ALTITUDE	(M)	1800		CONSERVETER FITTED WITH PRESERVATION BAG	YES
PERCENT IMPEEDANCE VALUES AT 75×C AND AT STATED SOMETHING SHOWN BELOW		SOMETHING LEVELS (INPULSE/FONTR PROTECTION)				SUITABLE FOR ABC SOMETHING QUIT	NO
NORMAL POSITION TAP 5	2	175 AMPS	HV LINE	0.0	550/750	INITIAL OPEN INSTALLATION VALUE OF INSTALLATION	
MAXIMUM VOLTAGE TAP 1	2	175 AMPS	HV NEUTRAL	0.0	250/95	TRANSFORMER NOIS LEVEL (DEC 6-10)	
MINIMUM VOLTAGE TAP 1T	1	175 AMPS	LV LINE	0.0	95/28	THIS TRANSFORMER IS SUITABLE FOR OVERLOADS IN ACCORDANCE WITH IFC 60354	
			LV NEUTRAL	0.0			

DETAILS OF CURRENT TRANSFORMERS TO IEC 60044-1

APPLICATION	EF	RET	REF	REF	REF	O/C	O/C	O/C	NIL				
NUMBER	1TN	2TN	6	8	11	12	3	11	13				
SERIAL N×													
RATIO OR IP	200	300	300	300	300	200	2400	2400	1110/1.5				
TRANS RATIO	200/1	300/1	300/1	300/1	300/1	200/1	2400/1	2400/1					
ACROSS	S1-S2	S1-S2	S1-S2	S1-S2	S1-S2	S1-S2	S1-S2	S1-S2	S1-S2				
VA OR VN/IN	200/0.50	300/0.33	300/0.33	300/0.33	300/0.33	200/0.50	150/0.042	150/0.042	13				
CLASS & MF	TPS	TPS	TPS	TPS	TPS	TPS	TPS	TPS	OOP				
KV/sec													
A1/MINUTE													
As S1 75×C	<0.3	<1.5	<1.5	<1.5	<1.5	<0.3	<4.5	<4.5					

VOLTS	AMPS	ON LAOD CONNECTIONS		POSITION	ACROSS	VOLTS	AMPS	ACROSS
138 600	165.5	30-1	1-12	1			2099.16	
138 750	148.5	30-1	2-12	2			2099.01	
135 300	110.7	30-1	3-12	3			2099.61	
133 650	110.3	30-1	4-12	4			2099.52	
137 300	115.0	30-1	5-12	5	A-B-C	10000	2100	a-b-c
130 300	117.3	30-1	6-12	6			2099.87	
128 100	115.4	30-1	7-12	7			2099.86	
127 650	99.4	30-1	8-12	8			2099.19	
125 400	100.2	30-1	9-12	30			2099.86	
125 400	100.2	30-1	10-12	30			2099.86	
125 400	100.2	30-1	11-12	9			2099.86	
125 400	100.2	30-1	12-12	90			2099.86	
125 400	100.2	8-1	1-1	90			2099.86	
125 400	100.2	8-1	1-1	12			2099.86	
125 150	100.2	8-1	2-10	8			2099.86	
122 100	100.2	8-1	3-10	1			2099.86	
120 450	100.2	8-1	4-10	12			2099.86	
118 200	100.2	8-1	5-10	10			2099.86	
110 550	100.2	8-1	6-10	11			2099.86	
105 550	100.2	8-1	7-10	15			2099.86	
105 850	100.2	8-1	8-10	16			2099.86	
105 800	100.2	8-1	9-10	17			2099.86	

BUSHING DETAILS (TYPE & RATTING)

POSITION	MAKE & TYPE	INC LEVEL	AMPS
HV LINE	ABB, OEC 750 / 1250	750	1250
HV NEUTRAL	ABB, OEC 350 / 800	350	800
LV LINE	ABB, OEC 200 / 2500	200	2500
LV NEUTRAL			

RELATIVE POSITIONS OF TERMINALS AND SOMETHING SOMETHING VALVE

HV WINDING INSULATION PARTIALLY GROUNDED. HV NEUTRAL SHALL BE SOLIDLY EARTHED OR PROTECTED BY A 48kV CONTINOUSLY RATED METAL OXIDE SURGE ARRESTER WITH A163 kV PEAK RESIDUAL VOLTAGE (10kV)

Figure 12 – Typical Rating and Diagram plate

4.20 Life Cycle Costs

Other things being equal, the adjudication of transformers will weigh heavily on the life cycle cost calculated on the following basis:

a) Life cost of transformer (LC):

$LC = C + 44829 \times W_i + 3074 \times W_c$

where:

C = Capital Cost of Transformer (AUD$)

W_i = Iron Loss (kW) at maximum rating

W_c = Copper Loss (kW) at maximum rating

NOTE: - For auto-transformers the load loss with the MV fully loaded but the Tertiary unloaded, will apply.

Typical loading cycles are used in the calculations.

To assist in the evaluation, the following typical drawings and descriptive data as specified in Schedule A in Appendix C and as deemed applicable by the Supplier shall be provided:

1) Outline drawing showing the position of terminals, conservator and gauge glasses and control cubicle and surge arresters where applicable
2) Type test certificates of identical units shall be submitted when available
3) Outline drawings of bushings
4) All drawings mentioned in clause 4.16.1 – Drawings

Information shall be submitted relating to the pre-treatment and sizing of windings and the assumptions made for the calculation of short-circuit strength.

Information shall include descriptive data and illustrations in sufficient detail to enable the equipment offered to be fully considered in respect of materials, design and construction of the individual parts. Consideration should include all consumables (e.g. seals, gaskets, breather gel, etc.).

4.21 Special tools and equipment

The Supplier shall provide, all the special tools and equipment that will be required for the normal maintenance of the transformer. A complete listing of such equipment and tools with their specific characteristics, including the type, manufacturer and purpose and the tools shall be handed over with the transformer. Tools and equipment may be used for the erection of the transformer but shall essentially be in as good as new condition when handed over. Horizon Power shall have the right to demand new equipment and tools of good quality if they are not in satisfactory condition.

4.22 Training of Horizon Power staff

The Supplier shall propose an appropriate training programme for Horizon Power's operating and engineering staff. This shall include the nomination of an appropriate venue and the duration of the training period.

If the proposed training involves travelling and accommodation and subsistence away from the purchaser's home country, the purchaser shall be responsible for all the direct travelling and subsistence expenses involved for a maximum number of four of Horizon Power's staff.

Horizon Power shall have the option at their own expense, to add a further two staff members.

The Supplier shall provide a complete and detailed Schedule of the training events but it is expected that formal training should last not less than 5 consecutive working days nor more than 10 consecutive working days.

The Supplier shall advise Horizon Power of the minimum pre-requisite level of education required for its employees to successfully participate in the training programme.

Over and above any formal training, the programme shall include, as a minimum, an on-site component covering:

a) on site preparation for transportation;

b) loading and off-loading procedure and precautions

c) fitting of accessories like tap-changers, bushings and their testing;

d) sensors and protective devices and their testing;

e) vacuum treatment, drying filtering and impregnation; and

f) all testing of the completed system to ensure that it is ready for service.

Special emphasis shall be placed on quality control processes and the maintenance of the oil and insulation system in the best possible condition to ensure maximum life for the transformer, as well the underlying theoretical aspects.

4.23 Erection

4.23.1 General

Erection if required in Schedule A in Appendix C, shall include off-loading, lifting, handling, positioning on foundations prepared by the purchaser, oil filling and installation of the transformer, together with the provision of all materials and ancillary equipment necessary for completing the installation. All work to be in accordance with the relevant Horizon Power safety standards.

4.23.2 Foundation tolerances and site details

Foundations provided by Horizon Power shall be levelled to within a tolerance of ±3 mm in 3 m in all directions. Newly constructed pedestal foundations for separate cooler bank arrangements will be 15 mm lower than the main transformer plinth to facilitate line-up of cooler pipes by using spacers.

4.23.3 Processing on site

Erection shall include filtering of oil and any drying-out and testing and checking procedures that are necessary to ensure that the transformer is ready for operation before handing over, together with the provision of the necessary materials, apparatus and instruments for these processes.

4.23.4 Testing on site

Refer to 5.1.5 On Site Tests for details on the relevant test that shall be performed on site.

4.23.5 Painting on site

Damage to paintwork sustained during transport and/or erection shall be made good by the contractor.

If site re-spraying is necessary, labels and all other areas not to be painted shall be carefully masked.

Any overspray that occurs despite this masking shall be removed by the contractor.

4.24 Transport

4.24.1 General conditions, blanking plates and gas filling

It shall be the Supplier's responsibility to make all arrangements for transport to the site with the appropriate authorities.

Horizon Power will only accept delivery of transformer on site. It shall be the Supplier's responsibility to co-ordinate the arrangements for all stages of the transport of the transformer from the manufacturer's works to site, including trans-shipping where necessary.

Where off-loading is required, all apparatus, materials and packages shall be addressed to the Supplier, who shall take delivery of the same at site.

The dimensions of the transformer shall be such that when packed for transport, it will comply with the requirements of the loading and clearance restrictions for the approved route.

All metal blanking plates and covers that are specifically required to transport the particular transformer, shall be considered part of the transformer and be handed over to the purchaser after completion of erection. A listing of all these items and relevant drawings shall be included in the manuals, to enable the purchaser to have duplicates of the plates manufactured if required. The dimensions and quantity of each item required for transport shall be on the drawings.

Where the supply of oil is included in the contract and where transport weight limitations permit, the transformers shall be transported with sufficient oil to cover the core and windings during all transport and storage conditions. The tank shall be sealed for transport to prevent all breathing.

Alternatively, where the above method is not applicable, the transformer shall be maintained continuously under positive pressure of dry air of at least 10 kPa during transport and storage until final installation. The pressure and the temperature at the time of filling shall be documented as part of the quality system. A pressure gauge and non-return valve, fitted directly to the transformer tank and suitably mechanically protected, shall be attached to each transformer to facilitate checking of gas pressure during transit and on site. If another gas, such as nitrogen is used, appropriate safety labelling shall be provided.

The total duration that the unit is filled with dry gas shall be limited to three months where after the transformer shall be appropriately processed and filled with oil as for service. Dehydrating breathers to be fitted at this stage.

Every precaution shall be taken to ensure that the transformer arrives at site in a satisfactory condition so that, after proper oil processing and filling, the transformer

can be put into service without the necessity for extensive drying out, provided that oil quality requirements are met.

NOTE: — Note the requirements of clause 4.3.3.1 Degree of polymerisation.

Full details of the proposed method of transport shall be submitted for approval.

The costs of any necessary extensions and/or improvements to existing facilities for transporting to site and escort and permit fees shall be included in the Supplier's prices.

All transformers 5 MVA and above shall be transported without the following items attached:

a) Radiators

b) Conservator

c) Piping

d) Bushings

4.24.2 Accelerometer limits (Impact recorders)

An accelerometer shall be attached to the top of each transformer tank as well as the active part for the duration of the transport process. The accelerometer shall record continuously the acceleration of the transformer in three directions perpendicular to each other of which the main direction shall be in the direction of transport. These recordings shall be date and time stamped.

The recording shall continue until the unit is in its final position. The traces shall be inspected as part of the quality process.

The Supplier shall specify, in Schedule A in Appendix C, the acceleration limit in any direction. Horizon Power shall verify this limit once the transformer has been installed.

4.24.3 Road transport

The transport arrangements shall include any necessary extensions and/or improvements to road routes, bridges, and civil works, and also the assurance that any abnormal loads comprising the transformers, their transporters, ancillary apparatus and plant and equipment required for erection shall pass without obstruction throughout the selected route.

4.24.4 Availability of lifting lugs and jacking pads

The lifting lugs and jacking pads shall not be prevented from fulfilling their functions when the transformer is arranged for transport on the vehicle, or when being moved on site with all attachments connected.

4.24.5 Transport support brackets

Attention is drawn to the necessity of receiving approval of the design and spacing of transport support brackets to avoid overstressing of the relevant trailer carrying beams.

4.24.6 Unloading

Unloading the transformer onto anti-vibration pads and other components to a designated location at the destination, is required. The anti-vibration pads shall be designed and supplied by the Supplier. Sealing material shall be installed during transformer unloading. Skating and craning of the transformer shall be included in the proposal.

Unloading shall be between the hours of 8H00 and 15H00 on a normal working day. Deliveries outside these hours shall require Horizon Power's approval. If approved, the Supplier shall make arrangements at no cost to Horizon Power, and if necessary, accept any charges representing expenses incurred by Horizon Power because of that delivery.

Crane outrigger loadings shall not exceed 250 MPa.

5 TESTS

5.1 General

5.1.1 Supplier's testing capabilities

The Supplier shall be fully responsible for performing or having performed all the required tests as specified in the Quality Assurance Inspection Plan (as described in clause 4.15.1.1). Any limitations shall be clearly stated. The Supplier shall bear all additional costs related to not being able to test as tendered at his own works.

5.1.2 Witnessing of tests

Horizon Power reserves the right to witness any of the tests specified.

The Supplier shall ascertain the sequence of tests required in each particular case and whether witnessing of tests is required, and, after completion of all works preliminary tests, shall then give the purchaser not less than 14 days notice of the firm date when the transformers and associated apparatus will be ready for the witnessing of testing. For overseas suppliers the minimum required notification time period is eight weeks. Inspection and test plans (ITPs) shall be provided at the time notice is given. As many tests as required shall be arranged to take place on the same day. ITPs shall comply with the requirements of the Quality Assurance Inspection Plan.

No transformer shall be despatched from the Supplier's works without Horizon Power's approval of its testing and overall quality.

Any costs incurred by the Supplier as a result of abortive or protracted visits by Horizon Power's representatives, due to poor organisation on the part of the Supplier or test failures, shall be the Supplier's responsibility.

Horizon Power shall be notified as soon as possible of all test failures and corrective measures. This shall take the form of abbreviated reports that shall, upon request, be supported by more detailed reports. It is desirable that Horizon Power is notified of test failures to allow in situ inspection if desired.

5.1.3 Test instruments and apparatus

The testing apparatus shall be subject to Horizon Power's approval, and, where required, instruments shall be re-calibrated by an agreed independent body at the Supplier's expense.

All apparatus shall be arranged and operated with due regard to the safety of personnel and so as to minimise damage to the test object in case of breakdown.

5.1.4 Test certificates

Test results and certificates in English shall be supplied electronically to Horizon Power within 30 days of the completion of the tests. Results shall be supplied as spreadsheets, while certificates shall be supplied as PDF.

Test certificates shall be incorporated into each maintenance/operating manual provided for that transformer.

5.1.5 On Site Tests

The results of the all the site tests done during commissioning shall be documented and included in the transformer manual. The results shall be supplied electronically, with results in spreadsheet format, and certificates in PDF format. The tests shall include the verification of:

a) voltage ratios on all three phases for each tap position;

b) the vector group;

c) measure insulation, HV to tank MV to tank HV to MV (5 kV);

d) a functional test for all alarm and trip contacts;

e) CT insulation, HV to tank at 5 kV, secondary to tank at 1 kV, max magnetising curve the cores to be used, ratio tests for all taps and polarity;

f) the fan and oil pump directions and operation of starting and overload protection relays;

g) the control/power cabling insulation (min 1 kV);

h) the correct operation and indication of tap-changers and timing checks;

i) the correct position of all valves in the oil circuits;

j) nameplate impedance to be verified;

k) wiring to the marshalling Interface Box terminals and to the tap change mechanism box terminals;

l) verify winding and oil thermometer accuracies;

m) Tan Delta tests to be done on all bushings with test taps;

n) disconnect the transformer core earth and megger to tank to ensure that the core is not bonded to the tank, 1 kV max. Ensure reconnecting of the core earth on completion of testing;

o) main tank and tap change oil levels to be checked;

p) check to see if the main tank to conservator valve is open;

q) frequency response analysis;

r) check silica gel

The results of the above tests shall be documented, signed off as part of the quality process and included in the transformer manuals. All the above tests shall be witnessed by Horizon Power.

All equipment provided for erection shall be removed from site when erection is completed and the site cleaned of any debris and oil spillage.

5.2 Transformer Tests

The Supplier shall perform the routine tests on each unit during the various stages of manufacturing as well as a complete type test for each design. The type test shall be reviewed during the design review as described by clause 4.15.2 Technical Evaluation / Design Review.

Routine, Type and Special tests required to be performed are given in Table 26. ITPs shall be provided as described in clause 5.1.2.

Table 26 – Routine, Type and Special Testing Requirements

Test Description	Specification	Routine	Type	Special
Winding resistance test	AS 60076.1	✓		
Induced and Separate source Voltage Withstand Test	AS 60076.3	✓		
Switching Impulse Test (See also 6.7 Specific Test Requirements)	AS 60076.3	✓		
Voltage ratio and check of phase displacement	AS 60076.1	✓		
Measurement of short circuit impedance and load losses	AS 60076.1	✓		
No-load loss and current measurements	AS 60076.1	✓		
Temperature rise tests (See also 6.7 Specific Test Requirements)	AS 60076-2		✓	✓
Dielectric (Impulse Test)	AS 60076.3	✓		
Dielectric (Short Duration AC)	AS 60076.3	✓		
Dielectric (Separate Source)	AS 60076.3	✓		
Dielectric (Long Duration AC - partial discharge)	AS 60076.3			✓
On-load tap-changer tests	AS 60214		✓	
Tests applied to devices with alarm and tripping contacts	6.3 Tests applied to devices with alarm and tripping contacts	✓	✓	
Transformer tank tests	6.4 Transformer tank tests	✓		

Test Description	Specification	Routine	Type	Special
Bushing tests	AS 60137	✓	✓	
Current transformers – All routine and type tests as per the standard.	AS 60044.1	✓	✓	
Gas and oil actuated relay tests	6.5 Gas and oil actuated relay tests	✓	✓	
Digital Thermometers	6.6 Digital Thermometers	✓	✓	
Acoustic noise level measurement	AS 60076.10			✓
Determination of capacitances, windings to earth & between windings	AS 60076.1			✓
Zero sequence impedance measurement	AS 60076.1	✓		✓
Short-circuit withstand tests	AS 60076.5			✓
Measurement of insulation resistance to earth and between windings.	AS 60076.1	✓		
Swept Frequency Response Analysis (all transformers > 10 MVA)	IEC 60076.18	✓		
Partial Discharge Test (See also 6.7 Specific Test Requirements)	AS 60076.3		✓	
Full load winding temperature gradient test	IEC 60076.2		✓	

NOTES: - Only applicable to Auto Transformers

5.3 Tests applied to devices with alarm and tripping contacts

5.3.1 Routine tests

The manufacturer's routine tests shall be performed to confirm that individual protection instruments or relays have been correctly manufactured and set up.

ITPs shall be provided as described in clause 5.1.2.

5.3.2 Type tests

The following type tests shall be carried out on one complete instrument or relay of each design and rating and equipped with alarm and tripping contacts and mounted as in service.

5.3.2.1 *Contact life test*

With the contacts loaded as in service and monitored by electrically operated counters, the device shall be operated over 2500 complete cycles during each of which the making and breaking capabilities of the alarm and tripping contacts shall be demonstrated without sign of distress or failure.

5.3.2.2 *Additional tests*

The device/s shall comply with the following additional type tests:

Table 27 – Additional Tests

Item	Test	Standard	Test Level	Compliance Criteria
Power frequency magnetic field				
1	Steady State	AS 61000.4.8	Class 5	*100 A/m* continuous, *1000 A/m* short duration, 50 Hz
2	Pulsed	AS 61000.4.9	Class 5	*1000 A/m (6.4/16 µs* waveshape)
3	Damped Oscillatory	IEC 61000-4-10	Class 5	*100 A/m,* 100 kHz and 1 MHz
Insulation resistance				
4	Dielectric withstand	IEC 60255-5	-	2 V rms 50 Hz for 1 minute between all terminals to case earth
5	Insulation resistance	IEC 60255-5	-	Insulation resistance greater than 20 MΩ when measured at 500 Vdc
Environmental tests				
6	Cold	AS 60068.2.1	-10°C or less	Operates within tolerance at -10 °C (LCD screen operative)
7	Dry Heat	AS 60068.2.2	+55°C or more	Operates within tolerance at +55 °C
8	Cyclic Temperature and Humidity	AS 60068.2.30	Test Db	25 °C and 95% relative humidity/55 °C and 95% relative humidity, 12 + 12 hour cycle
9	Enclosure protection	AS 60529	IP53	Protected against ingress of dust particles, spraying water
Mechanical tests				
10	Vibration	IEC 60255-21-1	Class 2 (response and endurance)	Response: 19, 10 – 150 Hz, 1 sweep energised. Contacts should not close for longer than 2 ms. Withstand: 2 g 10 – 150 Hz, 20 sweeps, unenergised Contacts should not close for longer than 2 ms.

Item	Test	Standard	Test Level	Compliance Criteria
11	Shock	IEC 60255-21-2	Class 1 (response and withstand)	Response: 5 g, 11 ms, 3 pulses in each direction, energised. Withstand: 15 g, 11 ms, 3 pulses in each direction, unenergised
12	Bump	IEC 60255-21-2	Class 1	10 g, 16 ms, 1000 pulses unenergised.
13	Seismic	IEC 60255-21-3	Class 1	Test method A (single axis sine sweep test) 1 – 35 Hz, 1 sweep.

5.4 Transformer tank tests

5.4.1 Strength tests

5.4.1.1 Internal hydraulic pressure withstand

One tank, radiators and oil conservator of each type and size shall be subjected, for 1 min, to an internal hydraulic pressure equal to 70 kPa or the maximum operating pressure plus 35 kPa whichever is the greater, without suffering permanent deflection, measured after a first application greater than the amounts specified in Table 28 — Maximum permanent deflection of steel tank panels between stiffeners of this specification.

After a second application no further permanent deflection shall be measurable.

5.4.1.2 Vacuum withstand

One tank, radiators and oil conservator of each type and size, both empty of oil, shall be subjected, for 1 min, to an absolute internal pressure of 1.5 kPa, against atmospheric pressure at sea level on the outside, without suffering permanent deflection, measured after a first application greater than the amounts specified in Table 28 – Maximum permanent deflection of steel tank panels between stiffeners of this specification. After a second application no further permanent deflection shall be measurable.

NOTE: - The above two tests may, by agreement, be combined.

Table 28 – Maximum permanent deflection of steel tank panels between stiffeners

Maximum permanent deflection (mm)	Major dimension of fabricated assembly (mm)
16	≤ 3000
14	> 2700 ≤ 3000
12	> 2300 ≤ 2700
10	> 2000 ≤ 2300
8	> 1650 ≤ 2000
6	> 1300 ≤ 1650

4	> 950 ≤ 1300
3	> 750 ≤ 950
2	> 600 ≤ 750
1	> 450 ≤ 600
0	≤ 450

5.4.1.3 Dye penetrant testing

To avoid leaks, dye penetrant testing shall be done prior to corrosion proofing of the tank (and other manufactured fittings), and after any welding.

5.4.2 Routine oil leakage test

These tests shall be performed following the strength tests specified above in clause 5.4.1.

5.4.2.1 Tank and fittings

Each transformer tank complete with all the fittings and attachments normally in contact with the transformer oil, and filled with oil with a viscosity not greater than that specified in AS 1767.1, shall withstand, for 24 hour, at room temperature, without leakage, a hydraulic pressure that is not less than 35 kPa above the maximum working pressure at every point in the transformer.

5.4.2.2 Pressure relief valve

One pressure relief valve of each make and type, set to open at the specified pressure, shall withstand, for 24 hours, at room temperature, an internal pressure of oil of 20 kPa above the maximum working pressure at the position of the valve, without leakage.

5.5 Gas and oil actuated relay tests

5.5.1 Routine tests

These tests shall be carried out on each relay completely assembled as in service.

5.5.1.1 Oil-tightness

The relay shall be subjected to an internal hydraulic pressure of oil of 70 kPa for 24 hour, at room temperature, without leakage.

5.5.1.2 Insulation

The insulation of all circuits which include contacts of switches, relays or contactors for isolation functions shall be tested for insulation resistance. This shall be not less than 20 MΩ when measured at 500 Vdc.

The relay circuits shall withstand, for 60 s, an applied voltage of 2 kV r.m.s. applied in turn between each electrically independent circuit and the casing of the relay and between the separate and independent electrical circuits.

5.5.1.3 Alarm signalling

Air shall be introduced into the relay mounted as specified in clause 4.11, and at a minimum angle of 5 degrees rising towards the oil conservator but at the same angle as it would be in service, until the alarm signalling contacts close. This shall take place before air escapes freely from the relay towards the oil conservator, but, not before a minimum quantity of air has been collected in the relay housing. This minimum shall be, in the case of a 25 mm relay, approximately 0.2 L, and in case of 50 mm and 75 mm relays 0.3 L and 0.4 L respectively.

The quantity of air in the relay at the point of closure of the alarm signalling contacts shall be recorded on the relay test card specified in clause 4.11.11.

5.5.1.4 Tripping

With the relay mounted as in clause 5.5.1.3 – Alarm signalling, the tripping functions shall be verified by tests to prove that the tripping contacts will close as follows:

a) with steady rates of oil flow through the relay within the limits given in Table 24 of this specification, at room temperature;

b) with an oil surge through the relay, produced by the rapid opening of a lever operated valve, preferably also within the limits given in Table 24 of this specification.

In both a) and b), the closure of the relay contacts shall be unaffected by the presence in the relay of sufficient gas to escape freely through the oil conservator pipe connection;

c) with further accumulation of gas in the relay but before gas escapes to the conservator.

NOTE: - The results of these tests, together with the flow rates producing contact closure at a 5° rising angle shall be recorded on the standard relay test card.

The quantity of gas in the relay at the point of closure of the trip contacts shall be recorded on the relay test card specified in clause 4.11.11.

5.5.2 Type tests

One relay of each make, size and type shall, after routine testing, be subjected to the following tests (unless acceptable certificates of previous tests on identical relays are available):

5.5.2.1 Vacuum

The empty relay shall be subjected to an internal pressure of 1.5 kPa against atmospheric pressure at sea level without damage.

5.5.2.2 Contact life, vibration and shock

The alarm signalling and tripping contacts shall be tested as specified in clause 5.3 – Tests applied to devices with alarm and tripping contacts including the vibration, shock, bump and seismic mechanical tests.

After these tests the routine testing of the relay shall be repeated.

5.6 Digital Thermometers

5.6.1 Routine tests

These tests shall be carried out on each instrument completely assembled as in service.

5.6.1.1 Insulation

The insulation of all circuits which include contacts of switches, relays or contactors for isolation functions shall be tested for insulation resistance. This shall be not less than 20 MΩ when measured at 500 V dc.

All device circuits shall withstand, for 60 s, an applied voltage of 2 kV r.m.s. applied in turn between each electrically independent circuit and the casing of the relay and between the separate and independent electrical circuits.

5.6.1.2 Alarm and trip signalling

The device shall include the facility to simulate rising oil and winding temperatures so as to force operation of the alarm and trip contacts. This facility shall be used to confirm the thresholds at which the various contacts operate and reset.

5.6.2 Type tests

One relay of each make, size and type shall, after routine testing, be subjected to the following tests (unless acceptable certificates of previous tests on identical relays are available):

5.6.2.1 Auxiliary Power supply

The instrument shall operate with the auxiliary supply voltage in the band $V_{Nominal}$ ± 20 %.

For supply interruptions lasting less than 10 ms, the device shall function as if no interruption had occurred.

5.6.2.2 AC current inputs

Current transformer inputs shall preferably be rated at 1 A nominal with the following overload capabilities:

a) 50 x I_n for 3 s or 100 x In for 1 s

b) 2 x I_n continuously

5.6.2.3 Additional type tests

The type tests of as specified in clause 5.3 – Tests applied to devices with alarm and tripping contacts shall apply. In addition to these, the device shall comply with the following type tests:

Table 29 – Additional type tests

Item	Test	Standard	Test Level	Compliance Criteria
Impulse				
1	Electrical impulse (1.2/50 µs)	IEC 60255-5	-	5 kV 1.2/50 µs waveform, 0.5 J
Electromagnetic compatibility				
2	1 MHz Disturbance Burst	IEC 60255-22-1	Class 3	2.5 kV common mode, 1 kV differential mode, 2 s total test duration, 6 - 10 bursts
3	Fast Transient	IEC 60255-22-4	Class A (IV)	4 kV, 2.5 kHz 2 kV, 5 kHz on Comms ports
4	Electrostatic Discharge	IEC 60255-22-2	Class 3	6 kV Contact Discharge, 8 kV Air Discharge
5	Surge immunity	IEC 60255-22-5	-	2 kV
6	Radiated Radio Frequency EM field immunity	IEC 60255-22-3	-	10 V/m, 80 MHz -1 GHz
7	Conducted Radio Frequency EM field immunity	IEC 60255-22-6	-	10 Vrms, 150 kHz – 80 MHz

5.7 Specific Test Requirements

5.7.1 Temperature rise test

5.7.1.1 Test requirement

DGA samples shall be taken before any test is conducted, and at the conclusion of the dielectric test, temperature rise test, and the overload test.

Directly following the temperature rise test the overload test shall be carried out with an overload rating of 1.5 pu for 2 hours. At 15 min intervals the tank shall be observed with an IR camera to determine any hot spots developing. At the end of the temperature rise test the tank thermal image shall be determined with an IR camera.

IR camera images shall be labelled appropriately and submitted electronically with DGA and other test results.

5.7.1.2 Acceptance criteria

The following acceptance criteria shall be applied to the results of this test:

a) The hot-spot temperature of the windings and any metallic parts in contact with oil shall not exceed 140 °C, subject to the conditions in clause 4.8.7.
b) The top oil temperature shall not exceed 115 °C.
c) No exorbitant gas development.

5.7.2 Partial Discharge test

Partial Discharge test must be carried out for all transformers rated 66 kV and above. The contractor shall perform the preliminary partial discharge measurements prior to the induced over voltage test (clause 5.2).

Following the impulse voltage test as described in clause 5.7.3 the Supplier shall perform the final partial discharge measurement.

These measurements shall be made in accordance with AS 60076.3. The partial discharge intensity shall not exceed 100 pico-coulombs at a test voltage of 1.5 Um/√3.

5.7.3 Switching Impulse Voltage Withstand test

The test shall be carried out on ALL TERMINALS at a nominal tap for Phase A, bottom tap for phase B and top tap for Phase C.

Before commencing the test sequence the Supplier shall demonstrate, to the satisfaction of Horizon Power, the sensitivity of the fault detection circuitry proposed for both full wave and chopped wave impulses. The demonstration shall be based upon the simulation of a single turn short circuit.

Two fault detection channels shall be used during the tests; one channel is to have a time sweep not greater than 300 microseconds and not less than 100 microseconds. The second channel is to have a time sweep not greater than 30 microseconds and not less than 10 microseconds.

The current traces shall include the 50% and 100% traces, attenuated so that the trace magnitudes are identical. This shall apply for both chopped and full wave impulses.

The current traces will be used to assess if the transformer has passed the impulse test.

To increase the sensitivity of fault detection, loading resistors will be used on the non-impulse test windings, but the transfer voltage will not exceed 75 % of the B.I.L. of the winding.

The impulse test shall be carried out in accordance with AS 60076.3 and shall include the chopped wave tests.

The reduced voltage chopped wave shall have a time to chop differing from the full voltage time to chop by no more than 0.2 microseconds. If this is not achieved during any of the test sequences then additional impulses shall be applied.

APPENDIX ‘A’ - REVISION INFORMATION

Informative - for Horizon Power use only.

Horizon Power has endeavoured to provide standards of the highest quality and would appreciate notification if any errors are found or even queries raised.

Each Standard makes use of its own comment sheet which is maintained throughout the life of the standard, which lists all comments made by stakeholders regarding the standard.

The Document **HPC-8DC-23-0001-COM** found in **DM#: 2905784** can be used to record any errors or queries found in or pertaining to this standard, which can then be addressed whenever the standard gets reviewed.

Date	Rev No.	Notes
17/08/2015	0	First Issue
20/11/2020	1	Amendment based on comments provided.

APPENDIX 'B' – STANDARD IMPEDANCE FOR TRANSFORMERS

Nominal Voltage			Impedance Type	Standard MVA Rating								HV/MV Impedance (%) referred to prime power rating		HV/Ter Impedance (%) referred to tertiary power rating		Vector Group
Primary	Secondary	Tertiary		160	80	40	20	10	5	2.5	1.25	Nom@ Tap 5	Min@ Tap 17	Nom@ Tap 5	Min@ Tap 17	
220	132	66		160/20	80/20							11	10			YNyn0d11
220	132	22		160/20	80/20							11	10			YNyn0d11
220	66	22		160/20	80/20							11	10			YNyn0d11
220	66	22	STD	160/20	80/10	40/10	20/5					10	9			YnAOd1
132	66	22	STD	160/20	80/10	40/10	20/5					10	9			YnAOd1
132	11		HIGH			X						22	20			YNd11
132	66		STD				X					11	10			YNd11
132	66		STD		X	X	X					11	10			YNd11
132	33		STD		X	X	X					11	10			YNd11
132	33		STD					X				10	9			YNd11
132	22		STD			X	X					11	10			YNd11
132	22		STD					X				10	9			YNd11
132	11		STD			X	X					11	10			YNd11
132	11		STD					X				10	9			YNd11
66	22		STD			X	X					11	10			YNd1
66	22		STD					X	X			10	9			YNd1
66	11		STD				X					11	10			YNd1
66	11		STD					X	X	X		10	9			YNd1
33	22		STD					X	X	X	X	6	5			YNd1
33	11		STD				X	X	X	X	X	6	5			YNd1
22	11		STD				X	X	X	X	X	6	5			YNd1

APPENDIX 'C' – TYPICAL TECHNICAL SCHEDULES A & B

Schedule A: Purchasers specific requirements

Schedule B: Guarantees and technical particulars of equipment offered.

Item	Description	Schedule A	Schedule B
1	**Delivery and off-loading**		
1.1	• Transformer delivered to		
1.2	• Delivery effected not before		
1.3	• Off-loaded from transport vehicle by supplier Yes / No		
1.4	• Transformer transferred to intended operating position by supplier Yes / No		
2	**Erection and oil filling**		
2.1	• Erected ready for service	Yes	
2.2	• Erection completed not later than Date		
2.3	• Place 3 ply Malthoid on plinth	Yes	
3	**Site details**		
3.1	• Access to site	Gravel Road	
3.2	• Distance from off-loading position m		
3.3	• Rise or fall to off-loading position m		
4	**Operating environment**		
4.1	Corrosion protection: Yes/No		
4.2	Pollution level: Medium/ Very Heavy	Heavy	
5	**Quantity of units required**		
6	**Rated power**		
6.1	• HV MVA		
6.2	• MV (with MV tertiary unloaded) MVA		
6.3	• MV tertiary (with HV fully loaded) MVA		
7	**Nominal system voltage** "u," **and rated voltage on** principal tapping		
7.1	• HV kV r.m.s		
7.2	• MV kV r.m.s		
7.3	• MV tertiary kV r.m.s		

Typical Technical Schedules A and B

Schedule A: Purchasers specific requirements

Schedule B: Guarantees and technical particulars of equipment offered.

Item	Description	Schedule A	Schedule B
8	**Vector group**		
8.1	• Type Ynd11 / YNyn0+d / YNa0d11/ YNd11d11		
9	**Tap-changers**		
9.1	• Type OLTC		
	• Tapping Range		
10	**Bushing**		
10.1	• Type Outdoor/Cable boxes		
11	**Special tests** **(List costs in price schedule)**		
11.11	• Acoustic noise level measurements Yes/No		
12	**Maximum continuous ratings on any tapping with rated cooling OFAF or ONAF**		
12.1	• HV MVA	xxxxxxxxxx	
12.2	• MV (MV tertiary unloaded) MVA	xxxxxxxxxx	
12.3	• MV tertiary (with HV fully loaded) MVA	xxxxxxxxxx	
13	**Continuous ratings on any tapping with ONAN cooling**		
13.1	• HV MVA	xxxxxxxxxx	
13.2	• MV (MV tertiary unloaded) MVA	xxxxxxxxxx	
13.3	• MV tertiary (with HV fully loaded) MVA	xxxxxxxxxx	
14	**Maximum current density in windings**		
14.1	• HV *A/mm²*	xxxxxxxxxx	
14.2	• MV *A/mm²*	xxxxxxxxxx	
14.3	• MV tertiary *A/mm²*	xxxxxxxxxx	
15	Rating of LV (delta tertiary) winding based on maximum current density in HV winding MVA	xxxxxxxxxx	

Typical Technical Schedules A and B

Schedule A: Purchasers specific requirements

Schedule B: Guarantees and technical particulars of equipment offered.

Item	Description		Schedule A	Schedule B
16	**Short-circuit current that the transformer is designed to withstand, in per unit of r.m.s. rated current**			
16.1	• HV	p.u.	xxxxxxxxxx	
16.2	• MV	p.u.	xxxxxxxxxx	
16.3	• MV tertiary	p.u.	xxxxxxxxxx	
17	**No-load loss on principal tapping (Note - No plus tolerance allowed)**			
17.1	• at 1.00 Un	kW	xxxxxxxxxx	
17.2	• at 1.10 Um	kW	xxxxxxxxxx	
18	**Core design**			
18.1	• Manufacturer of core steel		xxxxxxxxxx	
18.2	• Grade and thickness of core steel grade/mm		xxxxxxxxxx	
18.3	• Number and length of limbs	*no/mm*	xxxxxxxxxx	
18.4	• Core diameter	mm	xxxxxxxxxx	
19	**Cross sectional area of:**			
19.1.1	• Wound limbs	mm^2	xxxxxxxxxx	
19.1.2	• Yoke	mm^2	xxxxxxxxxx	
19.1.3	• Unwound limbs	mm^2	xxxxxxxxxx	
19.2	Distance between core limb centers	mm	xxxxxxxxxx	
19.3	Total core mass	kg	xxxxxxxxxx	
19.4	The design flux density at Un for:			
19.4.1	• Yoke	T	xxxxxxxxxx	
19.4.2	• Wound limbs	T	xxxxxxxxxx	
19.4.3	• Unwound limbs		xxxxxxxxxx	

Typical Technical Schedules A and B

Schedule A: Purchasers specific requirements

Schedule B: Guarantees and technical particulars of equipment offered.

Item	Description	Schedule A	Schedule B
19.5	Volts per turn at the above flux densities	xxxxxxxxxx	
19.6	Magnetizing current at rated frequency, on principal tapping, in percent of rated current at maximum HV rating		
19.6.1	• at 0,90 u %	xxxxxxxxxx	
19.6.2	• at 1,00 Ut %	xxxxxxxxxx	
19.6.3	• at 1,10 Ut %	xxxxxxxxxx	
19.7	Load loss (I^2R + stray) at 75 °C and at maximum HV rating with MV fully loaded but LV unloaded (Note - No plus tolerance allowed)		
19.7.1	• On principal tapping kW	xxxxxxxxxx	
19.7.2	• On extreme plus tapping kW	xxxxxxxxxx	
19.7.3	• On extreme minus tapping kW	xxxxxxxxxx	
20	**Input to coolers for maximum rated output in service**		
20.1	Fans		
20.1.1	• Power kW	xxxxxxxxxx	
20.1.2	• Current A	xxxxxxxxxx	
20.2	Oil pumps		
20.2.1	• Power kW	xxxxxxxxxx	
20.2.2	• Current A	xxxxxxxxxx	
21	**Ohmic impedance at 75°C and rated frequency based on maximum rated power of HV winding**		
21.1	HV/MV	xxxxxxxxxx	
21.1.1	• On principal tapping %	xxxxxxxxxx	
21.1.2	• On extreme plus tapping %	xxxxxxxxxx	
21.1.3	• On extreme minus tapping %	xxxxxxxxxx	

Typical Technical Schedules A and B

Schedule A: Purchasers specific requirements

Schedule B: Guarantees and technical particulars of equipment offered.

Item	Description		Schedule A	Schedule B
21.2	HV/MV tertiary		xxxxxxxxxx	
21.2.1	• On principal tapping	%	xxxxxxxxxx	
21.2.2	• On extreme plus tapping	%	xxxxxxxxxx	
21.2.3	• On extreme minus tapping	%	xxxxxxxxxx	
21.3	MV/MV tertiary		xxxxxxxxxx	
21.3.1	• On principal tapping	%	xxxxxxxxxx	
21.3.2	• On extreme plus tapping	%	xxxxxxxxxx	
21.3.3	• On extreme minus tapping	%	xxxxxxxxxx	
21.4	Tolerance applicable to guaranteed impedance			
21.4.1	HV/MV			
21.4.1.1	• On principal tapping	%	xxxxxxxxxx	
21.4.1.2	• On extreme plus tapping	%	xxxxxxxxxx	
21.4.1.3	• On extreme minus tapping	%	xxxxxxxxxx	
21.4.2	HV/MV tertiary			
21.4.2.1	• On principal tapping	%	xxxxxxxxxx	
21.4.2.2	• On extreme plus tapping	%	xxxxxxxxxx	
21.4.2.3	• On extreme minus tapping	%	xxxxxxxxxx	
21.5	Zero sequence impedances in percent of Un^2/M			
21.5.1	HV/MV			
21.5.1.1	• On principal tapping	%	xxxxxxxxxx	
21.5.1.2	• On extreme plus tapping	%	xxxxxxxxxx	
21.5.1.3	• On extreme minus tapping	%	xxxxxxxxxx	

Typical Technical Schedules A and B

Schedule A: Purchasers specific requirements

Schedule B: Guarantees and technical particulars of equipment offered.

Item	Description		Schedule A	Schedule B
21.5.2	HV/Neutral			
21.5.2.1	• On principal tapping	%	xxxxxxxxxx	
21.5.2.2	• On extreme plus tapping	%	xxxxxxxxxx	
21.5.2.3	• On extreme minus tapping	%	xxxxxxxxxx	
21.5.3	MV/Neutral			
21.5.3.1	• On principal tapping	%	xxxxxxxxxx	
21.5.3.2	• On extreme plus tapping	%	xxxxxxxxxx	
21.5.3.3	• On extreme minus tapping	%	xxxxxxxxxx	
22	**Maximum acoustic noise**	dB(A)	xxxxxxxxxx	
23	**Winding design**			
23.1	Indicate per coil the following:			
23.1.1	• Type(i.e multilayer helix)		xxxxxxxxxx	
23.1.2	• Number of turns		xxxxxxxxxx	
23.1.3	• Conductor size, number of configuration		xxxxxxxxxx	
23.1.4	• Number and width of support spacers per turn		xxxxxxxxxx	
23.1.5	• Total conductor mass kg		xxxxxxxxxx	
23.1.6	• Dry insulation mass kg		xxxxxxxxxx	

Typical Technical Schedules A and B

Schedule A: Purchasers specific requirements

Schedule B: Guarantees and technical particulars of equipment offered.

Item	Description	Schedule A	Schedule B
23.2	Metal-oxide surge arrester protection for neutral ends of primary wye-connected windings		
23.2.1	Continuous rating voltage kV rms	48 (for 66 and 132 kV primary) 95 (for 220 kV primary)	
23.2.2	Peak residual voltage kV peak	165 (for 66 and 132 kV primary) 165 (for 220 kV primary)	
24	**Minimum insulation for windings (Provide detailed test plan for evaluation)**		
24.1	Impulse withstand test voltage for:		
24.1.1	• HV kV peak	xxxxxxxxxx	
24.1.2	• MV kV peak	xxxxxxxxxx	
24.1.3	• MV tertiary kV peak	xxxxxxxxxx	
24.2	Sixty-second, separate source		
24.2.1	• HV kV peak	xxxxxxxxxx	
24.2.2	• MV kV peak	xxxxxxxxxx	
24.2.3	• MV tertiary kV peak	xxxxxxxxxx	
24.3	Induced-overvoltage withstand test voltages		
24.3.1	• HV to earth kV r.m.s	xxxxxxxxxx	
24.3.2	• MV kV r.m.s	xxxxxxxxxx	

Typical Technical Schedules A and B

Schedule A: Purchasers specific requirements

Schedule B: Guarantees and technical particulars of equipment offered.

Item	Description		Schedule A	Schedule B
24.4	Induced-overvoltage withstand test voltages			
24.4.1	• HV	kV r.m.s	xxxxxxxxxx	
24.4.2	• MV	kV r.m.s	xxxxxxxxxx	
24.4.3	Test frequency	Hz	xxxxxxxxxx	
24.4.4	Test duration	sec	xxxxxxxxxx	
25	**Main terminal bushing**			
25.1	Impulse withstand test voltage at sea level (1.2/50 µs)			
25.1.1	• HV	kV peak	xxxxxxxxxx	
25.1.2	• MV	kV peak	xxxxxxxxxx	
25.1.3	• MV tertiary	kV peak	xxxxxxxxxx	
25.1.4	• HV/MV Neutral	kV peak	xxxxxxxxxx	
25.2	Sixty seconds, power-frequency withstand test voltage to earth			
25.2.1	• HV	kV r.m.s	xxxxxxxxxx	
25.2.2	• MV	kV r.m.s	xxxxxxxxxx	
25.2.3	• MV tertiary	kV r.m.s	xxxxxxxxxx	
25.2.4	• HV/MV Neutral	kV r.m.s	xxxxxxxxxx	

Typical Technical Schedules A and B

Schedule A: Purchasers specific requirements

Schedule B: Guarantees and technical particulars of equipment offered.

Item	Description	Schedule A	Schedule B
25.3	Total creepage distance		
25.3.1	• HV mm	xxxxxxxxxx	
25.3.2	• MV mm	xxxxxxxxxx	
25.3.3	• MV tertiary mm	xxxxxxxxxx	
25.3.4	• HV/MV Neutral mm	xxxxxxxxxx	
25.4	Protected creepage distance		
25.4.1	• HV mm	xxxxxxxxxx	
25.4.2	• MV mm	xxxxxxxxxx	
25.4.3	• MV tertiary mm	xxxxxxxxxx	
25.4.4	• HV/MV Neutral mm	xxxxxxxxxx	
25.5	Type, rating and dimensions (attach data sheet)		
25.5.1	Service bushings		
25.5.1.1	• HV	xxxxxxxxxx	
25.5.1.2	• MV	xxxxxxxxxx	
25.5.1.3	• MV Tertiary	xxxxxxxxxx	
25.5.1.4	• HV/MV Neutral	xxxxxxxxxx	
25.5.2	Test bushing Type, rating and dimensions (attach data sheets)	xxxxxxxxxx	
25.5.3	Give particulars of special turrets etc. that will be used	xxxxxxxxxx	
25.5.4	Will special test items be supplied as part of the contract?	xxxxxxxxxx	

Typical Technical Schedules A and B

Schedule A: Purchasers specific requirements

Schedule B: Guarantees and technical particulars of equipment offered.

Item	Description		Schedule A	Schedule B
26	**Transformer general information**			
26.1	• Manufacturer		xxxxxxxxxx	
26.2	• Place of manufacture		xxxxxxxxxx	
26.3	• Type of transformer	core/shell	xxxxxxxxxx	
26.4	• Numbers of limbs	2/3/5	xxxxxxxxxx	
26.5	• Type of transformer		xxxxxxxxxx	
27	**Oil quantities**			
27.1	•Transformer tank		xxxxxxxxxx	
27.2	• Place of manufacture		xxxxxxxxxx	
27.3	•Tape changer			
27.4	•Total		xxxxxxxxxx	
28	**Masses**			
28.1	• Mass of core and windings	kg	xxxxxxxxxx	
28.2	• Mass of core steel	kg	xxxxxxxxxx	
28.3	• Mass of windings copper(insulation excluded)	kg	xxxxxxxxxx	
28.4	• Mass of tank and fittings	kg	xxxxxxxxxx	
28.5	• Mass of coolers	kg	xxxxxxxxxx	
28.6	• Mass of oil	kg	xxxxxxxxxx	
28.7	• Total mass	kg	xxxxxxxxxx	
28.8	• Greatest transportable mass of core steel	kg	xxxxxxxxxx	
29	**Filling medium for transport**			
30	**Overall dimensions of tank only**			
30.1	• Length		xxxxxxxxxx	
30.2	• Base plate thickness		xxxxxxxxxx	

Typical Technical Schedules A and B

Schedule A: Purchasers specific requirements

Schedule B: Guarantees and technical particulars of equipment offered.

Item	Description	Schedule A	Schedule B
31	**Height over HV bushings**	xxxxxxxxxx	
32	**Tank and cooler material thickness**	xxxxxxxxxx	
32.1	• Cooler tubes	xxxxxxxxxx	
32.2	• Pressed-sheet radiators	xxxxxxxxxx	
33	**Safe withstand vacuum at sea level, kPa**	xxxxxxxxxx	
34	**Motors (Forced cooling)**		
34.1	• Make	xxxxxxxxxx	
34.2	• Type	xxxxxxxxxx	
35	**Tap changer**		
35.1	On-load tap-changer		
35.1.1	• Manufacturer and type designation	xxxxxxxxxx	
35.1.2	• Precise electrical location of tappings	xxxxxxxxxx	
35.1.3	• Diagrammatic arrangement shown on Drawing No.	xxxxxxxxxx	
35.2	Tapping range of HV/MV ratio % of the ratio on the principal tapping:		
35.2.1	• Max %	xxxxxxxxxx	
35.2.2	• Min %	xxxxxxxxxx	
35.2.3	• Number of steps No	xxxxxxxxxx	
35.2.4	• Size of steps %	xxxxxxxxxx	
35.2.5	• Number of positions(including transition positions)	xxxxxxxxxx	
35.3	Nominal 50 Hz ratings of tap – changer :		
35.3.1	• Voltage kV	xxxxxxxxxx	
35.3.2	• Current A	xxxxxxxxxx	

Typical Technical Schedules A and B

Schedule A: Purchasers specific requirements

Schedule B: Guarantees and technical particulars of equipment offered.

Item	Description		Schedule A	Schedule B
35.4	Insulation levels of tap – changer			
35.4.1	• Lightning impulse level (1.2/50 µs full wave)		xxxxxxxxxx	
35.4.2	• phase to ground	kVpeak	xxxxxxxxxx	
35.4.1	• phase to phase	kVpeak	xxxxxxxxxx	
35.5	Tap – changer 50 Hz withstand			
35.5.1	• phase to ground	kV r.m.s	xxxxxxxxxx	
35.5.2	• phase to phase	kV r.m.s	xxxxxxxxxx	
35.5.3	• Nominal voltage and current rating of tap - changer		xxxxxxxxxx	
36.6	Tap – changer contacts			
35.6.1	• Selector	kV/A	xxxxxxxxxx	
35.6.2	• Selector switch	kV/A	xxxxxxxxxx	
35.6.3	• Diverter switch	kV/A	xxxxxxxxxx	
35.7	Tap – changer transition resistor	kV/A	xxxxxxxxxx	
35.8	Tap – changer driving motor		xxxxxxxxxx	
35.8.1	• Type of driving motor	3 Phase	xxxxxxxxxx	
35.8.2	• Power	kW	xxxxxxxxxx	
35.8.3	• Current	A	xxxxxxxxxx	
36	**Resulting no-load voltage appearing**			
36.11	• On principal tapping	kV	xxxxxxxxxx	
36.2	• On extreme plus tapping	kV	xxxxxxxxxx	
36.3	• On extreme minus tapping	kV	xxxxxxxxxx	

Typical Technical Schedules A and B

Schedule A: Purchasers specific requirements

Schedule B: Guarantees and technical particulars of equipment offered.

Item	Description	Schedule A	Schedule B
37	**Is supply of contract drawings guaranteed?**	xxxxxxxxxx	
38	**Type test certificates shall be submitted with the tender for approval, otherwise it will be assumed that no type tests for identical units are available**	xxxxxxxxxx	
39	**Indicating and protective devices**		
39.1	• Winding temperature thermometer(s)	xxxxxxxxxx	
39.2	• Oil Temperature thermometer	xxxxxxxxxx	
39.3	• Oil and gas actuated relay	xxxxxxxxxx	
39.4	• Pressure relief device	xxxxxxxxxx	
39.5	• Tap-changer procedure device (detail)	xxxxxxxxxx	
39.6	• Dehydrating breathers	xxxxxxxxxx	
39.7	• Conservator bag	xxxxxxxxxx	
39.8	• Oil level indicators	xxxxxxxxxx	
40	**Current Transformer**		
40.1	Rated Primary Voltage		
40.2	Rated short time current 1 sec		
40.3	Rated short time current 3 secs		
40.4	Rated primary current		
40.5	Rated secondary current		
40.6	Thermal limit secondary current		
40.7	Rated frequency		
	Insulation Level:		
40.8	i) Lightning impulse withstand voltage		
40.9	ii) Lightning impulse withstand voltage		
40.10	iii) Lightning impulse withstand voltage		

Typical Technical Schedules A and B

Schedule A: Purchasers specific requirements

Schedule B: Guarantees and technical particulars of equipment offered.

Item	Description	Schedule A	Schedule B
41	**Fall Restraint System**		
41.1	Rated holding capacity kN		
42	**Spares recommended by the manufacturer(provide detailed list)**		
43	**Deviation from specification**		

APPENDIX ‘D’ – DEVIATION SCHEDULE

Any deviation offered to this specification shall be listed below with reasons for deviation. In addition, evidence shall be provided that the proposed deviation will be more cost – effective that specified by Horizon Power

Item	Clause	Proposed deviation

APPENDIX 'E' – IMPACT ASSESSMENT

HORIZON POWER	**Impact Assessment**			
	Document Title:	**Power Transformer Technical Specification**		
	Document No:	HPC-8DC-23-0001-2015	**Revision No:**	1
	CS No:			

Activity	**Detail**
1. What training is required to implement this standard?	Different equipment used on the power transformer requires special training
2. Who will require training?	Operators of the transformer
3. What equipment will be required for training?	Supplier will decide
4. What special tools/equipment will be required for training?	Supplier will decide
5. Time period for training to be completed	Supplier will decide
6. Does the document affect the budget?	Project Budgets shall incorporate
7. Time period for implementation of requirements after training is completed.	N/A
8. Were the critical points in the document determined?	N/A

	Total Implementation period	N/A
	Total training cost	N/A
	Total cost of tools/equipment	N/A
	Total cost involved	N/A

Comments:
The standard will have a minimum impact on normal operational business because it affects new equipment that will be purchased on a project basis and does not require retroactive actions.
The manufacturer shall finish the required training before the delivery of the goods

Assessment Compiled by:		**Recommended by (Functional Responsibility)**	
Name:		Name:	
Designation:		Designation:	
Department:		Department:	
Date:		Date:	

APPENDIX ‘F’ – QUALITY ASSURANCE (TO BE COMPLETED BY STORES)

Document Number:					**QUALITY AUDIT**		**CS NUMBER:**	
Device Description	Label Material No.				**Power Transformer Purchase**		**Asset Owner:**	Horizon Power
	Asset ID/ Stock No							
Manufacturer:			**Dimension:**					

ITEM	OPERATION/EQUIPMENT/FACILITY	DOCUMENT REF.	WHO CHECKS	INITIALS	DATE/ TIME	QUALITY ASSURANCE CRITERIA	PASS Y/N	Comments
1.0	**Transformer Inspection**							
1.1	Physical Integrity Check	Seller’s certificate				All material shall be as specified in the ’Power Transformer Specification’.		
1.2	Equipment check	Seller’s certificate				All the equipment installed on the transformer shall be as specified in the ’Power Transformer Specification’		
1.3	Oil Transformer	Oil Certificate				Oil shall be as specified in the ’Power Transformer Specification’		
1.4	Tap-changer	Seller’s test certificate				Tap-changer shall be as specified in the ’Power Transformer Specification’		
1.5	Main terminals and bushings	N/A				Shall be as specified in the ’Power Transformer Specification’		
1.6	Windings and connections	N/A				Shall be as specified in the ’Power Transformer Specification’		
1.7	Current Transformers	Seller’s certificate				Shall be as specified in the ’Power Transformer Specification’		

Document Number:		HORIZON POWER	**QUALITY AUDIT**	**CS NUMBER:**	
Device Description	Label Material No.		**Power Transformer Purchase**	**Asset Owner:**	Horizon Power
	Asset ID/ Stock No				
Manufacturer:		**Dimension:**			

ITEM	OPERATION/EQUIPMENT/FACILITY	DOCUMENT REF.	WHO CHECKS	INITIALS	DATE/ TIME	QUALITY ASSURANCE CRITERIA	PASS Y/N	Comments
1.8	Auxiliary supplies ,terminal boxes	Seller's test Certificates				Shall be as specified in the 'Power Transformer Specification'		
1.9	Valves and oil sampling devices	N/A				Shall be as specified in the 'Power Transformer Specification'		
1.10	Oil conservator tank	N/A				Shall be as specified in the 'Power Transformer Specification'		
1.11	Gas and actuated relays(Buchholz)	Seller's test certificates				Shall be as specified in the 'Power Transformer Specification'		
1.12	Dehydrating breather	N/A				Shall be as specified in the 'Power Transformer Specification'		
1.13	Oil level indicators, alarm and signalling devices	Seller's test certificates				Shall be as specified in the 'Power Transformer Specification'		
1.14	Tests by Manufacturer	Tests certificates				Shall be as specified in the 'Power Transformer Specification'		
1.15	Tank tests	Tests certificates				Shall be as specified in the 'Power Transformer Specification'		
1.16	Gas and oil actuated relay tests	Tests certificates				Shall be as specified in the 'Power Transformer Specification'		

Document Number:		HORIZON POWER	**QUALITY AUDIT**	**CS NUMBER:**	
Device Description	Label Material No.		**Power Transformer Purchase**	**Asset Owner:**	Horizon Power
	Asset ID/ Stock No				
Manufacturer:		**Dimension:**			

ITEM	OPERATION/EQUIPMENT/FACILITY	DOCUMENT REF.	WHO CHECKS	INITIALS	DATE/ TIME	QUALITY ASSURANCE CRITERIA	PASS Y/N	Comments
1.17	Temperature thermometers tests	Tests certificates				Shall be as specified in the 'Power Transformer Specification'		
1.18	Specific Tests	Tests certificates				Shall be as specified in the 'Power Transformer Specification'		
1.19	Ratings and operating condition check	Seller's certificate				Shall be as specified in the 'Power Transformer Specification'		
1.20	Manuals/Drawings Check	Seller's manuals/ drawings				Shall be as specified in the 'Power Transformer Specification'		

SYMBOLS AND ABBREVIATIONS		DATE:							
H=HOLD POINT	S=SUPERVISOR	HP APPROVED:							
W=WITNESS POINT	T=TECH, F=FITTER, LH=LEADING HAND	REVISION:							
V=VERIFICATION POINT	E=ENGINEER	DATE:							
S/c= SUBCONTRACTOR	PM=PROJECT MANAGER	APPROVED BY:							

NOTE: -Any alteration of any kind shall be considered not acceptable if wasn't previously approve