



	REFERENCE	REV
<b>TITLE:</b>	<b>CP_TSSPEC 037</b>	<b>10</b>
<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV and 45 MVA 88/11 kV</b>	<b>DATE: MARCH 2023</b>	
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## FOREWORD

Recommendations for corrections, additions or deletions shall be addressed to the:

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2016

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## 1 INTRODUCTION

This document provides the basic design requirements for the design, manufacturing, supply, delivery, testing and cold commissioning of new power transformers for City Power, the electrical utility serving the greater Johannesburg area in South Africa. This document details the technical requirements of the power transformer.

This specification applies to oil immersed, air-cooled, three-phase, three-winding power transformers with ratings of 40 MVA with a nominal ratio of 88/11 kV, 45 MVA with a nominal ratio of 88/11/6.6 kV, and 40 MVA with a nominal ratio of 132/11 kV. The 6.6kV winding is a stabilizing tertiary winding. This specification applies to transformers purchased directly by City Power or via third parties on behalf of City Power.

## 2 SCOPE OF WORK

The scope of work shall include:

The design, manufacturing, factory acceptance testing, transport, delivery to site in the City Power area of supply, of power transformers with ratings of 40 MVA with a nominal ratio of 88/11 kV or 132/11 kV, or 45 MVA with a nominal ratio of 88/11 kV with a 6.6 kV stabilizing tertiary winding as outlined in the tender documents.

## 3 NORMATIVE REFERENCES

The following standards contain provisions that, through reference in the text, constitute requirements of this specification. The most recent editions of standards shall apply to this specification, unless otherwise stated specifically.

SANS 60072: Dimensions and output series for rotating electrical machines

SANS 60034: *Rotating electrical machines*

IEC 60044-1: *Instrument transformers, Part 1 - Current transformers*

IEC 60085: *Thermal evaluation and classification of electrical insulation*

SANS 60137: *Insulated bushings for alternating voltages above 1000 V*

IEC 60156: *Insulating liquids – determination of the breakdown voltage at power frequency*

IEC 60214: *On-load tap changers*

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IEC 60296: *Specification of unused mineral insulating oils for transformers and switchgear*

IEC 60450: Measurement of the average viscometric degree of polymerization of new and aged cellulosic electrically insulating materials

IEC 60599: Mineral oil-impregnated electrical equipment in service - Guide to the interpretation of dissolved and free gases analysis

SANS 60815: Guide for the selection and dimensioning of high-voltage insulators for polluted conditions IEC 60947: *(All parts) Low voltage switchgear and control gear*

SANS 61850: *(All parts) Communication network and systems in substations*

SANS 121: *Hot dip galvanization coatings on fabricated iron and steel articles – specifications and test methods*

SANS 9001: *Quality management systems - requirements*

SANS 1091: *National Colour Standard*

SANS 14001: *Environmental systems – Requirements with guidance for use*

SANS 60076-1: *Power Transformers – Part 1: General*

SANS 60076-2: *Power Transformers – Part 2: Temperature rise*

SANS 60076-3: *Power Transformers – Part 3: Insulation level and dielectric tests*

SANS 60076-4: *Power Transformers – Part 4: Guide to lightning impulse and switching impulse test – Power transformers and reactors*

SANS 60076-5: *Power Transformers – Part 5: Ability to withstand short circuit*

SANS 60076-7: *Power Transformers – Part 7: Loading guide for oil-immersed power transformers*

SANS 60076-8: *Power Transformers – Part 8: Application guide*

SANS 60076-10: *Power Transformers – Part 10: Determination of sound levels*

SANS 60076-10-1: *Power Transformers – Part 10-1: Determination of sound levels – application guide*

SANS 60076-13: *Power Transformers – Part 13: Self-protected liquid-filled transformers*

SANS 60076-14: *Power Transformers – Part 14: Design and application of liquid-immersed power transformers using high temperature insulation materials*

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SANS 60076-18: *Power Transformers – Part 18: Measurement of frequency response*

NRS 029: *Current transformers for rated a.c. voltages from 36 kV up to and including 420 kV (Maximum voltage for equipment)*

NRS 054: *Power Transformers*

NRS 048: Electricity Supply – Quality of Supply CP\_TSDRAW\_050, Wiring of the marshalling kiosks

CP\_TSSPEC\_001: *Specification for 11 kV and 22 kV Paper and XLPE cables*

CP\_TSSPEC\_002: *Specification for low voltage insulated wire, power and multi-core control cables*

CP\_TSSPEC\_030: *Specification for metal cable glands* CP\_TSSPEC\_016, Specification for contactors

CP\_TSSPEC\_017: Specification for miniature circuit breakers

CP\_TSSPEC\_064: Medium Voltage metering current transformers

CP\_TSSPEC\_117: *Specification for station class, metal-oxide surge arrestors without spark-gaps*

CP\_TSSPEC\_119: *Specification for HV current transformers*

CP\_TSSPEC\_116: Specification for new and regenerated mineral insulating oil

CP\_TSSPEC\_132: Specification for silica gel

CP\_TSSPEC\_179: Specification for on-line dissolved gas analyser

South African Occupational Health and Safety Act (as amended), Act no. 85 of 1993

If there is a conflict on this specification or a conflict between standards, clarity shall be obtained from City Power. This specification shall take preference over the standards listed above. The City Power specifications (CP\_TSSPEC\_XXX) are the second most important reference documents.

## 4 DEFINITIONS AND ABBREVIATIONS

The definitions and abbreviations defined in the normative references above shall apply to this document.

## 5 DESIGN BASIS

### 5.1 Design Reviews

A design review shall be done on the first transformer of each type. A design review in a planned exercise is envisaged to ensure that there is a common understanding of the applicable standards and specification requirements, and to provide an opportunity to scrutinize the design to ensure the requirements meet the Employer's requirements.



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The objective is to review specific aspects of the electrical, mechanical, magnetic and thermal design to:

- Ensure there is a clear and mutual understanding of the technical requirements.
- Verify the system and project requirements and to indicate areas where special attention may be required.
- Verify that the design complies with the technical requirements.
- Identify any prototype features and evaluate their reliability and risks.

A design review meeting is required before the procurement of any materials or manufacturing proceeds. The purpose of the design review is to allow City Power to understand the basic design, construction and installation of the transformer and to make sure that interchangeability requirements are met. City Power shall not be obliged to accept components and/or materials procured prior to the design review and without a written agreement from City Power. The design review shall follow an internationally benchmarked process.

The manufacturer shall design the transformer in order that it performs satisfactorily under all service conditions specified in this document.

The manufacturer has to demonstrate that all the decisive design parameters are well within the manufacturer's design limits based on proven research, or relevant limits specified in standards or internationally benchmarked criteria.

City Power reserves the right to reject the design when the manufacturer fails to demonstrate the capability for design and manufacturing of the transformer under review. This can happen when the presented design does not meet internationally and City Power's accepted criteria and the manufacturer cannot prove his design by previously tested transformers of the same concept and voltage class. The manufacturer shall inform City Power twelve (12) weeks prior to the design review. All the discussions and final decisions taken during the design review must be recorded, signed by all the parties, and submitted to City Power.

City Power's participation in the design review will in no way relieve the manufacturer of any of their duties in terms of any contract.

Preliminary design review details shall be supplied to City Power, two weeks before the design review meeting.

## 5.2 Service conditions

The requirements in this specification apply to transformers for use under the following general conditions described in Table 1.

*Table 1: Site conditions*

Environment	Limits
Application	Outdoors or indoors
Altitude	The design shall be based on an altitude of 1800 m a.m.s.l

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Maximum ambient air temperature	Hottest any time 40 °C Hottest monthly average 30 °C
Yearly average ambient air temperature	20 °C
Minimum ambient air temperature	Coldest any time –10 °C
Variation in humidity	10% to 90%

### 5.3 Insulation

The winding insulation shall be of a uniform nature, i.e. fully insulated. The copper conductors shall be covered by thermally upgraded paper. The rating of the winding insulation shall be as described in Table 2 below.

*Table 2 – Winding insulation (based on SANS 60076-3)*

Highest Voltage for equipment winding $U_m$ kV	Full Wave Lightning Impulse (LI) kV	Chopped Wave Lightning Impulse (LIC) kV	Switching impulse (SI) kV	Applied voltage or line terminal AC withstand (AV) (LTAC) kV
145	650	715	540 <sup>a</sup>	275
100	450	495	375 <sup>a</sup>	185
12	95	105	–	28
7, 2	75 <sup>a</sup>	83 <sup>a</sup>	–	20

#### Clearances

The minimum spacing in air between conductors of different phases and clearances between conductors and earth shall be as described in Table 3.

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Table 3: Minimum clearances (based on NRS054 and SANS 60071)

$U_m$ (kV)	Phase-to-earth clearance (mm)	Phase-to-phase clearance (mm)	Minimum vertical working clearance to live metal (mm)	Minimum distance from transformer base to bushing or surge arrester base (mm)	Creepage distance (mm)
145	1300	1300	3700	2500	4500
100	900	900	3500	2500	3100
12	200	200	3000	2500	372
7.2	200	200	3000	2500	372

## 5.4 Duty Requirements

The transformer shall meet the following requirements:

a Ability to withstand short-circuits

- i Source short circuit level used for design purposes is 80 kA rms at 100 kV for 88 kV systems and 80 kA at 145 kV for 132 kV systems. The 132 kV and 88 kV systems are solidly grounded. For the purpose of guarantees, design and possible tests, the supply system shall be represented by voltage sources having the appropriate values of highest system voltages,  $U_m$ , connected to the transformer through impedances with values such that the infeed fault current meets the values stated above. An X/R ratio = 17 shall be used for the purpose of calculating the amplitude of the first peak of the short-circuit current. The X/R is defined in SANS 60076-5:
- ii The following criteria's shall be acceptable by City Power which is the ability to withstand thermal effects which is done by calculation or the ability to withstand dynamic effect which is done by calculation or test.
- iii Notwithstanding the overcurrent limits tabulated in SANS 60076-5, the transformer with the minimum percentage impedance across the tapping range shall be capable of withstanding the thermal, mechanical and other effects of faults for a two (2.0) second duration per fault incident;

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- iv City Power reserves the right to review all the manufacturer's information regarding calculations and the philosophy of dealing with the short-circuit forces;
- b The emergency power rating of the transformer and bushings shall comply with SANS 60076-7 and SANS 60137 respectively. The OLTC, bushings and CTs shall not limit the continuous or overloading of the transformer;
- c The maximum flux density in any part of the core and yokes at normal voltage and frequency shall be such that the flux density under overvoltage conditions shall not exceed the maximum permissible values for the type of core and yoke material used.
- d The transformer shall be designed for the following overvoltage withstand capability as per NRS054:
  - $1,00 \cdot U_m$  continuous
  - $1.05 \cdot U_m$  for 5 minutes
  - $1.25 \cdot U_m$  for 5 s
  - $1.5 \cdot U_m$  for 1 s
  - $1.7 \cdot U_m$  for 0.25 s
- e The transformer shall be designed for a rated frequency of  $50.00 \text{ Hz} \pm 2.50 \text{ Hz}$  as per SA Grid Code for Transmission and NRS 054. The under frequency condition may be sustained for 30 minutes and the over frequency condition for 10 minutes. An under- or over frequency condition is defined as exceeding  $50.00 \text{ Hz} \pm 0.20 \text{ Hz}$ ;
- f Transformers shall be designed to not generate ferro-resonance and non-linear oscillations within the transformer that would require the use of internal surge arrestors on tapping or other windings. The manufacturer shall submit proof by calculation that no surge arrestors are required at the design review meetings. If internal surge arrestors are required the manufacturer shall formally apply for a deviation;
- g The design shall be based on a maximum negative phase sequence voltage in the supply system of 3.0% of  $U_n$ , as per NRS 048;
- h The design shall be based on a maximum zero phase sequence voltage of 2.0% of  $U_n$ , as per NRS 048;

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- i Maximum total harmonic distortion in supply voltage less than 5% as measured over a 10-minute period according to NRS 048. The dominant harmonics are 5<sup>th</sup>, 7<sup>th</sup>, 11<sup>th</sup> and 13<sup>th</sup>;

## 5.5 Constructional Features

- a The transformer and accessories shall be designed to facilitate ease of operation, inspection, maintenance and repairs;
- b All materials used shall be of the best quality and of the class most suitable for working under the conditions specified and shall withstand the variations in temperature and atmospheric conditions, arising under working conditions, without undue distortion or deterioration or setting up of undue stresses in any part and also without affecting the strength and suitability of the various parts for the work which they have to perform;
- c Patching, plugging, shimming or other such means of overcoming defects, discrepancies or errors shall not be accepted. If there are no other means of overcoming defects the manufacturer shall formally apply for a deviation; City Power may negotiate a reduction in the unit price or an extension of certain aspects of the warrantee;
- d Corresponding parts liable for replacement shall be interchangeable;
- e All outdoor apparatus, including bushing insulators with their mounting shall be designed so as to avoid pockets in which water can collect;
- f All mechanisms shall wherever necessary, be constructed of stainless steel or brass to prevent sticking due to rust or corrosion;
- g All taper pins used in any mechanism shall be of the split type;
- h Nuts, bolts and pins used inside the transformer and tap changer compartment shall be provided with spring washers or locknuts. All bolts shall be torqued to the required own specification and marked. Tests may be conducted during inspections to verify these torque values have been attained. The manufacturer shall provide a list with torque values for each bolt size at the design review meeting. Only high tensile bolts rated for 8.8 or higher shall be used inside the transformer;
- i Galvanising, where specified, shall be supplied by electro galvanising process and for all parts other than steel wires, which shall consist of a thickness of zinc coating equivalent to not less

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than 610 gram of zinc per square meter of outer surface, to prevent rusting. The zinc coating shall be smooth, of uniform thickness and free from defects;

- j Surfaces that are in contact with transformer oil, shall not be galvanised, contain any zinc, zinc plated or cadmium plated parts;
- k Labels or plates of non-corrosive material shall be provided for all apparatus such as relays, switches and fuses, contained in any cubicle or marshalling kiosks;
- l Stainless steel bolts and nuts exposed to atmosphere shall be used.
- m Before painting or filling with oil, un-galvanised parts shall be completely cleaned and freed from rust, scale and greases;
- n The interior of transformer tank and other oil filled chambers and internal structural steel work shall be cleaned of all scale and rust by shot-blasting or sand-blasting. These surfaces shall be painted with not less than two coats of hot oil resisting paint. The paint shall not react with the transformer oil in any manner. The manufacturer shall provide experimental proof that the paint is inert in transformer oil;
- o Similarly, the exterior of the transformer shall also be cleaned of all scale and rust by shot / sand blasting and then the primary coat shall be applied, immediately after cleaning. The second coat shall be of epoxy paint; the colour of the paint shall be as specified in Table 7 below. Before despatch, the transformer shall be given another final coat of epoxy paint. To ensure good drying the tank, marshalling box and conservator shall be baked after painted. The paint application shall be as for a coastal environment, with the primer being at least 45 µm thick and the two top coats each at least 40 µm thick when dry. The minimum total paint thickness shall be at least 125 µm when dry as defined in SANS 12944 for C5.
- p Metal parts not accessible for painting shall be made of corrosion resistant material;

## 5.6 Key dimensions

The maximum overall dimensions for the power transformer (excluding surge arresters and their mounting brackets) shall be as specified in table 4 below.

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*Table 4: Maximum overall dimensions of the power transformer (based on NRS 054)*

HV rating, U <sub>n</sub> (kV)	Height (mm)	Length (mm)	Width (mm)
88	5500	6800	5000
132	5500	7800	5000
<b>NOTE:</b> The bushings should be symmetrically arranged about the overall transverse centre line of the transformer			

## 6 GENERAL REQUIREMENTS

### 6.1 General

- a Nothing in this specification shall lessen the obligations of the Manufacturer to supply a high quality product. The Manufacturer shall be fully responsible for the design of the power transformer and its satisfactory performance in service. Approval by City Power shall not relieve the Manufacturer of the responsibility for the adequacy of the design.
- b Power transformers shall be manufactured in accordance with NRS 054 and SANS 60076. Where conflicting requirements with NRS 054 and SANS 60076 occur, this specification shall take precedence.
- c The specification covers transformers supplied from 132 kV and 88 kV with a secondary voltage of 11 kV and a stabilizing tertiary voltage of 6.6 kV (required on all-star/star designs).
- d The transformer should be designed, based on a 3-limb core configuration.
- e The tapping winding shall electrically be located on the neutral end of the HV winding.
- f All the bushings shall be mounted upright on the transformer tank lid.
- g All components used in the power transformers shall be PCB-free, i.e. containing less than 1 ppm polychlorinated biphenyls (PCBs);

## 7 ACTIVE PART REQUIREMENTS

### 7.1 Voltages and ratio transformation

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The voltages between phases of the 132/88 kV and 11 kV windings of each transformer, measured on no-load and corresponding to the normal ratio of transformation, shall be as specified in Table 5 below.

*Table 5: Transformer Voltage Ratios*

Power Rating (MVA)	Voltage Ratio (kV)
40	88/11
40	132/11
45	88/11/6.6

Note: The 6.6 kV winding is a stabilizing tertiary winding.

## 7.2 Regulation and Impedance

- The voltage regulation from no load to continuous rated output at unity power factor and at 0,8 lagging power factor with constant voltage across the high voltage windings shall be stated in Schedule B in Annex B;
- The impedance voltage corrected to 75°C at nominal voltage, on nominal tap, rated frequency and rated current, between HV and 11 kV windings shall be 17%;
- The permitted tolerance on these values shall not exceed +7.5% or -7.5% from the stated impedance. A reactor either inside or outside the tank shall not be used to achieve the percentage impedance voltage stated above;
- The impedance variation over the entire tapping range shall not exceed 2.0%, e.g. from 16.0% to 18.0%.
- To facilitate the modelling of the transformers on the network, the measured zero sequence impedance ( $Z_0$ ) shall be stated on the transformer rating plate;
- The positive sequence impedance shall be stated at highest, middle and lowest tap on the rating plate;

## 7.3 Electrical connection and main terminals

- The windings of the transformers shall be connected as shown in Table 6 below.



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*Table 6: Transformer winding configurations*

Power Rating (MVA)	Voltage Ratio (kV)	Vector Grouping
40	88/11	YNd1
40	132/11	YNd1
45	88/11/6.6	YNyn0(d11)

- b The primary (132kV or 88 kV) phase and neutral windings shall be fully insulated;
- c The secondary (11 kV) phase and neutral windings shall be fully insulated;
- d The primary (132kV or 88 kV) neutral and secondary (11 kV) neutral shall be brought out separately through bushing insulators;
- e The stabilizing tertiary (6.6 kV) phase windings shall be fully insulated to values of an 11 kV winding;
- f Only the A (U) phase connection of the tertiary winding shall be brought out in the form of an open delta winding with an external connection consisting of two bushings, of same specification as the 11 kV bushings, with a shorting bar;

#### **7.4 Core**

- a The cores shall be constructed from high grade, cold rolled, non-ageing, high permeability, low loss grain-oriented, silicon-steel laminations;
- b For rated voltage and rated frequency, the average core flux density in the limbs and in the yokes shall not exceed 1.75 Tesla with a maximum flux density anywhere in the core not exceeding 1.95 Tesla;
- c Slit or cut edge of the electromagnetic steel sheets shall be smooth and not be capable of causing damage to the insulation between sheets. The core sheets shall be properly step-lap stacked and all the insulation designed in a way that no detrimental changes in physical or electrical properties will occur during the lifetime of the transformer;

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- d The design of the magnetic circuit shall be such as to avoid static discharges, development of short circuit paths within itself or to the earthed clamping structure and the production of flux components at right angles to the plane of the lamination, which may cause local heating;
- e Bolts shall not be placed through the limbs and yokes for core clamping. The limbs shall be fastened by non-metallic strips. Steel straps or rods used around the yokes shall be insulated to withstand a test voltage of 5 kV dc, from the yokes to prevent shorts to the core and circulating currents.
- f There shall be a minimum distance of 20 mm between the core and the transformer tank floor separation;
- g The oxide silicate / carlite / magnetite coating given on the core steel shall be adequate to short circuit between lamination. Laminations shall be insulated on both sides by heat resistant insulation. The insulation shall be inert to the action of hot transformer oil;
- h Oil ducts shall be provided, where necessary, to ensure adequate cooling. The winding structure and major insulation shall not obstruct the free flow of oil through such ducts. Where the magnetic circuit is divided into pockets by cooling ducts, parallel to the planes of the laminations or by insulating material above 0.25 mm thick, tinned copper strip bridging pieces shall be inserted to maintain electrical continuity between pockets. The framework and clamping arrangements shall be earthed separately, to prevent circulating currents in core and the frame that produce extra heat and gassing.
- i The core shall have its own core grounding connection, brought out via a bushing and removable earthing strap for testing purposes. The core shall be such as to withstand a voltage of 3 000 V ac for one minute and 5 kV dc for 10 minutes to earth.
- j The insulation system for the core to tie bolts (or flitch plates) and core to clamping plates (yoke frame) shall be such as to withstand a voltage of 3 000 V ac for one minute and 5 kV dc for 10 minutes to earth. The yoke frame shall have its own grounding connection, brought out via a bushing and removable earthing strap for testing purposes. The bolts, fibreglass tubes and the clamping structure shall be constructed so that eddy currents will be minimized;
- k All parts of the core shall be of robust design, capable of withstanding any shocks to which they may be subjected during lifting, transport, installation and service;
- l Adequate lifting lugs shall be provided to enable the core and windings to be lifted. It shall not

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be lifted by the tank cover with a crane;

- m Adequate provision shall be made to prevent movement of the core and winding, relative to the tank, during transport and installation. The pressure on the yokes and limbs without cores shall be adequate to prevent movement of the laminations during shipping accelerations. Fiberglass strapping shall be placed on the limbs at intervals not exceeding 300 mm intervals on the limbs for support of the core;

## 7.5 Windings

- a The conductor shall be of electric grade copper and covered in a dust-free environment where the atmospheric conditions (temperature and humidity) are controlled. Electrolytic Tough Pitch Copper (Cu-ETP-2) grade copper is preferred for the windings. The copper shall have a purity of 99.9% or better (City Power reserve the right to request certificate from the manufacturers);
- b The winding conductor shall be wound in a dust-free environment where the atmospheric conditions (temperature and humidity) are controlled. If this not possible, the manufacturer shall apply for a concession;
- c No resin shall be add to / used on the windings by the manufacturer;
- d The windings shall be designed to reduce the out of balance forces in the transformer to a minimum. They shall comply with the power frequency test voltages and the impulse test voltages (full and chopped wave) as specified in this specification;
- e All the winding conductors shall be covered by at least two layers of paper. The wrapping direction of the paper on the conductor shall not all be in the same direction, e.g. clock wise vs. anti-clock wise. At least one third of the paper layers shall have a different wrapping direction of the rest of the layers of paper. CTC with netting tape is also acceptable on the 11 and 6.6 kV windings;
- f The conductors used in tapping winding shall be wound such that the width of the conductors are orientated at 90° to the core, where the width is larger than height of the conductors; should be fine but this depends on the design
- g The insulation of transformer windings and connections shall be free from insulating composition, liable to soften, ooze out, shrink or collapse. The insulation shall also be non-catalytic and chemically inactive in transformer oil during service, to ensure no degeneration of

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the oil or paper occurs during the transformer life span.

- h The stacks of windings shall receive adequate shrinkage treatment before final assembly. Adjustable devices shall be provided for taking up any possible shrinkage of coils in service. The windings shall be held under constant pressure for the 40 years design life of the transformer;
- i Coils shall be supported at frequent intervals by means of wedge type insulation spacers permanently secured in place and arranged to ensure proper oil circulation. To ensure permanent tightness of winding assembly, the insulation spacers shall be dried and compressed at high pressure before use;
- j The completed core and coil assembly shall be dried in a vapour phase oven with heating and vacuum cycles. Once the vacuum of not more than 0.5 mm of mercury absolute pressure is achieved, it shall be immediately impregnated with oil after processing to ensure the elimination of air and moisture within the insulation system;
- k Insulated sample conductors (same insulation material used during manufacturing) shall be made and placed inside the tank during the processing and drying of the transformer. These samples shall only be removed after FAT is complete, just before the tank overpressure test is done after the electrical part of the FAT. The paper strength shall then exceed a degree of polymerisation (DP) of 950 as per IEC 60450;
- l All threaded connections shall be provided with locking facilities and torqued to the manufacturer's recommended values and marked. All leads from the winding to terminals and bushings shall be rigidly supported to prevent damage from vibration. Guide tubes shall be used where practicable;
- m Adequate insulation and clearances between high voltage windings and low voltage windings shall be provided. All clearances of windings and other live parts shall be adequate for the rated voltage class;
- n The coil clamping arrangement and the finished dimensions of any oil duct shall be such as not to impede the free circulation of oil through the ducts;
- o The conductors shall be transposed at sufficient intervals in order to minimize eddy currents and equalise the distribution of currents and temperature along the windings;
- p The connections (leads) of all windings shall be brazed or crimped to withstand maximum

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through fault current;

- q End coil clamping shall be adequate to prevent distortion of end coils under any type of fault condition;
- r The primary and secondary windings shall be rated for 40 MVA or 45 MVA, depending on the specification;
- s Where applicable, the 11 kV neutral winding shall be solidly grounded or grounded via a neutral earth resistor (NER). Note: The NER is not included in the tender;
- t For transformers with tertiary windings the following shall be applicable.
  - i. The stabilizing tertiary winding shall be rated for not less than 10 MVA.
  - ii. According to SANS 60072, the tertiary winding shall at least be capable of carrying 20 times its rated current for 2.0 seconds without exceeding its thermal limits;
  - iii. The tertiary winding shall also be capable of withstanding the mechanical forces of a three-phase fault on its own terminals;
  - iv. The tertiary winding shall preferably be located as close to the core as possible to help suppress third harmonic currents in the transformer neutrals;

## 7.6 Temperature Rise

- a The transformer shall be capable of operating continuously at full rating without exceeding the temperature limits specified below:
  - i. Maximum temperature rise of top oil measured by thermometer, for ONAN and ONAF cooling is 55 K with maximum absolute top oil temperature of 95 °C when the air temperature is 40 °C (indoor or outdoor);
  - ii. Maximum hot spot temperature of the winding shall not exceed 113 °C when the air temperature is 40 °C;

## 8 ANCILLARY EQUIPMENT REQUIREMENTS

### 8.1 Tank Construction

- a The transformer tank shall be of conventional box type construction with ribs. The transformer tank and cover shall be fabricated from good quality low carbon steel of adequate thickness and

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shall be designed to withstand lifting of the complete transformer with the tank filled with oil by crane or jacks and transportation by sea, river, road or rail without overstraining any joints and without causing subsequent leakage of oil. Adequate stiffeners shall be provided, wherever necessary, for tank plates. A tank with a top lid is preferred compared to a dome or bell type construction. Should any damage occur during transportation it shall be the responsibility of the Manufacturer.

- b The manufacturer shall provide proof, including simulations, that the tank will not deform or rupture should an internal fault develop inside the tank.
- c The base of such tank shall be so designed that it shall be possible to move the complete transformer by skidding in any direction without injury using plates or rails. The base plate shall have a minimum thickness as specified in table 15 of NRS 054;
- d There shall be more than one manhole in the transformer cover to facilitate the removal and installation of bushings and current transformers. All manhole covers shall be fitted with gaskets for oil sealing;
- e All oil to air and gas to air seals shall utilize recessed groove gasketed joints. The gasket material shall be Nitrile (Buna N) or Viton and compression shall be between 15% and 33% for each location. The cross-sectional area of the gasket shall be 80% to 90% of the cross sectional area of the groove;
- f The tank shall be capable of withstanding filling by full vacuum (less than 0.5 mm on Hg scale), continuous internal pressure of 100 kPa over normal hydrostatic pressure of oil, short circuit forces and full vacuum (less than 0.5 mm on Hg scale), for drying purposes.
- g Adequate space shall be provided at the bottom of the tank for collection of sediments.
- h The tank shall be fitted with a top and bottom oil gate type valve with a minimum inside bore diameter of 75 mm. The gate valve shall be constructed of brass or gun metal, and shall be lockable. A bolted flange cover plate shall be fitted to the outside flange of the valve with an o-ring type seal.
- i The base and tank stiffeners shall be designed to prevent retention of water.
- j Wherever possible, the transformer tank and its accessories shall be designed without pockets, wherein gas may collect. Where pockets cannot be avoided, pipes shall be provided to vent the

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gas into the main expansion pipe. All vent pipes shall have a minimum inside diameter of 15 mm.

- k All seams and joints, other than those, which may have to be opened, shall be welded and wherever possible, double welded. All welding shall be stress relieved, if required. Tank stiffeners shall not cover welded seams, to allow for the repair of possible oil leaks.
- l Welding shall comply with NRS 054.
- m The complete serial number shall be stamped into the main tank at a height 1.5 m from the tank bottom. All other tank components, e.g. the lid and covers, shall be stamped with the last four digits of the tank serial number.

## 8.2 Transformer colours

The transformer colour coding system provided shall be in accordance with SANS 1091 and shall be as specified in Table 7.

*Table 7: Transformer colours (as per SANS 1091)*

Description	Colour required
Main tank	Dark Admiralty Grey (G12)
Terminal boxes	Dark Admiralty Grey (G12)
On-load tap changer drive mechanism	Dark Admiralty Grey (G12)
Marshalling kiosk (Outside)	Dark Admiralty Grey (G12)
Conservator tank	Cloud White (G80)
Marshalling kiosk (inside)	Cloud White (G80)

## 8.3 Lifting and Haulage Facilities

The tank shall be provided with:

- a Lifting lugs, suitable for lifting the transformer complete with oil and all other fittings;
- b At least four hauling eyes shall be provided to facilitate movement of the transformers and they shall be suitably braced in vertical direction, so that bending does not occur when the pull has a vertical component. The hauling eyes shall also be suitable for lashing during transport;
- c The transformer shall be equipped with four lashing lugs near the top lid of the transformer;

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- d The transformer shall be equipped with a minimum of four jacking pads as per NRS 054 requirements to enable the transformers, complete with oil and fittings, to be raised or lowered using hydraulic or screw jacks. The jacking pads shall be able to accommodate jacks with an outside diameter of at least 250 mm at its base;
- e A stress analysis of tank, lifting lugs and jacking pads shall be done using finite element analysis for the maximum mass of the transformer;

#### 8.4 Tank Cover

The tank cover shall meet the requirements of NRS 054 as well as the following:

- a The detachable tank cover (lid) shall be designed for adequate strength, to prevent distortion when lifted, for the transformer to withstand full vacuum (less than 0.5 mm on Hg scale) internally and to prevent collection of water on any part. It shall be separate from the core and windings and shall be capable of being lifted separately from the tank for inspecting the core and winding at site. Inspection openings shall be provided, as necessary to give easy access to bushings, core and windings, earth connection etc. Each inspection opening shall be of ample size for the purpose for which it is provided and at least two openings, one at each end of the tank cover, shall be provided. One opening shall be large enough for a man to enter the tank via this opening;
- b The tank cover and inspection covers shall be provided with suitable lifting arrangements. Unless otherwise approved, the mass of inspection covers mass shall not exceed 25 kg each;
- c The tank cover shall be fitted with pockets at the position of maximum oil temperature for PT100 pockets, used for oil and winding temperature indicators. Mechanical protection shall be provided for each PT100 pocket and the sensor on top. It shall be possible to remove these bulbs without lowering the oil in the tank. One of the pockets shall be positioned near the centre of the tank lid and the other above one the two outer windings;
- d Temperature indicator pockets shall be fitted with a captive screwed top to prevent ingress of water;
- e The tank cover shall be welded to the tank after final assembly and testing;

#### 8.5 Radiators

- a The following requirements are based on NRS 054.



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- b Radiators (coolers / oil to air heat exchanger) shall be of the bolt-on type and interchangeable without adjustment;
- c The radiators shall be hot dip galvanized on the outside and painted with an undercoat on the inside. The undercoat shall be completely dried and cured before the radiators are sealed for storage during manufacture or for filling with oil;
- d The tube thickness of the radiators shall be at least 1,0 mm;
- e The fins/tubes of the radiator shall be braced with at least two cross members to stiffen them;
- f The galvanizing shall be at least 55 µm thick. After galvanizing the radiators shall be pickled in phosphoric acid and then cleaned;
- g Radiators shall be flushed with hot oil (>80 °C) before fitted to the transformer;
- h Each radiator shall have two plugs, one at the top and the other at the bottom, and a lifting lug;
- j Each radiator shall be fitted with air/oil tight blanking plates on the flanges after manufacture and during shipping;
- k Each radiator shall be tested for leaks before being attached to the transformer, with a certificate of compliance;
- l The radiators shall be able to withstand full vacuum (less than 0.5 mm on Hg scale/ -100 kPa gauge pressure), and an overpressure of 170 kPa;
- m The radiators shall be fitted to a common header that is welded to the transformer tank on the top and the bottom. The headers shall have at least four ports to the tank and supports with gussets to ensure that no cracks develop during transport or from vibration during service. Each radiator port shall be fitted with a butterfly valve capable of sealing to withstand full vacuum (less than 0.5 mm on Hg scale), and an overpressure of 170 kPa;
- n The header shall be extendable in both horizontal directions and sealed on the ends with flanges with O-rings.
- o In some cases the radiator banks may be mounted to only one side of the transformer, e.g. in an indoor application or where there is a space restriction. In this case oil pumps may be added to aid circulation;

## 8.6 Transformer oil

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The transformer oil shall meet the requirements of City Power Specification for insulating oil, CP\_TSSPEC\_116, as well as the following:

- a Only virgin uninhibited naphthenic-based mineral insulating oils shall be used in new transformers for factory testing and filling on site;
- b The manufacturer and name / type of oil shall clearly be stated in Schedule B;
- c The transformer and all associated oil filled equipment shall be supplied along with sufficient quantity of oil, free from moisture and having uniform quality throughout for the first filling of the tank, conservator and coolers along with 400 ℓ of extra oil for topping-up, in non-returnable containers, suitable for outdoor storage;
- d The transformer main tank is shipped full of oil with 100mm below transformer cover and not exposing windings free headspace that is kept under a positive pressure of at least 35 kPa. The headspace shall be filled with dry air. The pressure in the headspace shall be regulated and the maintained from a 2.2 kg bottle for local shipping and from 50 kg bottle for international shipping. If not, the manufacturer shall apply for a concession. Once the transformer reaches Johannesburg it shall be filled immediately with oil with as per the oil commissioning procedures in this specification (to maximum filling level as per manufacturer);
- e The transformer oil required for first filling on site shall be included in the tender offer. This shall exclude the oil absorbed in the windings and insulation materials;
- f The oil shall meet the requirements of class 1 oils specified in IEC 60296, without any additives, and conform to IEC 60296 and IEC 60422;
- g The oil shall be tested for sulphur content using ASTM D1275B and D130, and Doble CCD tests.  
The tests results must show the oil to be non-corrosive with a tarnish level of 1a or 1b; s
- h The transformer oil shall not damage the enamelled or bare copper conductors with corrosive sulphur or other chemicals;
- i Under no circumstances shall poor quality oil be filled into the transformer;
- j The design and materials used in the construction of the transformer shall be such as to reduce the risk of the development of acidity in the oil;
- k The transformer oil shall not be conducive to stray gassing, e.g. from zinc parts in contact with

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oil, improper cooling or copper passivators. This shall be supported by documentation (test results) of the oil manufacturer indicating that the oil used by the manufacturer is not prone to stray gassing;

- l The power frequency dielectric breakdown strength of the oil in any part of the transformer shall meet the transformer manufacturer's requirements, but shall, in any case, not be less than 70 kV/2.5 mm for virgin oil prior to filling and not less than 60 kV/2.5 mm at time of takeover;
- m The moisture content of the oil before filling the transformer shall not exceed 5 ppm at 20 °C. At time of takeover, the moisture content in the insulating oil shall not exceed 10 ppm at 20 °C in the main tank;
- n The total combustible gasses in the oil (acetylene, carbon dioxide, ethane, ethylene and methane) shall be less than 10 ppm for the oil used filling during factory testing and site filling;
- o It shall be proven that the moisture content in the insulation material of the transformer is less than 1.0% at time of takeover by oil sample under stable temperature conditions and no-load. To demonstrate this a block of insulation material shall be sent in for analysis as with DP samples. These samples shall be shipped to the laboratory in sealed containers under oil.

## 8.7 Dissolved Gas Analyser (DGA)

- a An online moisture and Dissolved Gas Analyser (DGA) measurement (eight gasses) system shall be installed to monitor the moisture content and the dissolved combustible gasses in the transformer.
- b The DGA will be as per City Power specification for on-line dissolved gas analyser, CP\_TSSPEC\_179.

## 8.8 Conservator Tank and Oil Gauge

- a A conservator, complete with sump and drain valve, shall be provided in such a position, as not to obstruct the electrical connections to the transformer, having a capacity between the highest and the lowest visible levels to meet the requirement of expansion of the total cold oil volume in the transformer and cooling equipment from the minimum ambient temperature to -10 °C. The minimum indicated oil level shall cover the feed pipe from the main tank with not less than 50 mm depth of oil. The indicated range of oil level shall be from minimum to maximum with a mark to indicated the normal filling level at 20 °C;

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- b A nitrile membrane bladder shall be inserted in the conservator to prevent the atmospheric air to have direct contact with the oil. The bladder material in contact with the oil shall be oil resistant and the bladder material in contact with the air shall be oxygen and ozone resistant. The rating plate shall contain a warning that the conservator is fitted with a bladder;
- c One end of the conservator shall have a bolted cover, so that it can be removed for cleaning purposes;
- d The conservator shall have a magnetic type oil gauge, with:
  - Low oil level alarm contacts with 3 A rating
  - Dial, showing minimum, maximum and normal (at 20 °C) oil levels
  - An analogue output to be wired to the temperature and oil level monitoring system
- e The oil pipe from the transformer tank to the conservator tank shall be arranged at a rising angle of 3° to 9° to the horizontal with a pipe of 80 mm (or larger) diameter. A Buchholz relay shall be installed after a straight run of pipe for at least a length of 5 times the internal diameter of the pipe on the tank side of the Buchholz relay and at least 3 times the internal diameter of the pipe on the conservator side of the Buchholz relay. The inner radius of the pipe wall shall exceed 50 mm on all bends. Should the total Buchholz pipe length exceed 1500 mm it must be supported every at 1000 mm intervals;
- f A shut-off valve shall be fitted on both sides of the Buchholz relay;
- g A grounding strap shall electrically connect the conservator tank to the main tank;
- h The conservator shall be fitted with oil filling valve and drain gate type valve with a minimum inside bore diameter of 75 mm. The gate valve shall be constructed of brass or gunmetal and shall be lockable. A bolted flange cover plate shall be fitted to the outside flange of the valve with an O-ring type seal;

## 8.9 Valves and piping

- a The tank shall be equipped with the following valves:
  - Oil shut-off valves between oil coolers and tank header, one on the outlet pipe and one on the inlet pipe;
  - Two 50 mm valves, one at the top of the short side of the tank wall of the transformer

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and the other at a diagonally opposite end at the bottom with padlocking arrangement;

- Two sampling valves (size 20 mm) at top and bottom of the main tank, with provision for fixing a pipe with ½" BSP thread;
- b The conservator shall be fitted with an air venting valve. The vent valve shall be mounted 1.5 m above ground level with a pipe connection to the conservator;
- c Gas and oil sampling valves shall be fitted to the Buchholz relay and mounted 1.5 m above ground level with copper pipes connected to the Buchholz relay;
- d All valves with openings to the atmosphere shall be fitted with blanking flanges with an O-ring seal on the atmosphere side of the valve if the pipe has a diameter larger than 20 mm. For smaller pipes a blanking plug must be fitted on the atmosphere side of the valve;
- e All valves shall be of brass or gun metal;
- f Valves, larger than 20 mm diameter, shall be provided with flanges, having machined faces;
- g Valves between the tank and the radiators (heat exchangers) shall be of the cam lock type to indicate the valve position. These valves shall have a rated working pressure of 170 kPa;

#### **8.10 Pressure Relief Device**

- a Two pressure relief devices (valve) (PRV) shall be mounted on the main tank, one on each short side wall near the corner with a long side wall, and of such a design to prevent gas accumulation;
- b The pressure relief device valve opening just below the spring shall have a diameter of at least 140 mm;
- c The pressure relief device shall operate in less than 2.5 ms for a rapid pressure increase of 50 kPa, based on NRS 054.
- d The pressure relief devices shall be of sufficient size for rapid release of any pressure that may be generated within the tank and which might result in damage to the equipment, e.g. tank rupture. The device shall be operated at a static pressure of less than the hydraulic test pressure for transformer tank. Means shall be provided to prevent the ingress of moisture;
- e The pressure relief device shall be of safety valve type, capable of resealing after any pressure developed in the tank is released, and it shall be fitted with switches for actuating alarm or trip

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contacts, when it acts. The switches shall be manually reset, once the pressure is released;

- f Type tests shall be submitted to City Power as proof of the pressure relief device's performance before the design review meetings;

### 8.11 On-load tap changer

- a The on-load tap changing (OLTC) gear shall comply with NRS 054 and IEC 60214, be of the resistance bridging type with vacuum switches and have a flag switching cycle, capable of at least 1 million switching operations and maintenance free for at least 300 000 operations;
- b The tapping range shall be +5% to -15% in 1,25% steps;
- c The on-load tap changer and selector switchers shall be housed in pockets in the main transformer tank;
- d The on-load tap changing mechanism shall be connected to the HV (132/88 kV) winding of the transformer on the star point side;
- e The tapping winding with the OLTC shall be of the forward / reverse type;
- f The tap changer shall be designed for suitable remote control operation from a switchboard in the control room in addition to being capable of local manual as well as local electrical operation;
- g The tap changer shall be capable of permitting parallel operation with other transformers of the same type. The operation cubicle has to be supplied and the OLTC gear shall be capable of operating in parallel. OLTC shall be provided with the following modes of operation:
  - Local – manual (hand operated)
  - Local – electrical
  - Remote - electrical
- h The transformer output shall not be limited by the OLTC on any tap. The OLTC shall be rated for at least 400 A for 88 kV units and 300 A for 132 kV units. The OLTC shall not limit the overload capacity (as defined in SANS 60076-7 and IEC 60354) of the transformer;
- i The manufacturer shall provide evidence in the tender bid of comprehensive local technical and maintenance support for the OLTC.
- j The tap changer shall be able to carry the maximum through fault current of the transformer with

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a minimum rating for 20 kA for 2.0 seconds;

- k The OLTC shall be an integrated three-phase unit with a single drive mechanism;
- l The transformer manufacturer shall prove the transient overvoltage requirements for the tap changer. Calculations shall be provided to determine if tie-in resistors and / or surge arrestors are required;
- m It shall not be possible to operate the electrical drive when the hand operating mechanism is in use;
- n Each tapping operation of either the raise or lower control switch shall cause one tap movement only. The control switch shall be returned to the off position after each successive operation;
- o All electrical control switches and local operation gear shall be clearly labelled to indicate the direction of tap-changing;
- p The controller shall be equipped with an overcurrent blocking device to prevent OLTC operation during through fault conditions on the transformer;
- q Under abnormal conditions such as may occur if the contactor controlling one tap changer sticks, the arrangement must be such as to switch off the supply to the motor;
- r A cubicle shall be provided for housing motor drive mechanism for OLTC on the transformer. It shall be supplied complete with all wiring, fuses, links, cubicle illumination lamps, anti-condensation heater with thermostatic control switch, gland plate etc. The cubicle, which shall be rated for outdoor operation, weather and vermin proof, and mounted on the transformer with a minimum rating of IP64. The motor shall be suitable for operation with the limits of 85% to 110% of rated AC voltage of 400 V, 3-phase, 50 Hz external power supply;
- s As the motor shall be able to operate under wide variety of voltage conditions without damage to motor while restoring voltage stability to supply;
- t The tap changer cubicle shall contain the following:
  - Motor drive mechanism with overload protection for the motor
  - Tap position indicator
  - The tap changer drive mechanism shall be fitted with a disk on the drive shaft to indicate its position

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- Mechanical stops to prevent over-cranking of the mechanism beyond extreme tap positions
  - The manual operating device shall be removable and located at a height not exceeding 1200 mm above the base plate so that it can be operated by a man standing at the level of the transformer track. It shall be strong and robust in construction.
  - Operation counter
  - Local / remote selection switch
  - Auto / manual selection switch
  - Cubicle illumination with a cool white LED shall be provided
- u The tap changer shall have its own control / marshalling kiosk.

## 8.12 Current Transformers

- a Current transformers (CTs) shall comply with NRS 029, NRS 054, IEC 60044-1 and IEC 60044-2, CP\_TSSPEC\_064 and CP\_TSSPEC\_119;
- b Current transformers shall be able to withstand the same current overloading as the transformer, both electrically and mechanically;
- c Current transformers shall be able to withstand the same dielectric stresses as the transformer;
- d Current transformers shall be short circuited for all tests during the FAT and shall be delivered with short circuit conductors that are ferruled and marked;
- e The neutral CT shall be of the external type only, rated at IP 65, suitable for outdoor use,
- f The following information shall be provided on the rating plate:
  - i Wiring diagram
  - ii Position of CT
  - iii Turns ratio
  - iv Class and burden
  - v Rated short circuit current and time (25 kA for 3 s)
  - vi Secondary insulation level (2.5 kV DC for 1 minute)



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- vii Knee point voltage and excitation current
- viii Secondary winding resistance at 75 °C
- ix P2 and S2 shall be nearest to the MV neutral terminal (yn)
- g All secondary circuits of current transformer shall be wired with multi-strand soft 4.0 mm<sup>2</sup> panel wiring or cable;
- h Current Transformer specification shall be as shown in table 8;
- i The winding resistance shall NOT exceed 4 mΩ per turn for 1 A secondary winding and 1 mΩ per turn for 5 A secondary winding;
- j The external neutral CT shall be solidly bolted on top of the transformer tank;
- k The external neutral CT shall be mounted as close as possible to the MV neutral terminal (yn) to minimize the neutral earthing lead;

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*Table 8A: Current transformer ratings for 11kV neutral*

MV neutral (yn) external current transformer									
	yn	1yn		2yn		3yn		4yn	
Ratio	600/1	2000/1	2500/1	2000/1	2500/1	1600/5	3000/5	1600/5	3000/5
Turns Ratio	600	2000	2500			320	600		
Across	S1-S2	S1-S2	S1-S3	S1-S2	S1-S3	S1-S2	S1-S3	S1-S2	S1-S3
Vk(V)/Im(mA)	300/50		550/50	10VA	10VA		350/100	15VA	15VA
Class	TPS	TPS	TPS	5P10	5P10	TPS	TPS	10P10	10P10
Rs (max) at 75 deg. C	2,4 ohm		10 ohm				1 ohm		

*Table 8B: Current transformer for tank protection*

Location	Application	Core 1
Tank CT	Protection	400/1 Class 5P20 15 VA

*Table 8C: Current transformers for WTI*

Location	Application	Core 1
Between 11 kV windings and the neutral connection (one per phase)	Protection	2500/x Class 1 10 VA

### 8.13 88 kV and 132 kV Bushings

- Bushing insulators shall comply with SANS 60137 and be of the air to oil type terminal;
- The bushings shall be oil free, of a dry type and moisture free;
- Paper can be used inside the bushings. The insulation material shall be an epoxy resin;

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- d The weather sheds on the bushing insulator shall be of the silicone rubber type and directly moulded onto the insulation material rated for at least 31 kV/mm pollution class;
- e The bushing conductor shall be of a fixed solid rod type;
- f The bushings shall be rated one voltage class higher than the transformer, i.e. Um = 123 kV for 88 kV windings or Um = 145 kV for 132 kV windings and rated for 800 A. Resin impregnated paper (RIS) or resin impregnated synthetic (RIS) can be used.
- g The bushing shall be capable of withstanding 25 times its rated current and not overheat after 2.0 seconds. It shall also be able to withstand the short circuit forces associated with 40 kA rms through fault current;
- h The bushings shall have low dielectric losses ( $\tan \delta < 0, 4\%$ ), and be partial discharge free (PD < 10 pC at 1.1 Um measured phase to phase of bushing voltage rating). This shall be shown by the test certificate issued by the bushing manufacturer;
- i The stress control inside the bushing shall be of concentric aluminium foils;
- j Each bushing shall be fitted with a test point on the bushing flange to measure the capacitance and dissipation factor of the bushing insulation system. This shall be measured after the completion of the high voltage tests conducted during the FAT and compared to the bushing manufacturer's values;
- k The bushings shall be mounted upright on the transformer tank lid with a bushing turret to house the current transformers (3 cores) with 300 mm space for the current transformers;
- l The HV bushing turrets shall be constructed such that the bushing mounting plate for the bushing flange is removable to accommodate bushings with different bolt hole configurations;
- m The HV bushing turrets shall each be fitted with a CT terminal box that can accommodate 12 terminals;
- n Connections from the HV windings to bushing conductor shall be made with flexible conductors that are suitably braced;
- o A suitably sized shield shall cover the lower end of the bushing conductor where same connects to the flexible conductors of the HV windings;
- p Bushing insulators and fittings shall be unaffected by conditions due to weather, fumes, ozone,

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acids, alkalis, dust or rapid changes of air temperature between -20 °C and 65 °C under working conditions;

- o Every bushing shall be supplied complete with an air-side bushing terminal of electro tinned copper 38 mm in diameter and not less than 125 mm long;

#### **8.14 11 kV and 6.6 kV Bushings**

- a Bushing insulators shall comply with SANS 60137 and be of the air to oil type terminal;
- b The bushings shall be oil free, of a dry type and moisture free;
- c Paper can be used inside the bushings. The insulation material shall be an epoxy resin;
- d The weather sheds on the bushing insulator shall be of the silicone rubber type and directly moulded onto the insulation material rated for at least 31 kV/mm pollution class;
- e The internal connection shall be of a fixed solid rod type;
- q All the bushings shall be rated for a  $U_m = 36$  kV. The 11 kV bushings shall be rated for 3 000 A and the 6.6 kV bushings for 1000 A; Resin impregnated paper (RIP) or resin impregnated synthetic (RIS) can be used.
- f The bushing shall be capable of withstanding 25 times its rated current and not overheat after 2 seconds. It shall also be able to withstand the short circuit forces associated with 40 kA rms fault current;
- g The bushings shall have low dielectric losses ( $\tan \delta < 0,5\%$ ), and be partial discharge free (PD < 30 pC at 20 kV);
- h The 11 kV bushings shall be mounted upright on the transformer tank lid with a bushing turret to house the current transformers (4 cores) with 600 mm space for the current transformers;
- i Connections from the 11kV and 6.6 kV windings to bushing insulators shall be made with flexible conductors that are suitably braced;
- j Bushing insulators and fittings shall be unaffected by conditions due to weather, fumes, ozone, acids, alkalis, dust or rapid changes of air temperature between -20 °C and 65 °C under working conditions;

#### **8.15 11 kV terminals**

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- a Two suitable mounting brackets shall be fitted on top of the radiator bank on the 11 kV bushing side of the tank to support insulators that will connect the bushing air terminals to the cables coming up alongside the radiators. These brackets shall be spaced as far apart as possible to provide support to the copper busbar that will be mounted on top of suitable insulators. The insulators and copper busbar are not part of this specification. The two brackets shall each be at least 1600 mm long and bonded to the main tank wall;
- b A third suitable mounting bracket shall be fitted on top of the radiator bank on the 11 kV bushing side of the tank to support the 11 kV surge arrestors. The surge arrestors shall be mounted less than 400 mm from the 11 kV bushings. The base of each surge arrestor shall be bonded to the tank lid with flat aluminium or copper strip with a cross sectional area of at least 100 mm<sup>2</sup>;

#### **8.16 Surge arrestors for HV and MV**

Surge arresters shall be supplied by the transformer manufacturer and comply with CP\_TSSPEC\_117 as well as the following:

- a The mounting bracket for the surge arresters shall be as specified in NRS 054;
- b The surge arrestor shall be heavy duty, station class type, discharge Class III, gapless Zinc Oxide type suitable for use in solidly grounded neutral systems for 88 or 132 and 11 kV. The 6,6 kV system shall be ungrounded;
- c The energy rating shall exceed 9 kJ/kV;
- d The sheds on the surge arrestors shall be of the silicon rubber type;
- e The surge arrestors shall not violently disintegrate if overstressed;
- f Brackets shall be made to accommodate the 88 kV or 132 kV surge arrestors next to the HV bushings;
- g Surge counters shall be furnished for the 88 kV or 132 kV surges arrestors with the insulating bases for connection, supporting insulator and necessary hardware. Each counter shall have a continuous leakage current indicator and shall not require an external power source for operation. Discharge counter shall be mounted at approximately 1.5 m above the base plate of the transformer;
- h The minimum clearance in air between live phase-to-phase and phase-to-earth of the outdoor

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bushings shall be as per SANS standards. Creepage distance for the bushings shall be selected for a class IV environment as per table 1 of SANS 60815 to 31 mm / kV and shall meet the requirements of table 3 in section 5.3;

- i No radio interference shall be caused by the arrestors operating at the normal rated voltage;
- j The selection of the external surge arrestors must be co-ordinated with the City Power engineer doing the insulation co-ordination study for the substation;

#### **8.17 Gas and Oil Actuated Relays**

- a Double float gas detector relay (Buchholz relay) shall be provided with alarm and tripping contacts to detect accumulation of gas and sudden changes of oil flow, complete with shut off valves on both sides of the relay and flange coupling, to permit easy removal without lowering oil level in the main tank;
- b The Buchholz relay shall have a valve for gas sampling and an oil sample valve. The pipe work shall be so arranged to avoid sharp bends and that all gas emitted from the transformer shall pass into the relay. The sampling valves shall be placed 1.5 m above transformer tank base;
- c The Buchholz relay shall have minimum pipe size of 75 mm and operate if 0,4 ℓ of gas has accumulated;
- d The Buchholz relay shall be seismic (earthquake, shock) proof and not contain mercury type contacts;
- e There shall be no malfunction of the relay as a result of 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 the oil surges;
- f The design of the relay mounting arrangements, the associated pipe work and the cooling plant shall be such that mal-operation of the relays shall not take place under normal service conditions;
- g The Buchholz relay shall have an alarm and trip contact for the gas detection, and an alarm and trip contact for oil flow. Each contact shall be rated for 2.0 A dc at 120 V dc;

#### **8.18 Breathers**

- a The oil in conservators and other oil-filled compartments shall only be in contact with the

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atmosphere through a rubber air cell. The air inside the rubber air cell shall be connected to a self-dehydrating breather for the main oil tank only. Other conservators requiring a breather shall be filled with a non self-dehydrating breather;

- b Silica gel shall be used as a desiccant in the breather. The silica gel shall be as per City Power specification for Silica Gel (CP\_TSSPEC\_132);
- c The self-dehydrating breather shall house at least 2.2 kg of desiccant (silica gel) in each of the two cylinders for a total of 4.4 kg of desiccant;
- d The non self-dehydrating breather shall house at least 0,3 kg of desiccant (silica gel) per 1000 ℓ of transformer oil with a minimum of 1.0 kg of desiccant
- e The self-dehydrating breather shall consist of two units (cylinders) in parallel. The two units shall be dried in an alternating fashion;
- f A single atmospheric oil seal shall be provided to serve the entire breather group;
- g The dehydrating breather shall be carefully designed for easy changing of the silica gel charge;
- h The desiccant 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;
- h The self-dehydrating breather shall be maintenance free using a sensor-controlled heater element to dehydrate the desiccant charge at regular intervals to ensure optimal performance of the self-dehydrating breather. The moisture sensor and the heating element signals shall be recorded and sent to the local and remote logging system;
- i The self-dehydrating breather shall be equipped with a logger/controller to locally and remotely monitor and optimise the performance of the breather;
- j A logger/controller that is able to integrate with City Power's SCADA system for remote monitoring and alarm detection shall be installed;
- k These records shall be coupled to the Substation Automation System that communicates the data to a central City Power server;
- l The controller shall have the following digital communication ports:

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- USB port on the front of the controller
  - RS485
  - Ethernet port
- m The silica gel charge shall be contained in a transparent and independent container of weatherproof, UV-resistant and heat-resistant (up to 115 °C) material that can be simply and easily removed and replaced without the use of special tools;
- n Dehydrating breathers shall be mounted approximately 1,5 m above the transformer tank base;
- o The pipe diameter between the conservator and the breather shall have a diameter of at least 25 mm;
- p The fitting of a rubber bag in the conservator shall not exclude the use of a fully rated breather;

#### **8.19 Temperature and oil level monitor and controller**

- a The temperature controller shall have the following analogue temperature inputs:
- The transformer shall be provided with two top oil temperature PT100 sensors, one fitted above the centre winding and one above an outer winding;
  - The transformer shall be provided with two oil temperature PT100 sensors in the radiator assembly, one on the radiator inlet and one on the radiator outlet;
  - The ambient air temperature shall also be monitored with one PT100 sensor;
- b Three winding temperature CT inputs and shall provide a calculated winding temperature for each 11kV winding from a CT located on each winding;
- c Two analogue inputs for oil level in the conservators;
- d Two digital inputs for oil level in the conservators;
- e The temperature controller shall have a digital display that shows all measured qualities. Key variables shall form part of the default display;
- f The temperature controller shall have the following 4-20 mA transducer outputs:
- Oil temperature –one
  - Winding temperature –one



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- g The temperature controller shall have the following digital output contacts:
- Three for controlling the banks of three sets of fans;
  - Two for controlling the two oil pumps, when installed;
  - Two alarm and two trip contacts for oil level;
- h The fans controller shall be programmable to load all the fans equally over a 30-day period and fan groups shall be started to match the loading. The fan groups shall also periodically (once in two weeks) be started to ensure their reliable operation;
- i All analogue inputs shall be monitored for open circuits or failed input sensors and provide an alarm for such failures;
- j The controller shall be self-monitoring and generate a fail-safe alarm, should it fail;
- k It shall be able to store at least 20 000 records of oil, winding and air temperature and oil level values. These values shall be downloadable in Excel format;
- l These records shall be coupled to the Substation Automation System that communicates the data to a central City Power server;
- m It shall have a load dependant algorithm to start the cooling system once the load has increased, but before oil temperature has increased;
- n An alarm and trip signal shall be provided for each temperature sensor in LED and digital display format;
- o The controller shall have the following digital communication ports:
- USB port on the front of controller
  - RS485
  - Ethernet port
- p The remaining life of the transformer insulation shall be calculated based on SANS 60076 and ANSI standards;

## 8.20 Radiator Fans

- a The fan blades and ducting shall be made of a corrosion resistant metal, e.g. stainless steel;

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- b The fans shall be designed to keep noise to a minimum as per the noise and vibration requirements stated below;
- c The fans shall be balanced to keep vibration velocity levels (in any direction) to less than 2 mm/s rms when running;
- d Each fan shall be fitted with a stainless steel wire mesh guard to a IP20 rating;
- e The rotation and air flow directions shall be clearly and permanently marked with appropriate arrows on each fan assembly;
- f The fan assemblies shall be directly attached to the cooler banks;
- g Each fan motor shall be numbered to identify it, including the fan group it belongs to;

## 8.21 Pumps

If pumps are to be fitted in the case of the radiators being moved off the transformer the following shall apply:

- a If one of the oil pumps fails or trips due to a fault an alarm shall be generated. The second pumps must then start automatically. If both pumps fail, the transformer shall be tripped by sending two trip signals (dry contacts) to the substation automation system;
- b It shall be possible to remove the pump and motor for maintenance without removing the oil from the transformer. Valves shall be provided on both sides of the pump arrangement;
- c Provision shall be made to verify the direction of rotation by an approved method when the pump is in its normal service position. Oil-flow indicators with alarm contacts shall be provided and shall be able to withstand a reversal of the pumps without damage. In the event of accidental reversal, the flow indicators shall indicate "no flow";

## 8.22 Motors

- a The motors shall comply with SANS 60034 and be of the totally enclosed weatherproof type with IP65 rating;
- b All motors shall be started direct-on-line and have a life expectancy of 25 years;
- c Only three-phase 400 V ac, 50 Hz, motors shall be used;

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- d The bearings shall be of the ball bearing type, with 2RS seals, and self-lubricated;
- e The power cables for the motors shall have a minimum cross sectional area of 4 mm<sup>2</sup>;
- f An isolator switch and contactor, rated to carry and break the starting current for each pump motor shall be installed in the marshalling box. Contactors shall comply with the provisions of SANS 60947 and CP\_TSSPEC\_016;
- g Protection shall be provided for each motor for overload, stalling, locked rotor, single-phasing and short circuit conditions. The arrangement for electrical tripping of the motors shall not be self-resetting;
- h The motors shall not trip if subjected to a voltage dip of U = 0 for 1.0s, as per NRS 048. If the dip is longer, the pump motors must be automatically re-accelerated if the transformer has not tripped;
- i If a motor fails or trips due to a fault an alarm shall be generated and send to the substation automation system;
- j The motors shall be installed to facilitate their easy removal in the event of a failure;

## 8.23 Earthing and Bonding Arrangements

- a All metal parts of the transformer with exception of the individual core laminations, core bolts and associated individual clamping plates shall be earthed to the tank by means of copper clad steel conductor;
- b Two earthing terminals (at diagonally opposite bottom corners of the tank), capable of each carrying the 40 kA short circuit current for 3 seconds without injurious heating, shall be provided with clamp type terminal;
- c All tank-attached apparatus (including cable marshalling boxes, mechanism boxes and pump motors) shall be bonded to its supporting structures and the main tank;

## 8.24 Rating and diagram plates

The following plates shall be fixed to the transformer tank, at an average height of about 1.70 m above ground level:

- a A rating plate, bearing the data specified in the appropriate clause of SANS 60076 and NRS 054. The details of the current transformers and normal and operating pressure of pressure relief

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valve shall also be furnished;

- b A diagram plate, showing the internal connections and also the voltage vector relationship of the several windings in accordance with SANS 60076 and NRS 054, and in addition, a plan view of the transformer giving the correct physical relationship of the terminals. The no-load voltage shall also be indicated;
- c A plate showing the location and function of all valves and air release corks or plugs. This plate shall also warn operators to refer to the maintenance instructions before applying the vacuum treatment for drying and of the vacuum (less than 0.5 mm on Hg scale), and over pressure (170 kPa) that may be applied;
- d The rating plates shall be made of stainless steel and the diagrams, writings and other marked etched into the plate and painted with black paint that will not fade in direct sun light for the duration of the transformer lifetime.

## 8.25 Joints and Gaskets

- a All bolted connections shall be fitted with weather-proof, hot oil-resistant gaskets in between, for complete oil tightness. Special attention shall be given to the oil-tight joints between the tank and the cover and the bushing and other outlets to prevent ingress of moisture, or leakage of oil, even under high loading condition from the tank.
- b The tank lid to main tank walls shall be sealed using O-rings and a welded seam. The welded seam shall be manufactured in a manner to facilitate easy opening and re-welding. No cork or neoprene-cork gaskets shall be used. It shall be possible to remove the welding without contaminating the oil or paper with bits of metal or carbon;

## 8.26 Auxiliary supply

- a The auxiliary supply available on site will be as follows:
  - i. The auxiliary power supply shall be rated for 400/230 V ac, three-phase, four wire, 50Hz;
  - ii. The alarm and protection supply shall be 110 V dc and be provided from the substation battery system;

## 8.27 Marshalling Kiosks, Control and Instrument Wiring

- a The marshalling kiosks shall be as specified in NRS054.

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- b The marshalling kiosks shall be made of stainless sheet steel (3CR12), vermin and weather proof.
- c The box shall be painted white on the inside;
- d Vibration dampers shall be provided to reduce the vibration between the transformer and the kiosk;
- e The marshalling kiosk shall be divided into two separate compartments for the accommodation of the following:
  - Temperature indicators, metal-clad heater control, radiator fan control, auto-manual change-over switch and change-over links for the temperature indicator circuits;
  - The control and protection equipment for the tap changing gear and interposing relays for the supervisory control and equipment;
  - The control and protection equipment for the cooling plant isolating and change over switch for the incoming supplies for the cooling plant, tap changer and DC shall be of a six pole type, lockable in the off position, with off positions between each change-over position, and capable of carrying and breaking the total full load current.
  - The change-over switch for automatic or manual control of the fan and pump motors on the cooling plant.
- f Anti-condensation metal-clad heaters controlled by a switch mounted internally and a suitable MCB shall be provided;
- g Spring loaded terminals shall be used for connections, numbering of terminals and lugs shall also be provided. The lugs shall also be screwed down in the terminals. The terminals shall not be prone to breakage. Hook blade type lugs shall be used in these terminals;
- h Trunking for multicore cabling and wiring shall be provided;
- i Wiring shall be done neatly from various points to the marshalling box;
- j The marshalling kiosk shall be provided with vents and have an IP63 rating;
- k The internal lighting with door switch activation shall be mounted on both compartments.  
Cubicle illumination shall use two cool white LED type lamps each rated at 5 W;
- l A provision for 230 V ac SABS socket for test equipment shall be provided and protected by an

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earth leakage;

- m A single phase 230 V ac SABS socket outlet, for test equipment, shall be provided, including earth leakage protection (63 A);
- n Marshalling kiosk door shall have a glass panel to view temperature monitoring device. An internal swing frame shall be provided to facilitate the access to equipment for repair/replacement;
- o Marshalling kiosk door hinges and handles shall be of non-corrosive material;
- p The generic drawing shall be used for the design and wiring of marshalling kiosk. See Annex D;
- q All cables shall be glanded onto the base plate of the marshalling kiosk to prevent moisture/oil ingress. The cable gland shall be as specified in CP\_TSSPEC\_030. The gland plate shall be bolted to the marshalling kiosk;

## **8.28 Multicore cables and Terminal boxes**

- a All cables shall comply with City Power specification, CP\_TSSPEC\_002.
- b Glands shall comply with City Power specification, CP\_TSSPEC\_030.

## **8.29 Control Wiring, Terminal Boards, Fuses etc.**

- a All wiring connections, terminal boards and MCBs shall be suitable for tropical atmosphere. Any wiring liable to be in contact with oil shall have oil resisting insulation and the board ends of stranded wire shall be joined together to prevent creepage of oil along the wire;
- b To protect alarm and tripping contacts from burning during closing and tripping of circuits, electrical master trip relays shall be used. Some need to reset automatically (e.g. overload) and others manually depending on the circuit when faults occurred. The tripping philosophy shall be approved by City Power. These relays shall be of the anti-contact bounce type, operate in less than 12 ms, with fitted free-wheeling diodes if operated with DC voltage and meet the City Power specification for miniature circuit breakers, CP\_TSSPEC\_017;
- c There shall be no possibility of oil entering into the connection boxes, used for cables or wiring;
- d Panel connections shall be neatly and squarely fixed to the panel. All instruments and panel wiring shall be run in non-corrosive metal cleats of the limited compression type. All wiring to the panel shall be taken from terminal blocks;

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- e Where conduits are used, the runs shall be laid with suitable falls, and the lowest parts of the run shall be external to the boxes. All conduit runs shall be adequately drained and ventilated. Conduits shall not be run at or below ground level;
- f All box wiring shall be in accordance with SANS 10142. All wiring shall be of fine multi-stranded copper of 1000/600 V as per SANS 1507 grade and size not less than 4 mm<sup>2</sup> for CT leads and power cables for motors (coloured) and not less than 2.5 mm<sup>2</sup> (grey) for other connections;
- g All wires on panels and all multi-core cables shall have ferrules, which bear the same number at both ends;
- h At those points of interconnection between the wiring carried out by separate contactors, where a change of number cannot be avoided, double ferrule shall be provided on each wire;
- i The same ferrule numbers shall not be used on wires of different circuits in the same panels;
- j Ferrules (wire numbers) shall be of yellow insulating material and shall be provided with glossy finish to prevent the adhesion of dirt. They shall be clearly and durably marked in black and shall not be affected by moisture or oil ingress;
- k Stranded wires shall be terminated with crimped pre-insulated hook blade or ring type lugs on CT wiring. Separate lugs shall be used for each wire. The size of the lugs shall be suited to the size of the wire terminated. Wiring shall, in general, be accommodated on the sides of the box/kiosk and the wires for each circuit shall be separately grouped. Back of panel wiring shall be so arranged that access to the connecting stems of relays and other apparatus is not impeded;
- l Wires shall not be jointed or tied between terminal points;
- m Wherever practicable, all circuits in which the voltage exceeds 125 V, shall be kept physically separated from the remaining wiring. The function of each circuit shall be marked on the associated terminal boards;
- n Where apparatus is mounted on panel, all metal cases shall be separately earthed by means of copper wire or strip having a cross sectional area of not less than 6 mm<sup>2</sup>;
- o All wiring diagram for control and relay panels shall preferably be drawn as viewed from the back and shall show the terminal boards arranged as in service. All diagrams shall show which view is employed;
- p Multi-core cable tails shall be so bound that each wire may be traced without difficulty to its cable;

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- q The screens or screen pairs of multi-core cables shall be earthed at one end of the cable only. The position of earthing connections shall be shown clearly on the diagrams;
- r All terminal boards shall be mounted obliquely towards the rear doors to give easy access to terminations and to enable ferrule numbers to be read without difficulty;
- s Terminal board rows should be spaced adequately, not less than 150 mm apart to permit convenient access to wires and terminations;
- t Terminal boards shall be so placed with respect to the cable gland (at a minimum distance of 300 mm), as to permit satisfactory arrangement of multi-core cable tails;
- u Terminal boards shall have pairs of terminals for incoming and outgoing wires. Insulation barriers shall be provided between adjacent connections. The height of the barriers and the spacing between terminals shall be such as to give adequate protection while allowing easy access to terminals. The terminals shall be adequately protected with insulation and dust-proof covers;
- v No live metal parts shall be exposed at the back of the terminal boards;
- w All MCBs shall be of double-pole type and shall be labelled clearly as per the City Power Specification, CP\_TSSPEC\_017;
- x Terminal blocks shall be of spring loaded type M6/8 or M8/10 type. At least 20% spare terminal blocks shall be installed;
- y There shall also be terminals for three sets of CTs per HV phase for later installation.
- z All alarms and trip circuits shall be potential-free contacts, rated for 10.0 A and 110 V dc;

### **8.30 Fittings and Accessories**

The fittings and accessories mentioned here are the minimum requirements and any other fitting, which are generally required for satisfactory operation of the transformer, is deemed to be included.

### **8.31 Centre of Gravity**

The centre of gravity of the assembled transformer shall be low and as near the vertical centre line as possible. The transformer shall be stable with and without oil with the coolers fitted or not. The centre of gravity shall be marked on the all sides of the transformer for when filled with oil and when empty and indicated as such.



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## 9 TRANSFORMER PERFORMANCE REQUIREMENTS

### 9.1 Efficiency and losses

- a Transformer efficiency and loss figures shall be guaranteed, without positive tolerance, i.e. the values quoted and the measured values during the Factory Acceptance Test (FAT) shall not exceed the values stated by the manufacturer in Schedule B provided they are less than the maximum values given in Schedule A of Annex B. The tertiary winding shall not be loaded other than by circulating current;
- b The no-load losses in kW and the maximum load losses in kW at rated frequency, rated current and at 75 °C shall be quoted and these figures shall be guaranteed. The cooling losses from fans and pump motors shall also be included in these calculations;
- c The stray load losses and fan/pump motor losses shall be quoted separate from the copper losses;
- d The tap with the highest losses shall be used for the temperature rise (heat run) test;
- e The leakage flux produced by harmonics shall not be so high as to cause high stray losses and local overheating;
- f The efficiency and losses of each transformer shall be specified in Schedule B of Annex B and must be less than the maximum stated in Schedule A;
- g If the loss figures exceed the maximum values in Schedule A of Annex B the transformer shall be rejected;
- h If the measured temperature rises exceed the guaranteed values in Schedule B of Annex B, the highest deviation in degrees (top oil rise, average winding rise, hot spot rise) will be penalised. For each 1 K exceeding the guaranteed value, 1.5% of the transformer purchase price shall be penalised. If the deviation is more than 5 K the transformer will be rejected.
- i There will be no credit or payment of premium if actual values are better than guaranteed values.
- j The capitalized value of losses will be calculated using the rates as per Schedule A of Annex B1, B2 and B3 respectively, using the losses in Schedule B.

The transformer cost shall be evaluated as follows:  $\text{Evaluated Cost} = P + [A * E] + [B * L]$

Where: P = Transformer tender price

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A = Evaluated Cost of No-load loss per kW

B = Evaluated Coast of Load loss per kW

E = No-load loss in kW

L = Load loss in kW

## 9.2 Vibration and Noise

- a Radio interference level - The transformer shall be designed with particular attention to the suppression of maximum harmonic voltages, especially the third, fifth and seventh harmonics, so as to minimise interference with communication circuits;
- b The noise-level when energised shall not exceed the value specified in Table 9, below when measured under standard conditions as stated in point (c);

*Table 9: Noise levels (based on NRS 054 and SANS 60076-10)*

Transformer Rating (MVA)	Cooling	Average Sound Level (dBA)
40/45	ONAN	76
40/45	ONAF	77

Note: For all ONAF ratings, the sound levels are with the auxiliary cooling equipment in operation.

- c The noise levels shall be measured and recorded for each transformer during FAT:
  - under no-load conditions at rated voltage and frequency on the nominal tap without the fans running;
  - under no-load conditions at rated voltage and frequency on the nominal tap with all the fans running;
  - under no-load conditions at maximum tap and 110% fluxing at rated frequency on the nominal tap with all the fans running;
  - under full load conditions at rated current and frequency on maximum tap with all the fans running;

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### 9.3 Conditions of maximum rating, temperature rises and sustained overloads

Continuous maximum rating, temperature rise and overload shall comply with SANS 60076-7 requirements when operating with natural or forced cooling.

## 10 QUALITY ASSURANCE

### 10.1 Quality Assurance

A quality management system shall be set up in order to assure the quality of power transformers during design, development, production, testing. Guidance on the requirements for a quality management system may be found in the following standards: SANS 9001. City Power will review the quality management system and advise on its suitability.

### 10.2 Design Reviews

The manufacturer's transformer design is subject to City Power's design review process and include:

- a The design review of the transformer shall cover the electrical, mechanical, magnetic and thermal designs of the transformer. This will provide City Power and accredited representatives of City Power the opportunity to scrutinise the design to ensure it meets City Power's requirements and specifications. Information requested for review during the design review meetings shall be supplied to the City Power and accredited representatives of City Power seven days before the design review meetings take place;

The following detailed drawings shall be submitted within two months from the date of award of contract for review and approval:

- a General outline drawings, showing front elevations and plan views of the transformer and all accessories and external features with detailed dimensions, weights, crane lift for de-tanking and for erection / removal of bushings, size of lifting lugs and pulling eyes, HV and LV terminal clearances, live terminal to ground clearance, quantity of insulating oil and dimensional details for foundation;
- b Assembly drawings of HV and LV windings;
- c Schematic control and wiring drawings, and drawings showing temperature indicator circuits and control system for cooling equipment;
- d Drawing showing construction and mounting details of marshalling box;
- e Drawing, giving details of nameplate, terminal marking and connection diagram;

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- f Design calculations and simulations for requested elements of the design;

### **10.3 Interchangeability**

- a All transformers of a specific rating and ordered under the same contract shall be identical and the parts interchangeable without alteration;
- b All components of the transformer shall be made accurately to specific dimensions so that all corresponding components fit in place without any need for adjustment and can be fitted to any of the transformers of a specific rating ordered under the same contract;

### **10.4 Component approvals**

- a The components and fittings associated with transformers covered in this specification shall be subject to final written approval by City Power and accredited representatives of City Power during the design review meetings;
- b Samples, technical literature, drawings, test reports and lists of principle users, with experience gained, shall be supplied on request;
- c The manufacture shall use reliable standardized and approved components already proven on similar power transformers to minimize the variety of spares required;

### **10.5 Quality Plan Documentation**

- a City Power shall have access to visit the works at the different stages of manufacture and to ensure the quality of components used in the manufacturing process;

### **10.6 City Power Inspections**

- a The accredited representatives of City Power and City Power shall have access to the manufacturer's (and sub-contractors) works at any time during working hours for the purpose of inspection of manufacture or test on the plant and selection of samples of the materials going into the equipment. The manufacturer shall provide necessary facilities for such inspection or testing;
- b During quality checks, the manufacturer may be asked by City Power to provide SANAS certificates for the equipment used during testing.
- c The core and coil assembly shall be inspected by City Power and the accredited representatives of City Power prior to tanking and the readiness for such inspection shall be communicated at least seven days in advance for local manufacturers and 21 days for international manufacturers. The

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tanking of core and coil assembly shall be taken up only after approval by City Power and the accredited representatives of City Power;

- d Hold points for other key inspections shall be agreed with City Power and the accredited representatives of City Power during the design review meeting shortly after the purchase contract has been signed. The readiness for such inspection shall be communicated at least seven days in advance for local manufacturers and 21 days for international manufacturers;
- e All necessary facilities for inspection and testing shall be provided by the manufacturer;
- f The transformer shall be completely assembled and tested as such at the manufacturer's factory;
- g The manufacturer shall ensure that the test instruments (including instrument transformers and other transducers) have valid calibration certificates issued by an approved standard laboratory;
- h The readiness of the transformer for testing and final inspection shall be communicated to City Power and the accredited representatives of City Power at least seven days in advance for inspection / witnessing the tests for local manufacturers and 21 days for international manufacturers;
- i The transformer will be accepted at site by City Power and the accredited representatives of City Power, only once all the approved test certificates and all hand-over documentation have been provided;

## 11 TESTS

All tests are to be done at manufacturers cost and this cost shall be included as part of the transformer costing price.

Routine tests and special tests are to be witnessed by a minimum of two City Power officials and the accredited representatives of City Power. Manufacturers shall include separately, in their tender price, all associated costs to have the two City Power delegates witness the special final acceptance tests at the manufacturers test facilities. If the tests take place within the Gauteng province of South Africa this cost is zero.

### 11.1 Type, Special and Routine Test Requirements

- a All type tests shall comply with SANS 60076;
- b All routine and special tests shall comply with SANS 60076;

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c Refer to Table 10 for the type, special, and routine test requirements as per NRS054;

Table 10: Type, special and routine test requirements as per NRS 054

Test Description	Specification	Routine	Type	Special
Winding Resistance Test	SANS 60076-1	√		
Voltage Ratio and check of phase displacement	SANS 60076-1	√		
Measurement of Short Circuit Impedance and load losses	SANS 60076-1	√		
No-load loss and current measurements	SANS 60076-1	√		
Temperature rise tests	SANS 60076-2		√ <sup>b</sup>	
Dielectric (impulse test)	SANS 60076-3	√		
Chopped wave	SANS 60076-3	√		
HV neutral - impulse and chopped wave	SANS 60076-2			√
Dielectric (short duration AC)	SANS 60076-3	√		
Dielectric (separate source)	SANS 60076-3	√		
Dielectric (Long duration AC – partial discharge)	SANS 60076-3			√
On-load tap changer tests	IEC 60214		√ <sup>b</sup>	
Tests applied to devices with alarm and tripping contacts	NRS 054 (5.3)	√	√ <sup>b</sup>	
Transformer tank tests	NRS 054 (5.4)	√	√ <sup>b</sup>	
Bushing tests	IEC 60137	√	√ <sup>b</sup>	
Testing of current transformers	IEC 6189-2	√	√ <sup>b</sup>	
Gas and oil actuated relay tests	NRS 054 (5.5)	√	√ <sup>b</sup>	
Digital Thermometers	NRS 054 (5.6)	√	√ <sup>b</sup>	
Acoustic noise level measurement	SANS 60076-10			√
Determination of capacitances, windings to earth and between windings	SANS 60076-1			√
Zero sequence impedance measurement	SANS 60076-1	√ <sup>a</sup>		√
Short circuit withstand tests	SANS 60076-5		√ <sup>b</sup>	
Measurement of insulation resistance to earth and between windings	SANS 60076-1	√		
Sweep frequency response analysis				√
Corrosive sulphur test on the oil	IEC 60296			√
DP and moisture test on transformer insulation after the process cycle				√

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Note: <sup>a</sup>Only applicable to star-connected and zig-zag connected windings as well as auto transformers.  
Note: <sup>b</sup>City Power may request type test certificates of similar transformers during the tender evaluation phase.

- d Sweep frequency Response Analysis shall be done prior to loading the transformer for transportation and after commission to ensure that no winding and core displacement has occurred during transportation and installation on site.

## 11.2 Type tests

- a All type tests shall comply with IEC 60076 and shall be carried out on the transformer, in the presence of two City Power and the accredited representatives of City Power;
- b Manufacturers shall include separately, in their price, all associated costs to have three City Power delegates witnessing the type tests of every unit at the manufacturers or other test facilities. If the tests take place within a radius of 100 km of City Power's head office this cost is zero;
- c Temperature rise (heat run) tests as per SANS 60076-2 of latest issue shall be carried out on one transformer, in the presence of City Power and the accredited representatives of City Power on all three phases. City Power shall have the right to test the transformer at neutral agency if the manufacturer does not have the facility to perform the tests. The cost of these tests shall be for the manufacturer. Oil samples shall be taken at least every four hours during the tests including one sample at the beginning and another sample at the end each test and analysed for moisture, voltage breakdown and DGA. One fan motor shall be off during the heat run test;
- d Overload test – one transformer shall be loaded to 120% of rated current for two hours from hot at the end of the ONAF heat run test. City Power shall have the right to test the transformer at neutral agency if the manufacturer does not have the facility to perform the tests. The cost of these tests shall be for the manufacturer. Oil samples shall be taken at the beginning and another sample at the end of the test and analysed for moisture, voltage breakdown and DGA. During the overload test on the first unit the data shall be collected to produce a graph similar to that of figure E.1 in SANS 60076-7 using the method in Annex E of SANS 60076-7 and in compliance with IEC 60354;
- e City Power reserves the right to apply a short-circuit test to the transformer at any certified and accredited STL test laboratory before taking delivery, in order to prove the short-circuit strength of the windings. Such tests shall follow the guidelines laid down in SANS 60076-5. The manufacturer shall demonstrate to City Power's approval, using internationally accepted design calculations, that

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the transformer meets the requirements for short-circuit strength, before being subject to short circuit testing;

f The duty under fault conditions should be as follows:

- a. Transformers shall be capable of withstanding short circuits for the periods of time as specified in SANS 60076-5 when operating on any tap position, including that corresponding to minimum effective impedance;
- b. A minimum safety factor of 10% shall be added to these currents when calculating the forces exerted on the windings and clamping structures;

### 11.3 Special tests

- a All special tests shall comply with SANS 60076 and shall be carried out on the transformer, in the presence of City Power and the accredited representatives of City Power;
- b Overload test – each transformer shall be loaded to 120% of rated current for two hours from cold. City Power shall have the right to test the transformer at neutral agency if the manufacturer does not have the facility to perform the tests. The cost of these tests shall be for the manufacturer. Oil samples shall be taken at the beginning and another sample at the end of the test and analysed for moisture, voltage breakdown and DGA;
- c Measure the capacitance and dissipation factor of the bushing insulation system;
- d Measure the capacitance and dissipation factor of the windings to each other and the tank;
- e Sweep Frequency Response Analysis (SFRA) shall be done prior to loading the transformer for transportation and after commission on site to ensure that no winding and core displacement has occurred during transportation and installation on site. Should the signatures of the two SFRA tests differ the transformer shall be rejected and taken back to the manufacturer's works for a detailed inspection;
- f Manufacturers shall include separately, in their price, all associated costs to have three City Power delegates witnessing these special tests of every unit at the manufacturers test facilities. If the tests take place within Gauteng this cost is zero;

### 11.4 Routine tests



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- a All routine tests shall comply with SANS 60076 and shall be carried out on the transformer, in the presence of City Power and the accredited representatives of City Power.
- b Manufacturers shall include separately, in their price, all associated costs to have three City Power delegates witnessing the routine Factory Acceptance Tests of every unit at the manufacturers test facilities. If the tests take place within Gauteng this cost is zero.
- c The following routine tests as per SANS 60076 of latest issue and special tests shall also be carried out on the transformers:
  - Dielectric tests on oil as per SANS 555, moisture in oil and full DGA
  - Measurement of winding resistance
  - Measurement of insulation resistance on all windings
  - Measurement of voltage ratio and check of voltage vector relationship
  - Measurement of no-load losses and current
  - Measurement of impedance voltage (positive and zero sequence)
  - Measurement of load losses
  - Measurement of noise levels with all fans running
  - Impulse voltage withstand test on all terminals, standard and chopped wave
  - Dielectric tests (separate source and induced overvoltage withstand test) on each winding
  - Dielectric tests on oil as per SANS 555, moisture in oil and full DGA
- d The test sequence shall be:
  - Routine tests as per paragraph (a), excluding impulse voltage withstand test and dielectric tests
  - Excitation current from the 11 kV windings at 400 V, as a special test
  - Insulation resistance tests
  - Heat run test
  - Overload test 1.2\*In for 2 hours
  - Impulse test (standard and chopped wave)

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- Dielectric tests on windings
- Operation test of protection devices and routine tests on CTs
- Core insulation tests
- Capacitance and Tan  $\delta$  tests on HV bushings at 5 kV or less, as per the bushing manufacturer's test guideline
- Capacitance and Tan  $\delta$  test for all windings, as a special test at 2 kV measuring the all possible combinations of windings to each other and the tank;
- Insulation resistance tests on all windings
- Remove paper test samples and perform DP tests
- Tests on transformer tank, including overpressure, paint thickness and deformation
- Noise level testing
- Dielectric tests on oil as per SANS 555, moisture in oil and full DGA
- SFRA test, as a special test after FAT

## 11.5 Site tests

After erection at site, the transformers shall be subjected to the following tests:

- Insulation resistance test on core and windings
- Ratio and polarity test
- Oil be tested before commissioning comply with City Power specification. Tests shall include dielectric tests, moisture in oil and full DGA
- Excitation current from the 11 kV windings at 400 V, as a special test
- Operation test of protection devices and interlocks
- Measurement of winding resistance
- Bushing capacitance and Tan  $\delta$  at the same test voltage as during the FAT
- SFRA test, as a special test after hot commissioning

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- Any other test as may be insisted upon by City Power and the accredited City Power representative. If the transformer was manufactured overseas the transformer shall be subjected to field tests that include:
  - \* Measurement of no-load losses and current
  - \* Measurement of impedance voltage (positive sequence)
  - \* Measurement of load losses
  - \* Dielectric tests (separate source and induced overvoltage withstand test) on each winding

## 12 TEST REPORT DOCUMENTATION

- a Type and Routine tests reports of a similar transformer to the one tendered, may be requested from the manufacturer during the tender evaluation phase;
- b A list of similar transformers that were short circuit tested must be submitted by the manufacturer during the tender evaluation phase;
- c Three copies of the test reports on the above type tests / special tests / routine tests with the signature of the Inspecting Officer representing City Power shall be furnished for approval by City Power;
- d Test certificates shall be supplied for all current transformers as per IEC 60044-1 and IEC 60044-2 and witness tested during the FAT;
- e The following data shall be supplied during the design review before ordering of current transformers: ratio, class, dynamic range, excitation curves, secondary winding resistance and insulation resistance;
- f The type of core material and values of flux density in the core for 100%, 110% and 125% of  $U_n$  and the hysteresis characteristic curves shall be included in the tender and shall be subject to City Power's approval.
- g Besides the above test certificates, manufacturer / sub-contractor's test certificates in respect of the following accessories shall also be furnished in six copies:
  - Bushings

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- Bushing current transformers (with excitation characteristic curves)
- Buchholz relays
- Magnetic oil level gauge
- Winding temperature controller
- Oil temperature controller
- Heat exchangers
- Transformer oil
- Any other components not specifically mentioned herein.

### 13 REJECTION

The transformer shall be rejected, if during the tests, any of the following conditions arose:

- No-load losses exceed the guaranteed value specified;
- Total load losses exceed the guaranteed value specified;
- Impedance value exceeds by the guaranteed value beyond tolerances, specified;
- Oil or winding temperature rise exceeds the specified value after changes to the cooling system failed to resolve the problem;
- Transformer fails the impulse test twice;
- Transformer fails the separate source or induced overvoltage withstand tests, or both, twice;
- If the test results conducted at factory and/or on site are not satisfactory;
- Transformer is proved to have not been manufactured in accordance with the agreed specification and approved drawings;
- The transformer fails the type tests;
- There is a SFRA mismatch between factory and site tests after delivery;

### 14 TRANSPORT AND ERECTION

#### 14.1 Transport

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- a The maximum transport dimensions (Low bed) are limited to the dimensions in Table 9:

*Table 9: Maximum overall dimensions of the power transformer*

HV rating, U <sub>n</sub> (kV)	Height (mm)	Length (mm)	Width (mm)
88	5500	6800	5000
132	5500	7800	5000

- b After the transformer has successfully passed the factory acceptance tests the oil shall be partially drained, the conservator and HV bushings removed. The openings shall be blanked off to create a gas tight vessel. The transformer tank shall be filled to 100 mm below the top lid with oil. All items removed after factory acceptance tests shall be packaged, crated and labelled before shipping;
- c The transformer shall then be filled with very dry high purity nitrogen (or dry air on approval of City Power) prior to shipping to a pressure of 35 kPa;
- d The gas pressure inside the transformer and in the filling bottle shall be recorded daily (every 24 hours). The gas supply from the filling bottle to the transformer may not be shut off en route. If there is a leak, a message shall immediately be sent to the manufacturer and City Power by the transporter. The monitoring of the gas pressures shall remain the responsibility of the manufacturer;
- e Two acceleration sensor transport monitors shall be fitted to the transformer on opposite ends to monitor the transport route and the shock impulses the transformer are subject to during transport. The transport monitors shall each be fitted with an internal GPS that is logged with the acceleration sensors. The acceleration sensors shall sense shocks in the x, y and z axes. Any measured acceleration of more than 2.0 g shall warrant an internal inspection of the transformer and possible stripping; following the delivery of the transformer unit to site The impact recordings shall be presented to City Power representatives and on approval and sign off these recordings shall be included in the hand over documentation.
- f When the transformer is transported by road the truck and trailer shall have air suspensions fitted to all wheels;

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- g Once on site the fittings removed prior to shipping (see point 11.1a) shall be fitted again. This shall be done before the transformer is rigged into its final place;

## 15 WARRANTIES

The Original Equipment Manufacturer shall supply a warranty covering the complete unit/s for a period of three (3) years from date of commissioning and/or five (5) years whenever unit/s is/are stored for later usage.

## 16 END OF JOB REQUIREMENTS

### 16.1 Documentation

- a Three hard copies of the Operating and installation manuals and 1 soft copy (in English), shall be provided;
- b Three sets of fully detailed and dimensioned drawings shall be provided;
- c All drawings shall be digitally supplied in AutoCAD 2012 and in Adobe PDF version;
- d Three complete sets of final as-built drawings shall be supplied for each transformer, sufficiently before the actual despatch of each transformer;
- e Three complete sets of FAT documents with all the test reports;
- f Six hard and soft copies of all bulletins, complete instruction manuals for the erection, operation and maintenance of each transformer are to be supplied before it is despatched to site;
- g Any approval given to the detailed drawings by City Power shall not relieve the manufacturer of the responsibility for the correctness of the design, completeness of the equipment supplied and in the execution of the works in accordance with the terms of specification;

### 16.2 Training

The following certified training courses, for City Power's staff, shall be provided for a minimum of 10 people:

#### Operation and maintenance of all components of the power transformer

The associated costs for the certified training course, per person, shall be stated in the offer and shall be fixed for the duration of the contract.

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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### 16.3 Spares

- a The manufacturer shall include in his offer a list of recommended spares and indicate which of those are critical;
- b Typical ex works delivery dates should also be included for these spares;
- c The cost of the spares shall be excluded from the total tender price, but included in the offer as a separate option.

## 17 QUALITY ASSURANCE

A quality management system shall be set up in order to assure the quality during manufacture, installation, removal, transportation and disposal of scrap material/Waste/E-waste .Guidance on the requirements for a quality management system may be found in the following standards: ISO 9001:2015. The details shall be subject to agreement between the purchaser and supplier

## 18 ENVIROMENTAL MANAGEMENT

An environmental management plan shall be set up in order to ensure the proper environmental management and compliance is adhered to during manufacture, installation, removal, transportation and disposal of scrap material/Waste/E-waste. Guidance on the requirements for an environmental management system shall be found in ISO 14001:2015 standards. The details shall be subject to agreement between City Power and the Supplier. This is to ensure that the asset created conforms to environmental standards and City Power SHERQ Policy.

## 19 HEALTH AND SAFETY

A health and safety plan shall be set up in order to ensure proper management and compliance during manufacture, installation, removal, transportation and disposal of scrap material/Waste/E-waste. Guidance on the requirements of a health and safety plan shall be found in ISO 45001:2018 standards. The details shall be subject to agreement between City Power and the Supplier.

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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#### **ANNEX A – BIBLIOGRAPHY**

None



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## ANNEX B - REVISION INFORMATION

DATE	REV. NO.	NOTES
May 2003	0	<b>First Issue</b>
May 2006	1	Inclusion of the general service conditions (Clause 4.2). Inclusion of the isolation flange (Clause 4.5). Marshalling kiosk revision (Clause 4.18). The design of insulators for 33 kV and above shall be such as to minimize corona discharge and radio interference (Sub clause 4.16.8). Frequency Response Analysis shall be done prior to loading the transformer for transportation and after commission (Clause 5.2). Inclusion of 40 MVA 88/11 kV and 45 MVA 132/11 kV Schedules.
May 2008	2	Inclusion of 80 MVA 88/33 kV Schedules
March 2016	3	Complete rewrite of specification for 40/45 MVA transformers
June 2020	4	General Editing Updated Work group Updated table 2 Updated table 8A – included yn Changed SANS 60078 to IEC 60078 Edited Annexure A Edited Annexure B Edited Annexure C Included 17 Quality Assurance Included 18 Environment management Included 19 Health and Safety Included OEM's details for comments
April 2021	5	Changed Page 103 (typing error) to 104 and removed header on Front page
May 2021	6	Replaced IEC with SANS Removed clause b and c on P50 Removed clause a, b and c on P51
Feb.2021	7	Included Design Review 5.1, changed all IEC to SANS, general editing, included 5.4. (a) 11.
August 2022	8	General Editing, Replaced tenderer's with manufacturers Removed 6.2 Removed CP_TSSPEC 065 and replaced with CP_TSSPEC_064 Updated SHERQ clauses
Dec. 2022	9	Included OEM details in schedules
March 2022	10	Changed 1,5 to 1,25 in technical schedule page 70 (typing error)

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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**ANNEX C1 - TECHNICAL SCHEDULES A AND B FOR POWER TRANSFORMERS RATED  
AT 40 MVA 88/11 KV YNd1 – SAP NUMBER 2627**

NOTE: TICKS [✓], ASTERISK [\*], WORD [NOTED], WORD [EQUIVELANT] OR TBA [TO BE ADVISED]

SHALL NOT BE ACCEPTED.

Schedule A: City Power's specific requirements

**Schedule B: Guarantees and technical particulars of equipment offered**

Item	Description		Schedule A	Schedule B
<b>1.</b>	General Site Conditions			
	a) System frequency	Hz	50	
	b) Site altitude above mean sea level	m	1800	
	c) Maximum ambient air temperature	°C	40	
	d) Hottest monthly average	°C	30	
	e) Yearly average ambient air temperature	°C	20	
	f) Minimum temperature	°C	-10	
	g) Variation in humidity		10% to 90%	
<b>2.</b>	Constitution of each transformer		3-phase unit	
<b>3.</b>	Nominal system voltages			
	a) Primary (High voltage) winding	kV	88	
	b) Secondary winding	kV	11	
<b>4.</b>	Rating			
	a) Continuous maximum rating (CMR) - Summer	MVA	40.0	
	b) Continuous maximum rating (CMR) – Winter (maximum ambient temperature 25 °C)	MVA	44.0	
	c) ONAN rating	MVA	28.0	
	d) ONAF rating	MVA	40.0	
<b>5.</b>	Temperature rise			
	a) Maximum temperature rise of top oil for ONAN and ONAF cooling when the air temperature is 40 °C	K	55	
	b) Maximum hot spot temperature of the winding when the air temperature is 40 °C	°C	113	

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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Item	Description		Schedule A	Schedule B
	c) Average winding temperature rise for ONAF cooling when the air temperature is 40 °C		60 K	
	d) Temperature gradient (g) of HV winding to oil for ONAF		< 20 K	
	e) Temperature gradient (g) of LV winding to oil for ONAF		< 20 K	
<b>6.</b>	Rated short duration power-frequency withstand voltage (kV) at 50 Hz			
	a) High voltage windings	kV	185	
	b) Secondary windings	kV	28	
<b>7.</b>	Impulse voltage test level (full wave 1.2/50µs)			
	a) High voltage windings and HV neutral	kV	450	
	b) Secondary windings	kV	95	
<b>8.</b>	Maximum three phase fault current on HV supply side	kA	80	
<b>9.</b>	Shell or Core Type		Core	
<b>10.</b>	Flux density in core at nominal voltage and frequency and at normal ratio			
	a) Absolute maximum	T	1.95	
	b) Average	T	1.75	
<b>11.</b>	Maximum current density in windings at 40 MVA:			
	a) 88 kV winding	A/mm <sup>2</sup>	3.5	
	b) 11 kV winding	A/mm <sup>2</sup>	3.5	
<b>12.</b>	Excitation current at nominal ratio:			
	a) At rated voltage –approximate average current	%	< 0.20%	
	b) At 110% voltage –approximate average current	%	XXXX	
<b>13.</b>	Maximum total losses at rated power on any tap with an ambient temperature of 75 °C:	kW	XXXX	
<b>14.</b>	Load losses at 75 °C and nominal voltage on nominal tap and rated current (ONAF) and rated frequency:			
	a) Max total load losses (copper + stray + cooling)	kW	234.0	
	b) Max. cooling losses all fans running	kW	9.0	

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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Item	Description		Schedule A	Schedule B
	c) Max. stray load losses	kW	40.0	
15.	No-load losses at 20 °C and nominal voltage on nominal tap	kW	16.0	
16.	Cost of losses			
	The capitalised value of losses will be calculated using the following rates :			
	a) For load losses	R/kW	14000	
	b) For no load losses	R/kW	63000	
17.	Efficiency at normal ratio and unity power factor at ambient temperature of 40 °C:			
	a) ONAN rating	%	XXXX	
	b) ONAF rating	%	XXXX	
18.	Voltage regulation at 75 °C and nominal ratio and rated current (as percentage of normal voltage):			
	a) At unity power factor	%	XXXX	
	b) At 0,8 lagging power factor	%	XXXX	
19.	Impedance voltage at 75 °C, nominal voltage, nominal tap, rated frequency and rated current between HV and LV winding	%	17.0	
	Maximum impedance variation across all taps (maximum impedance – minimum impedance)	%	2.0	
20.	Winding resistance at 75 °C		XXXX	
	a) 88 kV	Ω/phase	XXXX	
	b) 11 kV	Ω/phase	XXXX	
21.	Types of windings			
	a) 88 kV		Copper	
	b) 11 kV		Copper	
22.	Insulation of:			
	a) 88 kV windings		Thermally upgraded paper	

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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Item	Description		Schedule A	Schedule B
	b) 11 kV windings		Thermally	
<b>23.</b>	Winding insulation:			
	a) HV windings		Fully Insulated	
	b) LV windings		Fully Insulated	
<b>24.</b>	88 kV bushings:			
	a) Um / BIL	kV	123 / 550	
	b) In	A	800	
	c) Maximum PD at 106 kV	pC	<10	
	d) Maximum tan $\delta$		< 0,4%	
	e) Manufacturer		XXXX	
	f) Type		epoxy resin	
	g) Model		XXXX	
	h) Weather sheds		silicone rubber	
	i) Minimum pollution class		31 kV/mm	
	J) RIP or RIS bushing		XXXX	
<b>25.</b>	11 kV bushings:			
	a) Um / BIL	kV	33 / 200	
	b) In	A	3000	
	c) Manufacturer		XXXX	
	d) Type		epoxy resin	
	e) Model		XXXX	
	f) Weather sheds		silicone rubber type	
	g) Minimum pollution class		31 kV/mm	
	h) RIP or RIS bushing		XXXX	
<b>26.</b>	88 kV surge arrestors	4 units		
	a) U MCOV	kV	77	
	b) Manufacturer		XXXX	
	c) Type		epoxy resin	

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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	d) Model		XXXX	
	e) Weather sheds		silicone rubber type	
	f) Minimum pollution class		31 kV/mm	

<b>27.</b>	11 kV surge arrestors	4 units		
	a) U MCOV	kV	9.6	
	b) Manufacturer		XXXX	
	c) Type		epoxy resin	
	d) Model		XXXX	
	e) Weather sheds		silicone rubber type	
	f) Minimum pollution class		31 kV/mm	
<b>28.</b>	Noise Levels			
	a) ONAN at 2 m	dbA	76	
	b) ONAF at 2 m with all fans running	dbA	77	
<b>29.</b>	On-load tap changer			
	a) Tapping range		+5 to -15%	
	b) Tap step		1.25%	
	c) Number of steps		17	
	d) Which winding is tapped and where		88 kV Neutral side	
	e) Category of voltage variation		CFVV	
	f) Number of operation before maintenance		300 000	
	g) Type		Flag / vacuum	
	h) Resistor or reactor type		Resistor	
	i) Manufacturer		XXXX	
	j) Model		XXXX	
	k) Rated current		400 A	
	l) Rated voltage	kV	XXXX	
	m) BIL	kV	XXXX	
	n) Fully automatic OLTC required?	Yes/No	Yes	

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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	o) The on-load tap changer equipment shall be suitable for supervisory control and indication.	Yes/No	Yes	
--	--	--------	-----	--

	p) Linear or Forward/Reverse		Forward /Reverse	
	q) Motor rating in OLTC drive unit	Supply voltage	400 V	
		Rated current	XXXX	
		Rated power	XXXX	
		Rated speed	XXXX	
30.	Type of cooling		ONAN/ONAF	
	a) Number of fans (n + 1)		XXXX	
	b) Number of radiator banks		XXXX	
	c) Tube thickness of the radiators		> 1.0 mm	
	d) Radiator dimensions	Height Width	XXXX	
	e) Radiator mounting (tank or separate)		Tank	
	f) Mass of each radiator :	kg	XXXX	
	g) Average velocity of air through the cooler	m/s	XXXX	
	h) Speed of fan	rpm	XXXX	
	i) Type of fan motor		XXXX	
	j) Continuous rating of fan motor	kW	XXXX	
	k) Starting current of fan motor	A	XXXX	
	l) Efficiency of fan motor	%	XXXX	
	m) Power factor of fan motor	p.u	XXXX	
	n) Rated output of each fan	m <sup>3</sup> /s	XXXX	
	r) Manufacturer of radiator		XXXX	
	s) Model of radiator		XXXX	
	t) Manufacturer of fan		XXXX	
	u) Model of fan		XXXX	
	v) Manufacturer of fan motor		XXXX	

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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	w) Model of fan motor		XXXX	
<b>31.</b>	Calculated thermal time constant :			
	a) Natural cooling: winding	Min.	XXXX	
	b) Natural cooling: oil	hours	XXXX	
	c) Forced cooling: winding	Min.	XXXX	
	d) Forced cooling: oil	hours	XXXX	
<b>32.</b>	Current transformers outside (outdoor type) as specified table 8A:	none		
<b>33.</b>	Current transformer outside tank (outdoor type) specified table 8B:	1 unit		
	a) Manufacturer		XXXX	
	b) 11 kV tank CTs core 1		400/1 Class 5P20 15 VA $R_s < 1.60 \Omega$	
<b>34.</b>	Current transformer inside tank specified table 8C:			
	a) Manufacturer		XXXX	
	b) WTI CTs core 1	3 unit	2500/x Class 1 10 VA	
<b>35.</b>	Oil :			
	a) Manufacturer		XXXX	
	b) Type of oil		XXXX	
	c) Name of oil		XXXX	
<b>36.</b>	The marshalling kiosks or cabinets are to be fitted	Yes/No	Yes	
<b>37.</b>	Label materials :			
	a) Outdoors		S/Steel	
	b) Indoors		S/Steel	
	c) Inside cubicles and kiosks		Trafolite	
<b>38.</b>	Pressure relief device		Required	
	a) Number required		2	
	b) Size of port	mm	XXXX	
	c) Opening pressure		XXXX	
	d) Number of contacts		XXXX	



<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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Item	Description		Schedule A	Schedule B
	e) Manufacturer		XXXX	
	f) Model		XXXX	
<b>39.</b>	Oil and winding temperature monitor device		Required	
	a) Manufacturer		XXXX	
	b) Model		XXXX	
<b>40.</b>	Gas and oil actuated relay		Required	
	a) Manufacturer		XXXX	
	b) Model		XXXX	
	c) Size of port	mm	XXXX	
	d) Number of contacts		XXXX	
<b>41.</b>	Online gas and moisture monitoring unit/s		Required	
	a) Manufacturer		XXXX	
	b) Model		XXXX	
<b>42.</b>	Oil gauge device		Required	
	a) Manufacturer		XXXX	
	b) Model		XXXX	
	c) Number of contacts		XXXX	
<b>43.</b>	Dehydrating breather		Required	
	a) Manufacturer		XXXX	
	b) Model		XXXX	
	c) Mass of desiccant		XXXX	
	d) Type of desiccant		XXXX	
	e) Colour of desiccant		XXXX	
<b>44.</b>	Other breather		Required	
	a) Manufacturer		XXXX	
	b) Model		XXXX	
	c) Mass of desiccant		XXXX	
	d) Type of desiccant		XXXX	
	e) Colour of desiccant		XXXX	
<b>45.</b>	Transformer mounted marshalling kiosk		Required	

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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Item	Description		Schedule A	Schedule B
46.	Conservator bag		Required	
	a) Manufacturer		XXXX	
	b) Model		XXXX	
	c) Type		XXXX	
	d) Bag volume		XXXX	
47.	Filling medium of transformer tank for shipment		Oil & Dry Air	
48.	First filling of virgin oil for the transformer		Required	
49.	Total volume of oil	litres	XXXX	
50.	Volume of oil in radiators	litres	XXXX	
51.	Minimum quantity of oil to be removed from transformer including conservator to expose the top of the core	litres	XXXX	
52.	Total volume of conservator	litres	XXXX	
53.	Mass of copper required in the complete transformer	kg	XXXX	
54.	Mass of core steel	kg	XXXX	
55.	Total mass of transformer without oil and radiators	kg	XXXX	
56.	Total mass of transformer filled with oil with radiators fitted	kg	XXXX	
57.	Total mass of largest part of transformer during transport	kg	XXXX	
58.	Thickness of transformer tank:			
	a) Side	mm	XXXX	
	b) Bottom	mm	XXXX	
	c) Top	mm	XXXX	
59.	Dimensions of transformer including radiators and			
	a) Height overall	mm	5500 max	
	b) Length	mm	6800 max	
	c) Width	mm	5000 max	
60.	Dimensions of transformer arranged for transport			
	a) Height	mm	XXXX	
	b) Length	mm	XXXX	

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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	c) Width	mm	XXXX	
<b>61.</b>	Alarms and Indication	V <sub>DC</sub>	110	
<b>62.</b>	Motor Supply for cooling fans (3 phase, 4 wire) and auxiliaries	V <sub>AC</sub>	400 / 230	
<b>63</b>	OEM details:			
	a) Name of manufacturer		XXXX	
	b) Country		XXXX	

NOTE: TICKS [✓✗], ASTERISK [\*], WORD [NOTED], OR TBA [TO BE ADVISED] SHALL NOT BE ACCEPTED.

Tender Number: \_\_\_\_\_

Tenderer's Authorised Signatory: \_\_\_\_\_  
Name in block letters                      Signature

Full name of company: \_\_\_\_\_

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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**ANNEX C2 - TECHNICAL SCHEDULES A AND B FOR POWER TRANSFORMERS RATED  
AT 40 MVA 132/11 kV YNd1 – SAP NUMBER 4485**

NOTE: TICKS [✓], ASTERISK [\*], WORD [NOTED], WORD [EQUIVELANT] OR TBA [TO BE ADVISED]  
SHALL NOT BE ACCEPTED.

Schedule A: City Power's specific requirements

**Schedule B: Guarantees and technical particulars of equipment offered**

Item	Description		Schedule A	Schedule B
1.	General Site Conditions			
	a) System frequency	Hz	50	
	b) Site altitude above mean sea level	m	1800	
	c) Maximum ambient air temperature	°C	40	
	d) Hottest monthly average	°C	30	
	e) Yearly average ambient air temperature	°C	20	
	f) Minimum temperature	°C	-10	
	g) Variation in humidity		10% to 90%	
2.	Constitution of each transformer		3-phase unit	
3.	Nominal system voltages			
	a) Primary (High voltage) winding	kV	132	
	b) Secondary winding	kV	11	
4.	Rating			
	a) Continuous maximum rating (CMR) - Summer	MVA	40.0	
	b) Continuous maximum rating (CMR) – Winter (maximum ambient temperature 25 °C)	MVA	44.0	
	c) ONAN rating	MVA	28.0	
	d) ONAF rating	MVA	40.0	
5.	Temperature rise			
	a) Maximum temperature rise of top oil for ONAN and ONAF cooling when the air temperature is 40 °C	K	55	
	b) Maximum hot spot temperature of the winding when the air temperature is 40 °C	°C	113	
	c) Average winding temperature rise for ONAF cooling when the air temperature is 40 °C		60 K	

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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Item	Description		Schedule A	Schedule B
	d) Temperature gradient (g) of HV winding to oil for ONAF		< 20 K	
	e) Temperature gradient (g) of LV winding to oil for ONAF		< 20 K	
<b>6.</b>	Rated short duration power-frequency withstand voltage (kV) at 50 Hz			
	a) High voltage windings and HV neutral	kV	275	
	b) Secondary windings	kV	28	
<b>7.</b>	Impulse voltage test level (full wave 1.2/50µs)			
	a) High voltage windings	kV	650	
	b) Secondary windings	kV	95	
<b>8.</b>	Maximum three phase fault current on HV supply side	kA	80	
<b>9.</b>	Shell or Core Type		Core	
<b>10.</b>	Flux density in core at nominal voltage and frequency and at normal ratio			
	a) Absolute maximum	T	1.95	
	b) Average	T	1.75	
<b>11.</b>	Maximum current density in windings at 40 MVA:			
	a) 88 kV winding	A/mm <sup>2</sup>	3.5	
	b) 11 kV winding	A/mm <sup>2</sup>	3.5	
<b>12.</b>	Excitation current at nominal ratio:			
	a) At rated voltage –approximate average current	%	< 0.20%	
	b) At 110% voltage –approximate average current	%	XXXX	
<b>13.</b>	Maximum total losses at rated power on any tap with an ambient temperature of 75 °C:	kW	XXXX	
<b>14.</b>	Load losses at 75 °C and nominal voltage on nominal tap and rated current (ONAF) and rated frequency:			
	a) Max total load losses (copper + stray + cooling)	kW	234.0	
	b) Max. cooling losses all fans running	kW	9.0	
	c) Max. stray load losses	kW	40.0	

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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Item	Description		Schedule A	Schedule B
15.	No-load losses at 20 °C and nominal voltage on nominal tap	kW	16.0	
16.	Cost of losses			
	The capitalised value of losses will be calculated using the following rates :			
	a) For load losses	R/kW	14000	
	b) For no load losses	R/kW	63000	
17.	Efficiency at normal ratio and unity power factor at ambient temperature of 40 °C:			
	a) ONAN rating	%	XXXX	
	b) ONAF rating	%	XXXX	
18.	Voltage regulation at 75 °C and nominal ratio and rated current (as percentage of normal voltage):			
	a) At unity power factor	%	XXXX	
	b) At 0,8 lagging power factor	%	XXXX	
19.	Impedance voltage at 75 °C, nominal voltage, nominal tap, rated frequency and rated current between HV and LV winding	%	17.0	
	Maximum impedance variation across all taps (maximum impedance – minimum impedance)	%	2.0	
20.	Winding resistance at 75 °C		XXXX	
	a) 132 kV	Ω/phase	XXXX	
	b) 11 kV	Ω/phase	XXXX	
21.	Types of windings			
	a) 132 kV		Copper	
	b) 11 kV		Copper	
22.	Insulation of:			
	a) 132 kV windings		Thermally upgraded paper	
	b) 11 kV windings		Thermally upgraded paper	

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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Item	Description		Schedule A	Schedule B
<b>23.</b>	Winding insulation			
	a) HV windings		Fully Insulated	
	b) LV windings		Fully Insulated	
<b>24.</b>	132 kV bushings:			
	a) Um / BIL	kV	145/ 650	
	b) In	A	800	
	c) Maximum PD at 147 kV	pC	<10	
	d) Maximum tan $\delta$		< 0,4%	
	e) Manufacturer		XXXX	
	f) Type		epoxy resin	
	g) Model		XXXX	
	h) Weather sheds		silicone rubber	
	i) Minimum pollution class		31 kV/mm	
	j) RIP or RIS bushing		XXXX	
<b>25.</b>	11 kV bushings:			
	a) Um / BIL	kV	33 / 200	
	b) In	A	3000	
	c) Manufacturer		XXXX	
	d) Type		epoxy resin	
	e) Model		XXXX	
	f) Weather sheds		silicone rubber type	
	g) Minimum pollution class		31 kV/mm	
	h) RIP or RIS bushing		XXXX	
<b>26.</b>	132 kV surge arrestors	4 units		
	a) U MCOV	kV	77	
	b) Manufacturer		XXXX	
	c) Type		epoxy resin	
	d) Model		XXXX	

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Item	Description		Schedule A	Schedule B
	e) Weather sheds		silicone rubber type	
	f) Minimum pollution class		31 kV/mm	
<b>27.</b>	11 kV surge arrestors	4 units		
	a) U MCOV	kV	9.6	
	b) Manufacturer		XXXX	
	c) Type		epoxy resin	
	d) Model		XXXX	
	e) Weather sheds		silicone rubber type	
	f) Minimum pollution class		31 kV/mm	
<b>28.</b>	Noise Levels			
	a) ONAN at 2 m	dbA	76	
	b) ONAF at 2 m with all fans running	dbA	77	
<b>29.</b>	On-load tap changer			
	a) Tapping range		+5 to -15%	
	b) Tap step		1.25%	
	c) Number of steps		17	
	d) Which winding is tapped and where		132 kV Neutral side	
	e) Category of voltage variation		CFVV	
	f) Number of operation before maintenance		300 000	
	g) Type		Flag / vacuum	
	h) Resistor or reactor type		Resistor	
	i) Manufacturer		XXXX	
	j) Model		XXXX	
	k) Rated current		400 A	
	l) Rated voltage	kV	XXXX	
	m) BIL	kV	XXXX	
	n) Fully automatic OLTC required?	Yes/No	Yes	



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Item	Description		Schedule A	Schedule B
	o) The on-load tap changer equipment shall be suitable for supervisory control and indication.	Yes/No	Yes	
	p) Linear or Forward/Reverse		Forward /Reverse	
	q) Motor rating in OLTC drive unit	Supply voltage  Rated current  Rated power  Rated speed	400 V  XXXX  XXXX  XXXX	
<b>30.</b>	Type of cooling		ONAN/ONAF	
	a) Number of fans (n + 1)		XXXX	
	b) Number of radiator banks		XXXX	
	c) Tube thickness of the radiators		> 1.0 mm	
	d) Radiator dimensions	Height Width	XXXX	
	e) Radiator mounting (tank or separate)		Tank	
	f) Mass of each radiator :	kg	XXXX	
	g) Average velocity of air through the cooler	m/s	XXXX	
	h) Speed of fan	rpm	XXXX	
	i) Type of fan motor		XXXX	
	j) Continuous rating of fan motor	kW	XXXX	
	k) Starting current of fan motor	A	XXXX	
	l) Efficiency of fan motor	%	XXXX	
	m) Power factor of fan motor	p.u	XXXX	
	n) Rated output of each fan	m <sup>3</sup> /s	XXXX	
	r) Manufacturer of radiator		XXXX	
	s) Model of radiator		XXXX	
	t) Manufacturer of fan		XXXX	
	u) Model of fan		XXXX	

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	v) Manufacturer of fan motor		XXXX	
	w) Model of fan motor		XXXX	
<b>31.</b>	Calculated thermal time constant :			
	a) Natural cooling: winding	Min.	XXXX	
	b) Natural cooling: oil	hours	XXXX	
	c) Forced cooling: winding	Min.	XXXX	
	d) Forced cooling: oil	hours	XXXX	
<b>32.</b>	Current transformers outside (outdoor type) as specified table 8A:	none		
<b>33.</b>	Current transformer outside tank (outdoor type) specified table 8B:	1 unit		
	a) Manufacturer		XXXX	
	b) 11 kV tank CTs core 1		400/1 Class 5P20 15 VA Rs<1.60 Ω	
<b>34.</b>	Current transformer inside tank specified table 8C:			
	a) Manufacturer		XXXX	
	b) WTI CTs core 1	3 unit	2500/x Class 1 10 VA	
<b>35.</b>	Oil :			
	a) Manufacturer		XXXX	
	b) Type of oil		XXXX	
	c) Name of oil		XXXX	
<b>36.</b>	The marshalling kiosks or cabinets are to be fitted with metal-clad heaters	Yes/No	Yes	
<b>37.</b>	Label materials :			
	a) Outdoors		S/Steel	
	b) Indoors		S/Steel	
	c) Inside cubicles and kiosks		Trafolite	
<b>38.</b>	Pressure relief device		Required	
	a) Number required		2	
	b) Size of port	mm	XXXX	
	c) Opening pressure		XXXX	

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Item	Description		Schedule A	Schedule B
	d) Number of contacts		XXXX	
	e) Manufacturer		XXXX	
	f) Model		XXXX	
<b>39.</b>	Oil and winding temperature monitor device		Required	
	a) Manufacturer		XXXX	
	b) Model		XXXX	
<b>40.</b>	Gas and oil actuated relay		Required	
	a) Manufacturer		XXXX	
	b) Model		XXXX	
	c) Size of port	mm	XXXX	
	d) Number of contacts		XXXX	
<b>41.</b>	Online gas and moisture monitoring unit/s		Required	
	a) Manufacturer		XXXX	
	b) Model		XXXX	
<b>42.</b>	Oil gauge device		Required	
	a) Manufacturer		XXXX	
	b) Model		XXXX	
	c) Number of contacts		XXXX	
<b>43.</b>	Dehydrating breather		Required	
	a) Manufacturer		XXXX	
	b) Model		XXXX	
	c) Mass of desiccant		XXXX	
	d) Type of desiccant		XXXX	
	e) Colour of desiccant		XXXX	
<b>44.</b>	Other breather		Required	
	a) Manufacturer		XXXX	
	b) Model		XXXX	
	c) Mass of desiccant		XXXX	
	d) Type of desiccant		XXXX	
	e) Colour of desiccant		XXXX	
<b>45.</b>	Transformer mounted marshalling kiosk		Required	

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Item	Description		Schedule A	Schedule B
<b>46.</b>	Conservator bag		Required	
	a) Manufacturer		XXXX	
	b) Model		XXXX	
	c) Type		XXXX	
	d) Bag volume		XXXX	
<b>47.</b>	Filling medium of transformer tank for shipment		Oil & Dry Air	
<b>48.</b>	First filling of virgin oil for the transformer		Required	
<b>49.</b>	Total volume of oil	litres	XXXX	
<b>50.</b>	Volume of oil in radiators	litres	XXXX	
<b>51.</b>	Minimum quantity of oil to be removed from transformer including conservator to expose the top of the core	litres	XXXX	
<b>52.</b>	Total volume of conservator	litres	XXXX	
<b>53.</b>	Mass of copper required in the complete transformer	kg	XXXX	
<b>54.</b>	Mass of core steel	kg	XXXX	
<b>55.</b>	Total mass of transformer without oil and radiators	kg	XXXX	
<b>56.</b>	Total mass of transformer filled with oil with radiators fitted	kg	XXXX	
<b>57.</b>	Total mass of largest part of transformer during transport	kg	XXXX	
<b>58.</b>	Thickness of transformer tank:			
	a) Side	mm	XXXX	
	b) Bottom	mm	XXXX	
	c) Top	mm	XXXX	
<b>59.</b>	Dimensions of transformer including radiators and			
	a) Height overall	mm	5500 max	
	b) Length	mm	6800 max	
	c) Width	mm	5000 max	
<b>60.</b>	Dimensions of transformer arranged for transport			
	a) Height	mm	XXXX	
	b) Length	mm	XXXX	

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Item	Description		Schedule A	Schedule B
	c) Width	mm	XXXX	
<b>61.</b>	Alarms and Indication	V <sub>DC</sub>	110	
<b>62.</b>	Motor Supply for cooling fans (3 phase, 4 wire) and auxiliaries	V <sub>AC</sub>	400 / 230	
<b>63</b>	OEM details:			
	a) Name of manufacturer		XXXX	
	b) Country		XXXX	

NOTE: TICKS [✓✗], ASTERISK [\*], WORD [NOTED], OR TBA [TO BE ADVISED] SHALL NOT BE ACCEPTED.

Tender Number: \_\_\_\_\_

Tenderer's Authorised Signatory: \_\_\_\_\_  
Name in block letters                      Signature

Full name of company: \_\_\_\_\_

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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**ANNEX C3 - TECHNICAL SCHEDULES A AND B FOR POWER TRANSFORMERS RATED  
AT 45 MVA 88/11/6.6 KV YNyn0 (d11) – SAP NUMBER 4486**

NOTE: TICKS [✓], ASTERISK [\*], WORD [NOTED], WORD [EQUIVELANT] OR TBA [TO BE ADVISED]  
WILL NOT BE ACCEPTED.

Schedule A: City Power's specific requirements

**Schedule B: Guarantees and technical particulars of equipment offered**

Item	Description		Schedule A	Schedule B
<b>1.</b>	General Site Conditions			
	a) System frequency	Hz	50	
	b) Site altitude above mean sea level	m	1800	
	c) Maximum ambient air temperature	°C	40	
	d) Hottest monthly average	°C	30	
	e) Yearly average ambient air temperature	°C	20	
	f) Minimum temperature	°C	-10	
	g) Variation in humidity		10% to 90%	
<b>2.</b>	Constitution of each transformer		3-phase unit	
<b>3.</b>	Nominal system voltages			
	a) Primary (High voltage) winding	kV	88	
	b) Secondary winding	kV	11	
	c) Tertiary winding	kV	6.6	
<b>4.</b>	Rating			
	a) Continuous maximum rating (CMR) - Summer	MVA	45	
	b) Continuous maximum rating (CMR) – Winter (maximum ambient temperature 25 °C)	MVA	49,5	
	c) ONAN rating	MVA	30	
	d) ONAF rating	MVA	45	
<b>5.</b>	Tertiary winding rating	MVA	≥ 10	

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Item	Description		Schedule A	Schedule B
<b>6.</b>	Temperature rise			
	a) Maximum temperature rise of top oil for ONAN and ONAF cooling when the air temperature is 40 °C	K	55	
	b) Maximum hot spot temperature of the winding when the air temperature is 40 °C	°C	113	
	c) Average winding temperature rise for ONAF cooling when the air temperature is 40 °C		60 K	
	d) Temperature gradient (g) of HV winding to oil for ONAF		< 20 K	
	e) Temperature gradient (g) of LV winding to oil for ONAF		< 20 K	
<b>7.</b>	Rated short duration power-frequency withstand voltage (kV) at 50 Hz			
	a) High voltage windings and HV neutral	kV	185	
	b) Secondary windings	kV	28	
	c) Tertiary windings	kV	28	
<b>8.</b>	Impulse voltage test level (full wave 1.2/50µs)			
	a) High voltage windings	kV	450	
	b) Secondary windings	kV	95	
	c) Tertiary windings	kV	95	
<b>9.</b>	Maximum three phase fault current on HV supply side	kA	80	
<b>10.</b>	Shell or Core Type		Core	
<b>11.</b>	Flux density in core at nominal voltage and frequency and at normal ratio			
	a) Absolute maximum	T	1.95	
	b) Average	T	1.75	
<b>12.</b>	Maximum current density in windings at 45 MVA:			
	c) 88 kV winding	A/mm <sup>2</sup>	3.5	
	d) 11 kV winding	A/mm <sup>2</sup>	3.5	
	e) 6.6 kV winding	A/mm <sup>2</sup>	3.5	

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Item	Description		Schedule A	Schedule B
13.	Excitation current (higher voltages) at nominal ratio :			
	a) At rated voltage –approximate average current	%	< 0.2%	
	b) At 110% voltage –approximate average current	%	XXXX	
14.	Maximum total losses at rated power on any tap with an ambient temperature of 75 °C:	kW	XXXX	
15.	Load losses at 75 °C and nominal voltage on nominal tap and rated current (ONAF) and rated frequency:			
	a) Total load losses (Copper + stray losses + fans)	kW	239.0	
	b) Cooling losses all fans running	kW	9.0	
	c) Maximum stray load losses	kW	40.0	
16.	No-load losses at 20 °C and nominal voltage on nominal tap	kW	18.0	
17.	Cost of losses			
	The capitalised value of losses will be calculated using the following rates :			
	a) For load losses	R/kW	14000	
	b) For no load losses	R/kW	63000	
18.	Efficiency at normal ratio and unity power factor at ambient temperature of 40 °C:			
	a) ONAN rating	%	XXXX	
	b) ONAF rating	%	XXXX	
19.	Voltage regulation at 75 °C and nominal ratio and rated current (as percentage of normal voltage):			
	a) At unity power factor	%	XXXX	
	b) At 0,8 lagging power factor	%	XXXX	
20.	Impedance voltage at 75 °C, nominal voltage, nominal tap, rated frequency and rated current between HV and LV winding	%	17.0	
	Maximum impedance variation across all taps (maximum impedance – minimum impedance)	%	2.0	
21.	Winding resistance at 75 °C		XXXX	



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Item	Description		Schedule A	Schedule B
	a) 88 kV	$\Omega$ /phase	XXXX	
	b) 11 kV	$\Omega$ /phase	XXXX	
	c) 6.6 kV (open delta)	$\Omega$	XXXX	
<b>22.</b>	Types of windings			
	a) 88 kV		Copper	
	b) 11 kV		Copper	
	c) 6.6 kV		Copper	
<b>23.</b>	Insulation of:			
	a) 88 kV windings		Thermally upgraded paper	
	b) 11 windings		Thermally upgraded paper	
	c) 6.6. kV windings		Thermally upgraded paper	
<b>24.</b>	Windings insulation			
	a) HV windings		Fully Insulated	
	b) MV and LV windings		Fully Insulated	
<b>25.</b>	88 kV bushings:			
	a) Um / BIL	kV	123 / 550	
	b) In	A	800	
	c) Maximum PD at 106 kV	pC	<10	
	d) Maximum tan $\delta$		< 0,4%	
	e) Manufacturer		XXXX	
	f) Type		epoxy resin	
	g) Model		XXXX	
	h) Weather sheds		silicone rubber	

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Item	Description		Schedule A	Schedule B
	i) Minimum pollution class		31 kV/mm	
	j) RIP or RIS bushing		XXXX	
<b>26.</b>	11 kV bushings:			
	a) Um / BIL	kV	33 / 200	
	b) In	A	3000	
	c) Manufacturer		XXXX	
	d) Type		epoxy resin	
	e) Model		XXXX	
	f) Weather sheds		silicone rubber type	
	g) Minimum pollution class		31 kV/mm	
	h) RIP or RIS bushing		XXXX	
<b>27.</b>	6.6 kV bushings:			
	a) Um / BIL	kV	33 / 200	
	b) In	A	1000	
	c) Manufacturer		XXXX	
	d) Type		epoxy resin	
	e) Model		XXXX	
	f) Weather sheds		silicone	
	g) Minimum pollution class		31 kV/mm	
	h) RIP or RIS bushing		XXXX	
<b>28.</b>	88 kV surge arrestors	4 units		
	a) U MCOV	kV	77	
	b) Manufacturer		XXXX	
	c) Type		epoxy resin	
	d) Model		XXXX	
	e) Weather sheds		silicone rubber type	
	f) Minimum pollution class		31 kV/mm	
<b>29.</b>	11 kV surge arrestors	4 units		
	a) U MCOV	kV	9.6	
	b) Manufacturer		XXXX	

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	c) Type		epoxy resin	
	d) Model		XXXX	
<b>Item</b>	<b>Description</b>		<b>Schedule A</b>	<b>Schedule B</b>
	e) Weather sheds		silicone rubber type	
	f) Minimum pollution class		31 kV/mm	
<b>30.</b>	6.6 kV surge arrestors	1 unit		
	a) U MCOV	kV	XXXX	
	b) Manufacturer		XXXX	
	c) Type		epoxy resin	
	d) Model		XXXX	
	e) Weather sheds		silicone rubber type	
	f) Minimum pollution class		31 kV/mm	
<b>31.</b>	Noise Levels			
	a) ONAN at 2 m	dbA	76	
	b) ONAF at 2 m with all fans running	dbA	77	
<b>32.</b>	On-load tap changer			
	a) Tapping range		+5 to -15%	
	b) Tap step		1.25%	
	c) Number of steps		17	
	d) Which winding is tapped and where		88 kV Neutral side	
	e) Category of voltage variation		CFVV	
	f) Number of operation before maintenance		300 000	
	g) Type		Flag / vacuum	
	h) Resistor or reactor type		Resistor	
	i) Manufacturer		XXXX	
	j) Model		XXXX	
	k) Rated current		400 A	
	l) Rated voltage	kV	XXXX	
	m) BIL	kV	XXXX	

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	n) Fully automatic OLTC required?	Yes/No	Yes	
	o) The on-load tap changer equipment shall be suitable for supervisory control and indication.	Yes/No	Yes	
	p) Linear or Forward/Reverse		Forward /Reverse	
	q) Motor rating in OLTC drive unit	Supply voltage	400 V	
		Rated current	XXXX	
		Rated power	XXXX	
		Rated speed	XXXX	
<b>33.</b>	Type of cooling		ONAN/ONAF	
	a) Number of fans (n + 1)		XXXX	
	b) Number of radiator banks		XXXX	
	c) Tube thickness of the radiators		> 1.0 mm	
	d) Radiator dimensions	Height Width	XXXX	
	e) Radiator mounting (tank or separate)		Tank	
	f) Mass of each radiator :	kg	XXXX	
	g) Average velocity of air through the cooler	m/s	XXXX	
	h) Speed of fan	rpm	XXXX	
	i) Type of fan motor		XXXX	
	j) Continuous rating of fan motor	kW	XXXX	
	k) Starting current of fan motor	A	XXXX	
	l) Efficiency of fan motor	%	XXXX	
	m) Power factor of fan motor	p.u	XXXX	
	n) Rated output of each fan:	m <sup>3</sup> /s	XXXX	
	r) Manufacturer of radiator		XXXX	
	s) Model of radiator		XXXX	
	t) Manufacturer of fan		XXXX	
	u) Model of fan		XXXX	

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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Item	Description		Schedule A	Schedule B
	v) Manufacturer of fan motor		XXXX	
	w) Model of fan motor		XXXX	-
<b>34.</b>	Calculated thermal time constant :			
	a) Natural cooling: winding	Min.	XXXX	
	b) Natural cooling: oil	hours	XXXX	
	c) Forced cooling: winding	Min.	XXXX	
	d) Forced cooling: oil	hours	XXXX	
<b>35.</b>	Current transformers outside (outdoor type):			
	a) Manufacturer		XXXX	
	b) 11 kV neutral CT, as specified in Section 8.11 and as per table 4.	1 unit	3000/1 Class 5P20 15 VA Rs<12.0 Ω	
<b>36.</b>	Current transformers outside (outdoor type) as specified table 8A:	1 unit		
	a) Manufacturer		XXXX	
	b) Core 1 - 11 kV neutral CT with taps		2500/1 Class TPS Rs<10.0 Ω	
	c) Core 2 - 11 kV neutral CT with taps		2500/1 Class 5P20 15 VA Rs<10.0 Ω	
	d) Core 3 - 11 kV neutral CT with taps		3000/5 Class TPS Rs<0.6 Ω	
	e) Core 4 - 11 kV neutral CT with taps		3000/5 Class 5P20 15 VA Rs<0.6 Ω	
<b>37.</b>	Current transformer outside tank (outdoor type) specified table 8B:	1 unit		
	a) Manufacturer		XXXX	
	b) 11 kV tank CTs core 1		400/1 Class 5P20 15 VA Rs<1.60 Ω	

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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Item	Description		Schedule A	Schedule B
<b>38.</b>	Current transformer inside tank specified table 8C:			
	a) Manufacturer		XXXX	
	b) WTI CTs core 1	3 unit	2500/x Class 1 10 VA	
<b>39.</b>	Oil :			
	a) Manufacturer		XXXX	
	b) Type of oil		XXXX	
	c) Name of oil		XXXX	
<b>40.</b>	The marshalling kiosks or cabinets are to be fitted with metal-clad heaters	Yes/No	Yes	
<b>41.</b>	Label materials :			
	a) Outdoors		S/Steel	
	b) Indoors		S/Steel	
	c) Inside cubicles and kiosks		Trafolite	
<b>42.</b>	Pressure relief device		Required	
	a) Number required		2	
	b) Size of port	mm	XXXX	
	c) Opening pressure		XXXX	
	d) Number of contacts		XXXX	
	e) Manufacturer		XXXX	
	f) Model		XXXX	
<b>43.</b>	Oil and winding temperature monitor device		Required	
	a) Manufacturer		XXXX	
	b) Model		XXXX	
<b>44.</b>	Gas and oil actuated relay		Required	
	e) Manufacturer		XXXX	
	f) Model		XXXX	
	g) Size of port	mm	XXXX	
	h) Number of contacts		XXXX	
<b>45.</b>	Online gas and moisture monitoring unit/s		Required	
	a) Manufacturer		XXXX	

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Item	Description		Schedule A	Schedule B
	b) Model		XXXX	
46.	Oil gauge device		Required	
	a) Manufacturer		XXXX	
	b) Model		XXXX	
	c) Number of contacts		XXXX	
47.	Dehydrating breather		Required	
	a) Manufacturer		XXXX	
	b) Model		XXXX	
	c) Mass of desiccant		XXXX	
	d) Type of desiccant		XXXX	
	e) Colour of desiccant		XXXX	
48.	Other breather		Required	
	a) Manufacturer		XXXX	
	b) Model		XXXX	
	c) Mass of desiccant		XXXX	
	d) Type of desiccant		XXXX	
	e) Colour of desiccant		XXXX	
49.	Transformer mounted marshalling kiosk		Required	
50.	Conservator bag		Required	
	a) Manufacturer		XXXX	
	b) Model		XXXX	
	c) Type		XXXX	
	d) Bag volume		XXXX	
51.	Filling medium of transformer tank for shipment		Oil & Dry Air	
52.	First filling of virgin oil for the transformer		Required	
53.	Total volume of oil	litres	XXXX	
54.	Volume of oil in radiators	litres	XXXX	
55.	Minimum quantity of oil to be removed from transformer including conservator to expose the top of the core	litres	XXXX	

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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Item	Description		Schedule A	Schedule B
56.	Total volume of conservator	litres	XXXX	
57.	Mass of copper required in the complete transformer	kg	XXXX	
58.	Mass of core steel	kg	XXXX	
59.	Total mass of transformer without oil and radiators	kg	XXXX	
60.	Total mass of transformer filled with oil with radiators fitted	kg	XXXX	
61.	Total mass of largest part of transformer during transport	kg	XXXX	
62.	Thickness of transformer tank:			
	a) Side	mm	XXXX	
	b) Bottom	mm	XXXX	
	c) Top	mm	XXXX	
63.	Dimensions of transformer including cooling gear			
	a) Height overall	mm	5500 max	
	b) Length	mm	6800 max	
	c) Width	mm	5000 max	
64.	Dimensions of transformer arranged for transport			
	a) Height	mm	XXXX	
	b) Length	mm	XXXX	
	c) Width	mm	XXXX	
65.	Alarms and Indication	V <sub>DC</sub>	110	
66.	Motor Supply for cooling fans (3 phase, 4 wire) and auxiliaries	V <sub>AC</sub>	400 / 230	
63	OEM details:			
	a) Name of manufacturer		XXXX	
	b) Country		XXXX	

NOTE: TICKS [✓✗], ASTERISK [\*], WORD [NOTED], OR TBA [TO BE ADVISED] SHALL NOT BE ACCEPTED.

Tender Number: \_\_\_\_\_



<b>SPECIFICATION FOR POWER</b> <b>TRANSFORMERS RATED AT 40 MVA</b> <b>88/11 kV, 40 MVA 132/11 kV AND 45 MVA</b> <b>88/11 kV</b>	REFERENCE	REV
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Tenderer's Authorised Signatory: \_\_\_\_\_

Name in block letters

Signature

Full name of company: \_\_\_\_\_

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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#### ANNEX D – DEVIATION SCHEDULE

Any deviations offered to this specification shall be listed below with reasons for deviation. In addition, evidence shall be provided that the proposed deviation will at least be more cost-effective than that specified by City Power.		
Item	Subclause of CP_TSSPEC _037	Proposed deviation with motivation
1		
2		
3		

<b>SPECIFICATION FOR POWER</b> <b>TRANSFORMERS RATED AT 40 MVA</b> <b>88/11 kV, 40 MVA 132/11 kV AND 45 MVA</b> <b>88/11 kV</b>	REFERENCE	REV
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<b>4</b>		
<b>5</b>		
<b>6</b>		
<b>7</b>		

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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8		
9		
10		

Tender Number: \_\_\_\_\_

Tenderer’s Authorised Signatory: \_\_\_\_\_

Name in block lettersSignature

Full name of company: \_\_\_\_\_

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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## ANNEX E – RECOMMENDED SPARES LIST

	Spare name	Motivation for keeping this item as a spare	Delivery time in weeks
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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11			
12			
13			
14			
15			
16			
17			
18			

This list of recommended spares shall be duplicated in the price schedule with prices, but not included in the total tender price, as this is an option City Power may exercise.

Tender Number: \_\_\_\_\_

Tenderer's Authorised Signatory: \_\_\_\_\_  

  
Name in block letters Signature

Full name of company: \_\_\_\_\_

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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## **ANNEX F – GENERIC MARSHALLING KIOSK DRAWINGS**

NB: Refer to CP\_TSDRAW\_050, which details the wiring of the marshalling kiosk.

<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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## **ANNEX G – GENERIC TRANSFORMER LAYOUT**

NB: Refer to NRS054, Table 18, for a typical transformer layout.



<b>SPECIFICATION FOR POWER TRANSFORMERS RATED AT 40 MVA 88/11 kV, 40 MVA 132/11 kV AND 45 MVA 88/11 kV</b>	REFERENCE	REV
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## ANNEX H – STOCK ITEMS

Item	SAP No.	SAP Short Description	SAP Long Description
<b>1.</b>	<b>2627</b>	POWER TRANSFORMERS RATED AT 40 MVA 88/11 KV YNd1	POWER TRANSFORMERS RATED AT 40 MVA 88/11 KV YNd1, outdoor transformer used at substation, CP_TSSPEC 037 rev4
<b>2.</b>	<b>4485</b>	POWER TRANSFORMERS RATED AT 40 MVA 132/11 kV YNd1	POWER TRANSFORMERS RATED AT 40 MVA 132/11 kV YNd1, outdoor transformer used at substation, CP_TSSPEC 037 rev4
<b>3.</b>	<b>4486</b>	POWER TRANSFORMERS RATED AT 45 MVA 88/11/6.6 KV YNyn0(d11)	POWER TRANSFORMERS RATED AT 45 MVA 88/11/6.6 KV YNyn0(d11), outdoor transformer used at substation, CP_TSSPEC 037 rev4