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FOREWORD

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INTRODUCTION

City Power strives to become a world-class energy distributor. In line with this vision, the company continues to invest in innovative techniques and technologies that will improve the overall performance and management of City Power entire network infrastructure. In addition, City Power seeks to retain its ISO accreditations, in achieving this goal, a number of power transformers and switchgears require commission and maintenance in accordance to quality and safety management acceptable standards.

1. SCOPE

The purpose of this standard is to outline the specialised commission and maintenance of power transformers and switchgears. It is not the intent of this standard to restrict any Service Provider (SP) from exceeding the minimum requirements, described and prescribed in this document.

2. NORMATIVE REFERENCES

The following documents contain provisions that, through reference in the text, constitute requirements of this standard. At the time of publication, the editions indicated were valid. All standards and specifications are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the documents listed below.

CP_TSSPEC_006 Specification for Metal-enclosed ring main units for type B miniature substations

CP_TSSPEC_035, *Specification for Metal clad withdrawable switchgear*

CP_TSSPEC_037, *Specification for Power transformers rated at 40MVA 88/11kV, 45MVA 88/11kV and 45MVA 132/11kV*

CP_TSSPEC_145, *Specification for Post type circuit breaker up to 132kV*

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

NRS 054, *Rationalised User Specification - Power Transformers*

SANS 780, *Distribution Transformers*

SANS 1874, *Switchgear — Metal-enclosed ring main units for rated a.c. voltages above 1 kV and up to and including 36 kV*

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

SANS 60137, *Insulated bushings for alternating voltages above 1 000 V*

SANS 60076-3, *Power transformers Part 3: Insulation levels, dielectric tests and external clearances in air*

SANS 60076-24, *Power transformers - Part 24: Specification of voltage regulating distribution transformers (VRDT)*

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

IEC 60156, Insulating liquids - Determination of the breakdown voltage at power frequency - Test method

IEC 60214, Tap-changers - Part 1: Performance requirements and test methods

SANS 61000-4-29, *Electromagnetic compatibility (EMC) Part 4-29: Testing and measurement techniques — Voltage dips, short interruptions and voltage variations on d.c. input power port immunity tests.*

SANS 61598, *High-voltage prefabricated switchgear and controlgear assemblies – Voltage presence indicating systems*

SANS 62271-1, *High-voltage switchgear and controlgear Part 1: Common specifications for alternating current switchgear and controlgear*

SANS 62271-100, *High-voltage switchgear and controlgear Part 100: Alternating-current circuit-breakers*

SANS 62271-102, *High-voltage switchgear and controlgear Part 102: Alternating current disconnectors and earthing switches*

SANS 62271-200, *High-voltage switchgear and controlgear Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

NEMA ST-20, *Dry-Type Transformers for General Applications*

IEEE standard C57.12.00, *IEEE Standard General Requirements for Liquid-Immersed, Distribution, Power and Regulating Transformers*

IEEE standard C57.12.90, *IEEE Standard Test Code for Liquid -Immersed, Distribution, Power and Regulating Transformers and IEEE Guide for Short-Circuit Testing of Distribution and Power Transformers*

NFPA 70, *National Electrical Code: Article 450, Transformers and Transformer Vaults*

SANS 9001*: Quality management systems*

SANS 14001: Environmental management systems

SANS 45001: Occupational Health and Safety management systems.

3. DEFINITIONS

Definitions used in this document shall reference to those used at the normative reference documents.

4. REQUIREMENTS

4.1 Service Provider (SP)

4.1.1 Inspection and testing, a competent person shall carry out examination of the of power transformers and switchgears parts.

4.1.2 After the competent person has identified defects, he/she shall submit a report promptly to a City Power responsible person to take the necessary action within the required period.

4.1.3 The power transformers and switchgears maintenance shall be in accordance with the manufacturer's recommended procedures. All tools and equipment required for performing a task; shall be provided by the Service Provider, and remain their property.

4.2 Facilities

City Power shall ensure that the facilities required by the Service Provider in order to carry out the testing are allocated. The Service Provider shall cater for the following:

4.2.1 cordoned off area to prevent access by persons not directly involved in the examination;

4.2.2 provide their own testing equipment and tools ;

4.2.3 provide own resources (personnel) to remove covers or open up parts of power transformers and switchgears; and

4.3 Provisions for pre-testing

Before testing, transformers and switchgears shall be cleaned to remove all spilt matter and dirt that would otherwise conceal the structure or mechanisms and prevent an effective testing. The inspection shall be carried out in a logical sequence, (for example, top to bottom or left to right), to ensure that nothing is overlooked.

The Service Provider shall take into account the age, loading, environmental and duty cycle history of transformers and switchgears, and any testing which have traditionally been accepted as appropriate for that or similar equipment.

Note: A Service Provider shall develop a testing plan intended for each equipment to ensure that the transformers and switchgears remains safe to use and includes information on the required frequency of inspection.

4.4 Pre testing inspections

4.4.1 Visual inspection on transformers and switchgears for defects;

4.4.2 Carry out a visual examination and functional check on the inter-locking system for correct operation, for leaks, damage, corrosion and distortion, and for correct operation of all indicators.

4.4.3 Examine the tracks for wear and adjustment.

4.4.4 Inspect all bolts and fastenings to ensure that they are not coming loose.

4.4.5 Examine the full range of movements.

4.4.6 Examine all motors for leakage, and corrosion on the including and alignment. Visually check end fixings/stops for wear, security and lubrication.

4.4.7 Examine all pivoting joints and attachments of the lifting brackets for wear, corrosion, security and evidence of lubrication.

4.4.8 Check any means of access for completeness, security handrails and handholds.

4.4.9 Examine the control circuit for hotspots or flashovers, security, freedom of movement and nameplates markings to show the correct description.

4.4.10 Check whether all control buttons are marked with their function and mode of operation.

4.4.11 Check the oil and other fluids for the condition (for example by debris monitoring) and level of the fluid.

4.4.12 The functionally test all controls for smoothness of operation and to determine whether they are free from wear and other damage.

4.4.13 Check whether warning signs and other important instructions are present and readable, for example the rating plate for load lifting.

4.4.14 Operate the transformers and switchgears to check whether all motions operate smoothly and effectively without excessive play.

4.5 Precaution and Safety

Before proceeding with any measurements in a high-voltage substation, the SP shall be thoroughly familiar with the job and confirm all relevant equipment are de-energised or out of service, and isolated from the electrical Network before connecting any test leads. All safety regulations shall be followed and be aware of any energised equipment in the working area. Ground test equipment and test circuits to avoid stray voltages from energised lines, lightning or close-in faults in the area.

Note: - Extreme caution observed when test energising high voltage equipment, because high voltages shall be present at the terminals. Care shall be taken not to energise bus-couplers/sections or equipment that electricians or other personnel could be working on and that test equipment does not contact energized equipment.

Note: - A transformer winding that is carrying DC current generate a large voltage across the winding when disconnected. To prevent electric shock, use means of insulation from the connection when breaking the test connection. A hot-stick tool shall be recommended.

4.5.1 Personnel Protective Equipment (PPE)

The Service Provider shall conform to the Safety, Health, Environmental and Quality requirements. Any person working on equipment shall wear personal Protective Equipment (PPE) at all times. The Service provider shall ensure that the correct PPE shall be worn for specific activities during transformer and switchgear testing.

4.5.2 Warning signs and barriers

The test area shall be marked off with signs and easily visible tape. Warning signs shall conform to the requirements of ORHVS and Occupational Safety and Health.

4.5.3 Apparatus

Certain test procedures could result in equipment being on fire; therefore, fire-fighting equipment shall be available before beginning tests that apply dielectric stress to equipment insulation system.

4.5.4 Overvoltage

In some cases, voltage may accidentally exceed the desired maximum during the conduction of high-voltage tests. A sphere gap, adjusted to spark over at a voltage slightly above the desired maximum, shall be connected across the voltage source.

4.5.5 Graded insulation

When the insulation level of the winding is graded, from one end to the other, the magnitude of the applied test voltage should correspond to the lowest insulation level.

4.5.6 Testing under vacuum

Under no condition shall tests be performed on the transformer while the equipment is under vacuum. The dielectric strength of the system is significantly reduced under these conditions.

4.5.7 Surge arresters

Where test voltage is expected to approach or exceed the operating voltage of any transformer-mounted surge arresters, the arresters shall be disconnected before energising the transformer. This avoids arrester damage and limitation of the test voltage due to arrester operation.

4.5.8 Isolation and Disconnection

Equipment or circuits to be tested shall be disconnected from the power system. Typical safety procedures such as visual inspection of the disconnections or, when this is not possible, a check with a voltage indicator. Earthing shall then applied. All personnel shall be informed to treat all ungrounded apparatus as energised.

4.6 Inspection and certification

4.6.1 After testing has been completed, the Service Provider shall issue the appropriate certificate, which shall be included to the report of the inspection and testing.

4.6.2 After all the inspection and testing, the service provider shall provide a report detailing required information as per transformers or switchgears.

4.7 Non-destructive testing (NDT)

NDT of transformers and switchgears might be necessary, particularly when there is a suspicion of cracks or other damage being present in structural parts.

5. Power Transformers

High-voltage transformers are some of the most important (and expensive) pieces of equipment required for operating an electrical Network. The purchase, preparation, assembly, operation and maintenance of transformers represent a large expense to the power system. Modern transformers are designed closer to tolerances levels than units in the past. A regular maintenance and testing program is even more essential to continued operation when traditional "overdesign" cannot be relied on to overcome abnormal conditions.

5.1 Overview

When transformers are received from the factory or reallocated from another site; it is necessary to verify that each transformer is dry, no damage has occurred during transportation (Road and shipping), internal connections have not been loosened, the transformer's ratio, polarity, and impedance agree with its nameplate, its major insulation structure is still intact, wiring insulation has not been bridged, and the transformer is ready for service.

Physical size, voltage class, and kVA rating are the major factors that dictate the amount of preparation required to put a transformers into service. Size and kVA rating also dictate the kind and number of auxiliary devices a transformer shall require. All of these factors influence the amount of testing necessary to certify that a transformer as ready to be energised and placed into service. There are a multiple of checks and tests performed as a transformer is being commission or tested after a fault at a substation.

City Power electrical Network has hundreds of power transformers installed throughout the system, and few of them are identical. The following information is not intended to describe, or include, the details for performing the entire array of tests needed to prepare a transformer for service, only the tests that may be performed by Service Provider. Even though details have been limited, descriptions shall allow field SP to perform, or assist in performing, the basic tests they shall be requested to do.

5.2 Diagnostic and Benchmark

For the purpose of this standard, the diagnostic tests are described with reference to principle categories of systems that constitute the transformer (e.g., windings, bushings, insulating fluids, tap changers, core, tanks, and associated devices). In some equipment, further subdivision is necessary. In addition, the specific tests carried out vary according to the regular practice of the user and may depend on the history of the Network equipment. The establishment of benchmark values on a new piece of electrical equipment is very important when considering evaluation of future test results. Benchmark values are the first measurements taken on a piece of new or used equipment. Subsequent test results from tests on the same unit or from similar tests on similar equipment, when compared to these initial values and similar tests on similar equipment may indicate a trend.

5.3 Transformer tests

The following type of tests indicate fundamentally importance in achieving equipment compliance and state of readiness of an equipment before being energised. Since it is impossible to cover all aspects in this table, testing person or Serve Provider is required to consult latest standards, manufacturers' instruction manuals or City Power records.

Table 1: Transformer tests

Item	Component or Equipment description	Type of Test
1.	Windings	Resistance
		Ratio/Polarity/Phase
		Short circuit impedance
		Insulation resistance
		Capacitance
		Power factor/Dissipation factor

		Induced voltage/Partial discharge
		Sweep Frequency Response Analysis Tests
2.	Bushings	Capacitance
		Dielectric loss
		Power factor/Dissipation factor
		Partial discharge
		Temperature (Infra-red)
		Oil level
		Visual inspection
3.	Insulating oil	Water content
		Dissolved gas
		Dielectric strength
		Particle count
		Dielectric loss
		Power factor/Dissipation factor
		Interfacial tension
		Acidity
		Visual
		Colour
		Oxidation stability
4.	Tap-changer	Contact continuity (Load)
		Temperature/ Infra-red (Load)
		Ratio (Load)
		Timing (Load)
		Motor currents (Load)
		Limit switch (Load)
		Contact pressure (Off-load)
		Centring (Off-load)
		Ratio (Off-Load)
		Visual inspection (Off-load)
5.	Core	Insulation resistance
		Ground test
6.	Tanks and associated devices	Conservator (Visual)
		Inert air system (Visual)
		Gauges (Visual/Calibration)
		Fault pressure relay (Calibration/Continuity)
		Cooling system (Heat exchanger/Fans/Pumps)
		Pressure
		Temperature (Infra-red)
		Visual inspection

6. High and Medium Voltage Switchgear

The condition of transmission and distribution switchgears might affect security supply to all City Power customers and stakeholders. Without regular maintenance and testing, circuit breakers can develop problems that lead to unextinguished arc faults and arc flashes that could damage assets and injure workers. Condition monitoring Section performs switchgear inspections and advance testing to help in preventing these failures.

These tests on circuit breakers are performed according to the voltage capacity of the breaker and the extinguishing medium (e.g. oil, air, SF6). The below types of switchgear, tests are conducted on High Voltage (HV) and Medium Voltage (MV) circuit breakers:-

Table 2: Switchgear tests

Item	Type of test	Description of test
1.	Contact Timing Test	Contact timing testing measures the time between order initiation and the closing or parting of the contacts.
2.	Travel and Velocity Test	Travel and velocity testing measures the electrical current's travel and velocity curves to assess interruption capability.
3.	Functional Test	Functional testing assesses whether the circuit breaker is functioning properly.
4.	Vibration Test	Vibration testing measures the vibration signature of the circuit breaker.
5.	X-Ray Test	X-ray testing evaluates the condition of components that are located in closed assemblies.
6.	Contact Resistance Test	Contact resistance-testing measures the contact resistance between parts that conduct current.
7.	Dynamic Contact Resistance Test	Dynamic contact resistance testing measures contact resistance continuously from start to stop.
8.	AC Insulation Test	AC insulation testing measures the insulation that separates open contacts, as well as line and ground.
9.	Auxiliary Circuits Insulation Test	Auxiliary circuits insulation testing measures the insulation for low voltage

		control circuits.
10.	Tightness Test	Tightness testing is the manual testing of breaker connections for tightness.

The following precautions shall be considered as part of the safe working on switchgear and control gear. All leads and cables, which can be energised at dangerous voltages, shall be fully insulated and properly terminated. All connections of conductors that can be energised at a high voltage shall be electrically and mechanically tightly connected to prevent conductors becoming accidentally loss. There shall be no exposed conductors at high voltages at any purpose-built connectors or clamps into which the equipment is fixed for testing. Where practicable, apply test leads while the equipment is isolated and then energise it. To make sure that the equipment is isolated.

6.1 Test areas

In a workshop, the test area should be a separate, designated area where access by unauthorised employees are prevented while testing is in progress; at a substation a temporary barriers shall be used to form an enclosure within which testing work is to be carried out. The area shall be suitable to prevent unauthorised people accessing the danger area.

6.2 Routine tests

According to our internal specifications and IEC standard, switchgear panels shall be subjected to the following routine tests:

6.2.1 Dielectric tests on main circuits,

6.2.2 Dielectric tests on auxiliary and control circuits,

6.2.3 Measurement of the resistance of circuits,

6.2.4 Temperature rise tests,

6.2.5 Short-time withstand and peak withstand current tests on the main circuits,

6.2.6 Short-time withstand and peak withstand current tests on the earthing circuits,

6.2.7 Making and breaking tests of the circuit breaker,

6.2.8 Basic short-circuit test duties,

6.2.9 Single-phase and double-earth fault tests of the circuit breaker,

6.2.10 Three-phase short-circuit making tests on the earthing switch,

6.2.11 Internal arcing tests,

6.2.12 Verification of the degree of protection,

6.2.13 Mechanical operation tests and

6.2.14 Partial discharge tests.

6.3 Design and visual checks

Visual inspection to verify conformance of the switchgear shall be based on the current version of approved documentation and all other relevant information in accordance with each equipment specification, to validate the following as a minimum:

6.3.1 Compare equipment nameplate data with drawings and specifications;

6.3.2 Functional units and overall assembly (physical and mechanical condition) are correctly labelled;

6.3.3 Interchangeability of removable parts in accordance with specification;

6.3.4 Inspect anchorage, alignment, grounding, and required clearances;

6.3.5 Verify that insulating medium level is correct;

6.3.6 Operation, padlocking facility and effectiveness of safety shutters;

6.3.7 Effectiveness of interlocks, operating mechanisms and limit switches;

6.3.8 Integrity of internal wiring connections and earthing;

6.3.9 Correctness of wiring in accordance with final wiring diagrams;

6.3.10 Component layout and mounting and

6.3.11 Verify the unit is clean.

7. PRE COMMISSIONING TESTS

In addition to all these tests, transformers and switchgears shall be pre-commissioned on site (Site Acceptance Test- SAT). These tests shall be performed to assess the condition of transformer and switchgear after installation and compare the test results of all the low voltage tests with the factory test reports.

8. DOCUMENTATION

The Service Provider shall prepare Inspection; Testing and Functional performance test report covering all information, data sheets, and a comprehensive summary describing any test. The test report shall be submitted to City Power Responsible person. City Power shall then accept responsibility for operating the equipment being inspected or tested.

9. PERFORMANCE

City Power may inspect and test the various portions of the work at all times and shall have full power to discard all or any portion of the work that City Power may consider sub-standard or inferior as per the quality of testing workmanship with respect to the original design.

The Service Provider shall correct a portion of the work rejected, immediately. The Service Provider shall at his own expense, be at liberty to correct the work to the satisfaction of City Power, to prove that the contract requirements are met.

It is also primarily important that the Service Provider equipment are accredited with a valid SANAS Certification standards.

10. TRAINING OF STAFF

The following training courses, for City Power's staff shall be provided; which are listed into three main areas:

a) Operation (Equipment and Instruments);

b) Maintenance (Equipment and Instrument); and

c) associated disciplines/information, such as, examination and the safety

It is advisable that each of the above be separately offered, since they are applicable in different forms to different equipment.

11. QUALITY MANAGEMENT

A quality management system shall be set up in order to assure the quality of transformer and switchgear testing performed during service. Guidance on the requirements for a quality management system shall be

found in the following standards: ISO 9001:2015. The details shall be subject to agreement between the City Power and Service Provider.

12. HEALTH AND SAFETY MANAGEMENT

A health and safety management plan shall be set up in order to ensure proper management and compliance during transformer and switchgear testing performed during service. Guidance on the requirements of a health and safety management plan shall be found in ISO 45001:2018 standards. The details shall be subject to agreement between the City Power and Service Provider.

13. ENVIRONMENTAL MANAGEMENT

An environmental management plan shall be set up in order to ensure the proper environmental management and compliance to transformer and switchgear testing performed during service. 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 Service Provider. This is to ensure that the asset created conforms to environmental standards and City Power SHERQ Policy.

ANNEXURE A - BIBLIOGRAPHY

None

ANNEXURE B - REVISION INFORMATION

DATE	REV. NO.	NOTES
October 2022	0	First issue