Eskom	Standard	Technology

Title: **Technical Specification for Capacitor Bushings for Application in Power Transformers and Shunt Reactors in All Eskom Divisions Standard**

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Compiled by

.....

Sidwell Mtetwa

Corporate Specialist – Transformers and reactors

Date: 13/05/2014

Approved by

.....

Roger Cormack

Senior Manager – HV Plant Engineering

Date: 18/6/2014

Authorised by

.....

Prince Moyo

General Manager – Power Delivery Engineering

Date: 20/6/2014

Supported by TDAC

.....

Bheki Ntshangase

SCOT Plant SC Chairperson

Date: 20/6/2014

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1. INTRODUCTION

This document is required to clearly set out Eskom's requirements for the selection and purchase of oil to air bushings fitted to Power Transformers and Shunt Reactors.

2. SUPPORTING CLAUSES

2.1 SCOPE

This specification covers the technical requirements for the selection and purchase of oil to air bushings fitted to Power Transformers and Shunt Reactors.

2.1.1 Purpose

This document shall be used as a minimum requirement for the selection and purchase of oil to air bushings fitted to Power Transformers and Shunt Reactors.

Expected design life of the bushing must match the design life of a transformer, at least 40 years.

2.1.2 Applicability

- Bushings fitted to new Power Transformers and Shunt Reactors
- Bushings purchased for Strategic Spares or repaired Power Transformers and Shunt Reactors
- This specification excludes high current bushing applications as fitted to Generator Step Up Transformers
- This specification excludes single bushing replacement on an existing Power Transformer or Shunt Reactor where a match to the older installation set is required.

2.2 NORMATIVE/INFORMATIVE REFERENCES

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

[1] IEC 60137 Insulated Bushings for alternating voltage above 1000V

[2] IEC 60076-7 Loading guide for oil-immersed Power Transformers

[3] IEC 60076-18 Measurement of frequency response.

[4] IEC 61463 Seismic Qualification of Transformer High Voltage Bushings

[5] IEC 60815 Guide for Selection of Insulators in Respect of Polluted Conditions.

[6] BS EN 13601:2002 Copper and copper alloys. Copper rod, bar and wire for general electrical purposes

2.2.2 Informative

[7] ISO17025 General requirements for the competence of testing and calibration laboratories.

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2.3 DEFINITIONS

2.3.1 Disclosure Classification

Controlled Disclosure: Controlled Disclosure to External Parties (either enforced by law, or discretionary).

2.4 ABBREVIATIONS

Abbreviation	Description
A	Amperes
BIL	Basic Industrial Level
CoE	Centre of Excellence
CT	Current Transformer
HV	High Voltage
ID	Internal Diameter
ISO	International Organization for Standardization
kPa	Kilo Pascal
kV	Kilo Volts
mm	Millimetres
MVA	Mega Volt Ampere
Ø	Diameter
OIP	Oil Impregnated Paper
PCD	Pitch Circle Diameter
PD	Partial Discharge
RIP	Resin impregnated Paper
SIL	Switching Impulse Level
STC	Short Time Current
UV	Ultra Violet
°C	Degrees Celsius

2.5 ROLES AND RESPONSIBILITIES

This document shall be revised by Power Transformer and Reactors CoE before it expires or whenever it becomes necessary, whichever comes first.

2.6 PROCESS FOR MONITORING

None

2.7 RELATED/SUPPORTING DOCUMENTS

None

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3. CAPACITOR BUSHINGS FOR APPLICATION IN POWER TRANSFORMERS AND SHUNT REACTORS REQUIREMENTS

3.1 GENERAL REQUIREMENTS

All bushings from 33 kV (system voltage) and above shall be of the capacitive type and dry type. Paperless technology is preferred for classes where the technology has matured, and this shall be demonstrated by each supplier during each tender. Where the paperless is not matured, resin impregnated paper (RIP) dry type will be an alternative. External insulation material shall be manufactured from silicon composite rubber, except otherwise specified in the schedules. No movement of moisture must be possible through the external insulation to the condenser body, and proof of this must be supplied by the Contractor during a tendering stage.

Oil impregnated paper (OIP) bushings may be offered for 765kV applications when so specified while the dry type technology has not yet matured for this voltage class. Dry type will however be considered.

3.2 ENVIRONMENTAL REQUIREMENTS

Outdoor installation

Altitude above sea level – 1800m

Ambient temperatures

- Maximum 40°C
- Yearly average 25°C
- Minimum – (minus) 10°C

Average humidity 90%

Solar radiation 2500kW/m²

Atmospheric UV radiation High

Symmetrical three phase supply voltage, negative and zero phase sequence voltages up to 2% and total harmonic distortion of 3%.

Seismic conditions at a minimum of 0.3g, this requirement can be proved by test or by calculations.

The bushings shall withstand the effects of the transformer or reactor being subjected to full vacuum at sea level as well as an extended positive pressure of at least 100 kPa.

3.3 FACTORY TESTING

Each bushing shall be subjected to electrical tests performed at room temperature to measure the C1 and C2 power factor and capacitance. This test shall be carried out at 10 kV for the C1 measurement and at maximum allowable voltage for the C2 measurement.

Type tests shall be carried out according to IEC 60137. Type test reports shall be submitted to the Purchaser for approval.

Measurements for detection of internal PD shall be made. If a bushing fails the PD test, it shall be rejected and not be reprocessed for Eskom use.

All factory tests shall be performed in accordance with IEC 60137. All test facilities to be accredited to ISO 17025.

765kV OIP bushings shall be pressure tested with an over pressure of oil of 180 kPa for 12 hours at ambient temperature. No leakage is allowed.

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All test certificates and documentation shall be supplied to Eskom on delivery. For the type tests, they shall be submitted with the tender returns.

3.4 ELECTRICAL CREEPAGE DISTANCE

Electrical creepage distance of external insulation shall comply with “for very heavily polluted areas”.

All bushings shall have a creepage distance of 31 mm/kV. Protected creepage shall not be more than 50% of the total creepage distance.

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3.5 GENERIC BUSINESS REQUIREMENTS

Table 1: Standard sizes for capacitive type bushings

System Voltage	Rated Voltage	Type (note 1)	Rated Current	Stem Ø	Oil Ext	CT Ext	CT Ext Ø	Flange Ø	PCD	Fixing bolts	STC 1 sec	STC 3 sec	Cantilever Force	BIL (1.25/50)	Power Frequency	SIL
U_n kV	kV		A	mm	L1 mm	L2 mm	D mm	D1 mm	D2 mm	No & Hole Ø (# x mm)	kA peak	kA rms	kN	**kV peak** Micro sec	kV rms 60 sec @ 50 Hz	**kV peak** Micro sec
33 – 44	52	RIP	1000	26	440	300	130	290	250	8 x 16	120	63	2.0	250	80	
33 – 44	52	RIP	2500	38	440	300	130	290	250	8 x 16	120	63	2.0	250	95	
50 – 88	123	RIP	1250	38	560	300	140	290	250	8 x 16	40	25	2.0	550	230	
132	145	RIP	1250	38	660	300	160	290	250	8 x 16	40	25	2.5	650	275	
132	145	RIP	2500	38	660	300	160	290	250	8 x 16	40	25	2.5	650	275	
132	145	RIP	2700	38	660	300	160	290	250	8 x 16	40	25	2.5	650	275	
220 – 275	300	RIP	2000	38	890	300	225	450	400	8 x 20	63	40	4	1175	510	950
400	420	RIP	1000	38	1090	300	290	680	620	16 x 22	63	40	5	1550	630	1175
400	420	RIP	1600	38	1090	300	290	680	620	16 x 22	63	40	5	1550	630	1175
500	550	RIP	1600	38	1090	300	290	680	620	16 x 22	63	40	5			
765 (Type A)	800	RIP / OIP	2500	Pad	2350	685	555	800	740	12 x 32	63	40	6	2400	1000	1600
765 (Type B)	800	RIP / OIP	2500	Pad **Note 2**	1955	640	528	780	711	12 x 32	63	40	6	2550	1000	1600

Note 1: The paperless technology will be given preference on the classes where it has been evaluated and approved by Eskom in writing

Note 2 : See the diagram in Appendix A

3.6 BUSHING TERMINAL STEM SIZES

Air side bushing terminals shall be solid copper. Terminal stems shall be silver plated to minimum thickness of 20 micron. Dimensional tolerances shall be as specified in BS 1433: Copper for electrical purposes – rod and bar.

Terminal stems shall be manufactured to the correct size from a single piece of copper conductor. Spacers to increase the size of the copper conductors to the correct diameter are not acceptable.

Table 2: HV Bushing Terminal Sizes

Nominal System Voltage	Rated Current	Main HV Terminal Stems	
		Diameter	Length
Up to 400 kV	Up to 1000 A	26 mm	125 mm
	1001 to 2500 A	38 mm	125 mm
	>2500 A	60 mm	125 mm
765 kV	2500 A	8 hole pad (See attached picture for dimensions)	

3.7 BUSHING INTERNAL ELECTRICAL CONNECTION

Bushing connection to the active part shall be designed to allow (as far as possible) replacement of any bushing by performing a partial drain on a transformer, i.e. draining to a level without exposing cellulose insulation. Bushings fitted with draw leads and separate terminal stems are required on capacitor bushings.

On all bushings for new Power Transformers flexible draw lead with separate terminal stem must be supplied wherever possible. When this is not possible or the current rating does not allow it, bushings shall be fitted with a removable copper rod.

On all replacement bushings the internal electrical connection will be dictated by the actual terminations of the transformer active part. This shall be specified on the order.

The bushing internal electrical connections shall be made as per the table below:

Table 3: Bushing Conductor Requirements

Bushing current rating	Type of electrical connection
Up to 1000A	Flexible draw leads with separate terminal stems must be supplied.
1001A up to 2500 A	Wherever possible on new bushings for new transformers flexible draw leads with separate terminal stems must be supplied. Where not possible solid removable copper conductors must be supplied.
>2500 A	Removable solid conductor.

3.8 TEST POINT CONSTRUCTION

The bushing test point shall be provided to allow field testing of the internal insulation of the bushing without having to remove the HV bushing connections. The test point shall be positioned on the base flange of the bushing and face the main tank when the bushing is installed, so that there safe and easy access from the tank top.

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The test point shall be fitted with a dust cover that shall be removed and fitted by hand only. The test point shall be manufactured from non-corrodible material. An oil, heat and UV resistant seal shall be provided to prevent water and other impurities from entering the test point.

Connection of the test point to the internal insulation shall be by means of permanent electrical connection. Spring loaded connections are **not** acceptable. Where special attachments have to be used to enable connection of test leads to the insulation of the bushing, it shall be provided with the bushing packaging. The method of connecting test leads must be fail safe – if the external cover is left off.

3.9 CORROSION PROOFING

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

All fasteners shall be stainless steel – grade 316 bolts with grade 304 nuts and washers shall be used. Thread lubrication shall be applied to all threaded areas on bolts, studs and screws. Any good quality high temperature grease is acceptable, but silicone based grease is preferred.

Where cast components are used they shall be of high quality and non-porous castings. External copper terminal stems shall be silver plated.

3.10 BUSHING LIFTING LUGS

Two lifting lugs shall be located on opposite sides of the base flange, positioned 90° to the air vent plug. The lugs shall form part of the base flange casting or removable lugs may be fitted. Where necessary, lugs fitted on the top flange may be installed if required.

Lifting lugs shall be positioned to allow installation of bushings fitted at an angle with the air release plug and test point located in close proximity to each other, in order to avoid the risk to the bushing tester having to lean to the farthest part of the bushing.

3.11 BUSHING INSTALLATION POSITION

All bushings shall have an easily accessible test points that shall face inwards towards the centre of the tank after bushing installation.

In the case of the 765kV oil type bushings, the test tap shall face inwards and the oil level gauges/glass shall face outwards and shall be visible from the ground level. Only glass or polycarbonate shall be used as gauge glass material – and seals must all be compatible with the transformer and bushing oil.

3.12 AIRVENT PLUGS

Bushings shall be provided with air release plugs on the head of the bushing to release trapped air inside the central bushing tube.

Bushings must be provided with air release plugs on the base flanges these shall be positioned in the same area as the test point. This will allow installation with the test point facing inwards on bushings fitted at an angle. Vents must be in the highest point when bushing is installed

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3.13 NAMEPLATE INFORMATION

Bushing information shall be recorded on the bushing nameplate. The bushing nameplate shall be permanently engraved and manufactured from stainless steel. The labels shall be permanently fixed to the bottom flange next to the bushing test point.

The following information shall be recorded on the nameplate:

- Manufacturer
- Factory
- Relevant IEC standard
- Type
- Serial Number
- Year of manufacture
- Nominal Voltage Rating (kV)
- Nominal Current Rating (A)
- Short Time Current (kA)
- Lightning Impulse Level [BIL] (kV)
- Switching Impulse Level (kV) for ≥ 275 kV only
- C1 dissipation factor (%) and capacitance (pF)
- C2 dissipation factor (%) and capacitance (pF)
- Bushing mass (kg)
- Maximum angle to vertical (degree)
- Frequency (Hz)
- Design altitude 1800 m

3.14 DOCUMENTATION

Each bushing shall be provided with a manual placed inside the transportation crate and protected against the effects of moisture.

The manual shall contain the following information:

- Bushing handling, transportation and installation procedures
- Bushing storage procedures for crate and fitted applications (temporary and long term)
- Bushing maintenance and repair procedures
- Any special material required and procedures for cleaning and maintaining the bushing
- Factory test results
- Acceptable test values for C1 and C2 tested and the range for safe in service operation
- Impact limitations and action after indicator operation

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3.15 IMPACT INDICATOR FOR TRANSPORTATION

Bushings shall be fitted with visual impact indication on the crate and bushing body and set to the design impact levels of the particular bushing. The impact indication shall be non-resettable and operate in x, y and z planes.

3.16 STRESS SHIELDS

Stress shields to be supplied and included and they must be epoxy coated stress shields. Insulation paper covered stress shield are not acceptable, this is due to the need to eliminate the additional requirement of drying out the paper covered unit before fitting. All stress shields must be fitted with mountings which limit attachment to the bushing in only one direction (there must be no possibility of incorrectly installing the stress shield) and the mounting mechanising once the stress shield is fitted must be secure and locked in place to ensure no disconnection due to through faults, nor vibrations while in service nor seismic occurrences within the limits of the IEC requirements.

Directions for correctly fitting the stress shield must be included in the documentation listing the method of assembly and all precautions to be taken.

3.17 PACKING FOR SHIPMENT AND STORAGE

The oil side of the bushings shall be covered with permanent bolted and gasketed steel cover (ONLY when specified for storage) with a corrosion resistant coating. The bushing shall be protected against the elements of corrosion and moisture. Moisture absorbing material shall be placed inside the protective cover; alternatively it shall be filled with dry (water <10ppm) transformer oil.

The insulator body of the bushings shall be protected against dirt and moisture. Plastic sleeving covering the entire insulator body and secured at the top and bottom flanges is acceptable. Corona shields shall be packed inside the crate and protected against corrosion and damage.

Bushings shall be placed in non returnable wooden crates suitable for handling by overhead crane and forklift truck. Transport securing blocking on top of the bushings shall be removable to facilitate handling of the bushing. Securing of the removable top blocking by means of nails through the side of the crate is not acceptable.

The top lid of the bushing crate shall be completely removable to allow for easy handling of the bushing. The complete inside of the crate and top lid shall be lined with water tight plastic sheeting to prevent water and dirt from entering the crate. The crate shall bear permanent markings for: correct side up, centre of gravity, sling connections and total weight (crate & bushing).

Bushings shall not be transported or stored without insulator covering, permanent oil side protective cover, removable stiffeners and crate top lid.

3.18 TECHNICAL EVALUATION AND FINAL APPROVAL

This specification serves as a minimum requirement for manufacturers that supply bushings. Any deviation from this specification has to be approved by Eskom in writing.

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Final written approval shall be provided once a technical evaluation has been completed and equipment found in compliance with this specification and Eskom requirements.

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4. AUTHORISATION

This document has been seen and accepted by:

Name & Surname	Designation

5. REVISIONS

Date	Rev.	Compiler	Remarks
March 2014	1	L Jordaan	Draft document for review created from 32-633 • Paperless technology added as an option • Dry technology added as an option on 765kV • 400kV at 1675kV BIL removed • SIL for 275kV reduced to 950kV from 1050kV • Fixed conductor removed on Table 3 • Schedules AB added as part of the standard

6. DEVELOPMENT TEAM

The document was revised by Lionel Jordaan, Peter Busch, Adesh Singh, Nkosinathi Buthelezi and Sidwell Mtetwa

7. ACKNOWLEDGEMENTS

The team acknowledges the original team involved in the drafting of the original document registered before as ESP32-633.

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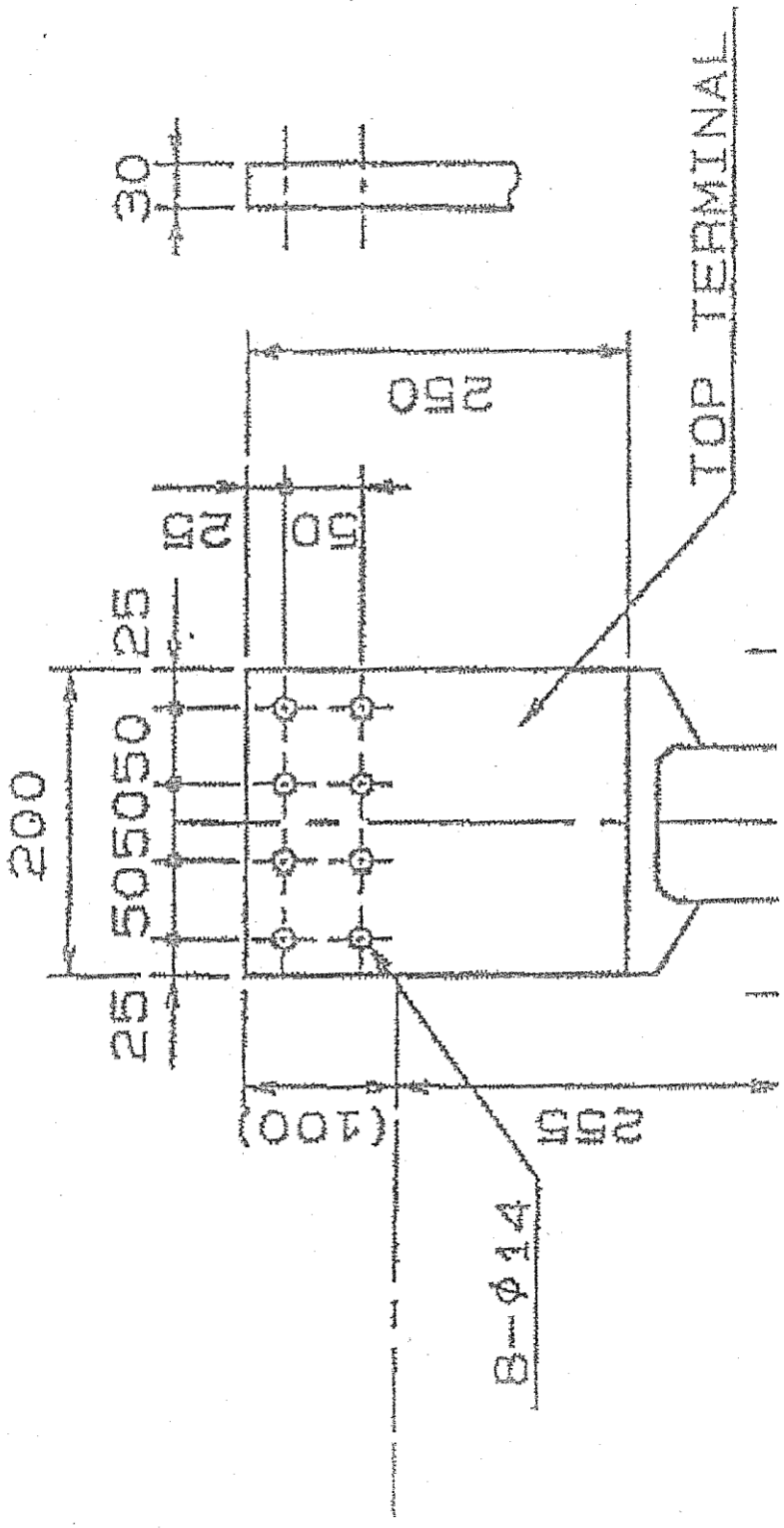
APPENDIX A: DIAGRAM



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Specification for Resin Impregnated Paper (RIP) and Paperless Bushings								
Schedule A: Purchasers specific requirements								
Project name:								
Customer / utilities		**Eskom**						
Applied standard				X	IEC 60137			IEEE C57.19.01
Eskom Specification is 24056062799								
Item		1		remark / additional information				
Application		Air / Oil		Outdoor				
		Wall bushing			indoor / indoor			indoor/ outdoor
		Special bushing						
Composite insulator					grey			normal sheds
Angle of mounting		Angle 0° to 90°			vertical			horizontal
Quantity			nos.					
Maximum rated voltage(Um)			kV	Max service voltage line to ground 243 kV				
Rated lightning impulse test (BIL)			kV	1.2/50 µs full wave				
Rated switching impulse test			kV	Switching surge test voltage 250/2500 µs wet				
Rated AC/Power frequency voltage test Dry/Wet			kV	50 Hz, 1 min				
Rated current			A					
Conductor type					draw lead			draw rod
Length of C.T. space min			mm					
Minimum creepage distance			mm	Original				
Cantilever load (IEC 60137)					normal			heavy
Rated ambient temperature range	X	-25°C to 50°C						
Installation altitude	X	1800m above sea level						
Seismic requirements	X	vertical excitation					horizontal excitation	
Flange	mm			PCD	mm			
Oil Side length	mm			Holes	number x diameter			

Schedule B: Contractors guarantees and technical particulars of equipment offered	
Description	Supplier Guarantees
1. SERIAL-NUMBER/ CATALOGUE NUMBER	
2. RATED VOLTAGE – **kV**	
3. SYSTEM VOLTAGE – **kV**	
4. Max Service Current (A)	
5. TYPE RIP/OIP/OTHER (SPECIFY)	
6. RATED CURRENT – **A & type of conductor**	
7. STEM Ø - **mm /** STEM LENGTH - **mm**	
8. OIL EXT – **mm**	
9. CT EXT – **mm**	
10. CT EXT Ø – **mm**	
11. FLANGE Ø – **mm**	
12. PCD – **mm**	
13. FIXING HOLES -_ **x** _ **mm**	
14. Rated short circuit-time current 2s Ith (A) 2= 25Ir peak and Rated dynamic current Id	
15. STC 3 SEC – **kA rms**	
16. CANTILEVER FORCE - **kN**	
17. BIL (1.25/50) – **kV peak µsec**	
18. POWER FERQUENCY - **kV rms 60 sec @ 50 Hz dry/wet**	
19. SIL – **kV peak µsec**	
20. Altitude above sea level	
21. Operating temperatures	
22. Life Span in years	
23. Corona Shield material and dimensions	
SUPPLIER REPRESENTATIVE (PRINT NAME)	
SIGNATURE	
DATE	