Eskom	Standard	Technology

Title: **SPECIFICATION FOR A DIGITAL TEMPERATURE INSTRUMENT FOR POWER TRANSFORMERS**

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1. Introduction

This document describes the requirements of the Distribution Operating Units for a digital temperature instrument for application on power transformers. The specification of such devices was formerly included within Distribution specification DISSCAAD3 “Specification for large power transformers up to 132kV, in the rating range of 1,25MVA to 160MVA” (Revision 8). A separate specification document for digital temperature instruments was created under document number DSP 34-486 so as to more fully address the technical requirements of the device, without overburdening the power transformer specification. This document is a republication of DSP 34-486 under a new document number and using the latest document template, without changes in technical content.

This specification details Eskom Distribution’s requirements for a digital temperature instrument for application on power transformers. Prior to the implementation of this specification (and that formerly provided in DISSCAAD3), power transformers for Eskom Distribution used discrete mechanical-type oil and winding temperature gauges using capillary tubes. Digital temperature instruments are, however, favoured owing to the following functional improvements brought about by the new technology:

a) A single digital instrument is capable of performing both the oil and winding temperature functions. Replacement of the mechanical oil temperature gauge with a digital instrument thus provides redundancy for the mechanical winding temperature gauge, with significant functional enhancements.

b) Simplified set-up, with “calibration” done via device settings rather than mechanical adjustment of components.

c) Simplified maintenance. Digital devices are capable of self monitoring - both the digital instrument itself and its inputs (temperature sensor circuit) and outputs (analogue circuits) - thus the ability to indicate any failure via an Alarm. In the Eskom application, a rudimentary check between the reading of the mechanical and digital instrument’s Winding Temperature measurements enhances this further.

d) Availability of historical data. All of the acquired data is stored in a database embedded in the device, available for later review. The device performs online calculations on the data and is able to indicate the transformer’s operational life expectancy based on an IEC calculation method.

e) The device is capable of communicating its output information directly to the RTU via a modern communication protocol.

The standard digital temperature instrument shall cater for ambient and oil temperature measurement and shall calculate the winding temperature of a single winding based on a current transformer input. It shall be possible to extend the digital temperature instrument, or to obtain a similar instrument of extended capabilities, so as to accommodate two additional current transformer inputs for two additional winding temperature calculations (e.g. for application with three winding transformers).

It is envisaged that a future revision of this standard will extend its scope to other Eskom Divisions, and include requirements for communication using IEC 61850.

2. Supporting clauses

2.1 Scope

2.1.1 Purpose

This document describes the technical requirements for a digital temperature instrument to be used for oil and winding temperature measurement on power transformers. This protection-class device will be used to provide temperature-related alarm and tripping signals, cooler controls, and will store a database of historical temperature and loading data.

2.1.2 Applicability

This document shall apply to the Distribution Division of Eskom Holdings SOC Limited. It is expected that the applicability of this document will be extended to cover all Eskom Divisions in a subsequent revision.

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] ISO 9001 Quality Management Systems.

[2] IEC354, Loading guide for oil immersed transformers.

Note: while IEC354 has been superseded by IEC 60076-7, most commercially available temperature instruments still use the simpler IEC354 hot-spot temperature calculation method. A description of the IEC354 method of winding hot-spot temperature calculation is given in Heathcote [15], pages 621 to 628.

[3] IEC 60068-2-1, Environmental testing — Part 1 Cold.

[4] IEC 60068-2-2, Environmental testing — Part 2 Dry Heat.

[5] IEC 60068-2-30, Environmental testing — Part 30 Damp heat, cyclic (12h + 12h cycle).

[6] IEC 60076-7, Power transformers — Part 7 Loading guide for oil-immersed power transformers.

[7] IEC 60255-5, Electrical relays. — Part 5 Insulation coordination for measuring relays and protection equipment.

[8] IEC 60255-21, Electrical relays. — Part 21 Vibration, shock, bump and seismic tests on measuring relays and protection equipment (All sections).

[9] IEC 60255-22, Electrical relays. — Part 22 Electrical disturbance tests for measuring relays and protection equipment (All sections).

[10] IEC 60715, Dimensions of low-voltage switchgear and controlgear. Standardised mounting on rails for mechanical support of electrical devices in switchgear and controlgear installations.

[11] IEC 60751, Industrial platinum resistance thermometer sensors.

[12] SANS 60529, Degrees of protection provided by enclosures (IP Code).

[13] SANS 61000-4, Electromagnetic compatibility (EMC): Test and measurement techniques (All sections).

[14] ST 240-64685228, Generic specification for protective Intelligent Electronic Devices (IEDs).

2.2.2 Informative

[15] Heathcote, M.J. “J&P Transformer Book” (12th ed), Newnes, Johannesburg, 1998.

2.3 Definitions

2.3.1 General

None

2.3.2 Disclosure classification

Controlled disclosure: controlled disclosure to external parties (either enforced by law, or discretionary).

2.4 Abbreviations

Abbreviation	Description
a.c. or A.C.	Alternating Current
CT	Current Transformer
d.c. or D.C.	Direct Current
DNP	Distributed Network Protocol
I_n	Nominal Current
I/O	Inputs and Outputs
LCD	Liquid Crystal Display
LED	Light Emitting Diode
r.m.s	root mean squared
RTU	Remote Terminal Unit
USB	Universal Serial Bus
V_n	Nominal Voltage

2.5 Roles and responsibilities

This document resides under the Design Care Group of the SCOT Protection & Automation Study Committee.

2.6 Process for monitoring

Not applicable.

2.7 Related/supporting documents

This document supersedes DSP 34-486 Revision 1.

3. Technical Requirements

3.1 Voltage supplies

The device shall include a universal power supply capable of operating using an auxiliary supply voltage anywhere from 88V to 265V d.c..

3.2 Inputs and Outputs

3.2.1 Analog inputs

a) The device shall accept a single phase Current Transformer input for each winding temperature measurement.

b) The current input nominal ratings shall be user-settable in the range from 0.5A to 5A step 0.5A, with the following overload capabilities:

1) 50 x I_n for 3 s or 100 x I_n for 1 s; and

2) 2 x I_n continuously.

c) The device shall accept Current Transformer ratios in the range 1:1 to 5000:1 step 1.

d) The instrument shall employ PT100 sensors for temperature measurement, as per IEC 60751.

e) The instrument shall accept input from an ambient temperature sensor to provide ambient temperature measurement.

3.2.2 Analog outputs

a) An analogue output signal preferably in the range of 0 to 5mA, but alternatively 4 to 20mA shall be provided for each top oil / winding hot-spot temperature measurement. The mA output range shall correspond to -20 °C to +140 °C. Accuracy shall be 0.5% of full range or better.

3.2.3 Outputs Contacts

a) The device shall include at least seven output contacts to be used for the following:

1) Winding temperature alarm signal;

2) Oil temperature alarm signal;

3) Winding temperature trip signal;

4) Oil temperature trip signal;

5) Device/measurement unhealthy alarm indication (i.e. watchdog), and

6) Two contacts suitable for cooler control (e.g. Air Forced (fans) and Oil Forced (pumps)). These contacts shall be independently adjustable for pick up by any of the temperature inputs bar the ambient temperature input.

b) All output contacts shall be self-resetting.

c) The watchdog contact shall be of the change-over type (i.e. three terminal: Normal Open – Common – Normal Closed). The watchdog shall be opened in the event of a loss of auxiliary supply to the device, an internal device failure, or for a defective or missing temperature sensor. Where a change-over contact cannot be provided, a normal-open contact (open in the failed state) will be accepted.

d) Contacts providing alarm and trip outputs shall be rated as follows:

1)	Make and carry for 200 ms	5 A at 250 V d.c.
2)	Carry continuously	2 A at 250 V d.c
3)	Break (inductive L/R = 40 ms)	30 W or 0.2 A @ 250 V d.c

e) Contacts providing cooler fan control shall be rated as follows:

1)	Make and carry for 200 ms	30 A at 250 V a.c.
2)	Carry continuously	12 A at 250 V a.c
3)	Break (inductive L/R = 40 ms)	3000 VA or 12 A @ 250 V a.c.

3.3 Indication

a) The device shall include six on-board LEDs. The LED functions, colours and operating mode (latched or self reset) shall be as follows.

1) Device unhealthy (mimics watchdog) – Amber (Self Reset);

2) Winding temperature alarm signal – Amber (Latched);

3) Oil temperature alarm signal – Amber (Latched);

4) Winding temperature trip signal – Red (Latched); and

5) Oil temperature trip signal – Red (Latched).

6) Cooling stages – Amber (Self Reset)

b) Where different coloured LEDs are not available, Amber coloured LEDs will be accepted for all functions.

c) Latched LED indications shall be reset by pressing a suitably marked push button on the device front panel.

d) The device front panel LEDs shall be pre-labelled in the factory to a professional standard with a clear description of its function and/or a clarification of the specific colours. The labelling shall be agreed on by Eskom and the Supplier prior to supplying the first production units.

e) The device shall include a LCD screen with text size suitable to ensure that the display can be easily read, even with sunlight shining directly onto the screen.

3.4 Temperature measurement and recording

3.4.1 General

The principal function of the device shall be to perform measurements of the ambient temperature and transformer top oil temperature. The device shall use this information, together with transformer loading information (derived from a CT input) to calculate the winding “hot-spot” temperature and transformer lifetime calculations for a single transformer winding. Where possible, the device shall be extendable such that it can perform a winding “hot-spot” temperature calculation on up to three different transformer windings. The device shall include database storage for the full range of data acquired e.g. temperatures, current etc. The collected data is to be date and time stamped.

The standard device shall include one CT input for the calculation of the winding temperature of a single winding. It shall be possible to extend the standard device to accommodate an additional two CT inputs for the calculation of winding temperatures from a further two windings. Alternatively, a stand-alone device fulfilling the requirements of the standard and extended functionality shall be provided. The device shall provide a common winding temperature alarm output contact and indication LED, but independent trip contacts and indication LEDs per winding. Analogue outputs shall be provided for each winding temperature (as per Section 3.2.2).

3.4.2 Top Oil and Winding temperature measurement

a) The instrument shall be used to measure the top-oil temperature of a transformer, and shall perform winding hot-spot temperature and transformer lifetime calculations as per IEC 354. The instrument shall provide local and remote indication of the transformer top-oil and winding temperatures. A typical measurement accuracy of ±0.8 °C is expected.

b) The instrument shall record the maximum top-oil and winding hot-spot temperatures in a given time period, arranged for manual resetting via the device front panel. One alarm signalling and one tripping contact shall be provided for each function as specified in Section 3.2.3. The contacts shall be user-settable to operate at predetermined temperatures.

c) The top-oil and winding hot-spot temperature measurements shall be displayed on the default screen of the LCD display. The maximum temperatures shall be displayed on the default screen, or via a scroll function on the device front panel.

d) The top-oil and all winding hot-spot temperature alarm and trip thresholds shall be settable in the range from +50 °C to +130 °C step 1 °C. Unless otherwise specified, the default device settings as supplied to Eskom shall be:

1) Oil temperature Alarm — 95 °C

2) Oil temperature Trip — 105 °C

3) Winding temperature Alarm — 110 °C

4) Winding temperature Trip — 120 °C

e) The instrument shall include suitable hysteresis characteristics so as to avoid hunting/output contact jitter.

3.4.3 Database function

a) The device shall include mass storage of a complete database of all acquired data (temperature, currents and all Alarm and Trip statuses) with an internal memory capable of storing 6 months of half hourly data. The database shall not be lost in the event of a loss of auxiliary supply to the instrument.

b) The downloaded database shall be in a format that may be imported into Microsoft Excel (version 2002 or later), and manipulated using standard formulae (e.g. MINIMUM, MAXIMUM, Graph).

3.5 Serial communication and software

a) The device shall include the following communication features:

1) An RS232 and/or USB serial interface for local communication to a personal computer.

2) Serial interface utilising RS485 and supporting the DNP3 Level 2 networking protocol. The device shall support multidropping (i.e. an addressable port). All temperature measurements/calculations, the lifetime calculation and the status of all output contacts and LEDs shall be available via this interface. The device shall support time synchronisation via a DNP3 Master (e.g. the substation RTU).

b) The product will be provided with Microsoft Windows-based interface software. The software shall comply with the requirements of [14], Section 3.19.1.

3.6 Additional requirements

a) The device shall comply with [14] with regard to hardware and firmware changes (Section 3.2), service history (Section 3.22) and repairs (Section 3.25).

b) The supplier shall provide a minimum of a 10 year warrantee on the temperature instrument. The warranty shall include the repair of all failures due to latent defects (i.e. excluding failure due to mishandling or misuse of the equipment by Eskom or Eskom appointed representatives). Any charges associated with the repair/replacements and shipping of the defective equipment from the local supplier's office to and from the works of the overseas principal shall be for the supplier's expense.

c) The supplier shall undertake to support each instrument type for a minimum period of 15 years. Product support shall include services to repair or replace any damaged or failed device that falls outside the terms of the abovementioned warrantee. Eskom shall be liable for all costs associated with these services. Replacement devices shall preferably be of the same type, model number and firmware as the failed IED, but alternative products of substantially similar physical dimensions and terminal layouts offering the same or increased functionality shall be accepted in fulfilment of this requirement.

d) The instrument shall include provision for mounting on a top-hat-section rail of dimensions 35 mm (w) x 7.5mm (h) in accordance with IEC 60715.

e) The device enclosure shall be rated to IP53 or higher in accordance with SANS 60529.

f) A label stating the device firmware version shall be fixed to the front fascia.

g) Any internal battery requirements for the device, i.e. battery lifetime, type of battery etc. shall be stated on a label attached to the front of the device.

4. Tests

4.1 Routine tests

The following tests shall be carried out on each instrument completely assembled as in service.

4.1.1 Insulation

a) The insulation of all circuits including inputs, outputs and power supplies shall be tested for insulation resistance. This shall be not less than 20 MΩ when measured at 500 V d.c..

b) All device circuits shall withstand an applied voltage of 2 kV r.m.s. for 60 s applied in turn between each electrically independent circuit and the casing of the relay and between the separate and independent electrical circuits.

4.1.2 Alarm and trip signalling

The device shall include the facility to simulate rising oil and winding temperatures so as to force operation of the cooler start, alarm and trip contacts and their associated indication LEDs. This facility shall be used to confirm the thresholds at which the various contacts and indication LEDs operate and reset.

4.2 Type tests

One relay of each make, size and type shall, after routine testing, be subjected to the following tests (unless acceptable certificates of previous tests on identical relays are available).

1.1.1 International standard tests

The device/s shall comply with the type tests as indicated in the Table 1 below.

Table 1: International standard type test requirements

Item	Test	Standard	Test Level	Compliance Criteria
Auxiliary power supply				
1	Operating range		-	88V d.c. to 265V d.c.
2	Interruption	IEC 60255-11	-	For supply interruptions lasting less than 10ms, the device shall function as if no interruption had occurred.
3	A.C. ripple	IEC60255-11	-	Device shall function correctly with 12% 100Hz a.c. signal superimposed on the d.c. supply.
Power frequency magnetic field				
4	Steady State	SANS 61000-4-8	Class 5	100A/m continuous, 1000A/m short duration, 50Hz
5	Pulsed	SANS 61000-4-9	Class 5	1000A/m (6.4/16□s wave shape)
6	Damped Oscillatory	SANS 61000-4-10	Class 5	100A/m, 100kHz and 1MHz

Item	Test	Standard	Test Level	Compliance Criteria
Insulation resistance				
7	Dielectric withstand	IEC 60255-5	-	2kV r.m.s 50Hz for 1 minute between all terminals to case earth
8	Insulation resistance	IEC 60255-5	-	Insulation resistance greater than 20M□ when measured at 500V d.c.
Environmental tests				
9	Cold	IEC 60068-2-1	-10°C or less	Operates within tolerance at -10°C (LCD screen operative)
10	Dry Heat	IEC 60068-2-2	+55°C or more	Operates within tolerance at +55°C
11	Cyclic Temperature and Humidity	IEC 60068-2-30	Test Db	25°C and 95% relative humidity/ 55°C and 95% relative humidity, 12 + 12 hour cycle, 6 cycles
12	Enclosure protection	SANS 60529	IP53	Protected against ingress of dust particles, spraying water
Mechanical tests				
13	Vibration	IEC 60255-21-1	Class 2 (response and endurance)	Response: 1g, 10 - 150Hz, 1 sweep energised. Contacts should not close for longer than 2ms. Endurance: 2g 10 – 150Hz, 20 sweeps, unenergised contacts should not close for longer than 2ms.
14	Shock	IEC 60255-21-2	Class 1 (response and withstand)	Response: 5g, 11ms, 3 pulses in each direction, energised Withstand: 15g, 11ms, 3 pulses in each direction, unenergised
15	Bump	IEC 60255-21-2	Class 1	10g, 16ms, 1000 pulses unenergised.
Mechanical tests (Continued)				
16	Seismic	IEC 60255-21-3	Class 1	Test method A (single axis sine sweep test) 1 – 35Hz, 1 sweep.
Impulse tests				
17	Electrical impulse (1.2/50 μs)	IEC 60255-5	-	5kV 1.2/50□s waveform, 0.5J
Electromagnetic compatibility				
18	1MHz Disturbance Burst	IEC60255-22-1 or SANS 61000-4-12	Class 3	2.5kV common mode, 1kV differential mode, 2s total test duration, 6–10 bursts
19	Fast Transient	IEC 60255-22-4 or	Class A (IV)	4kV, 2.5kHz 2kV, 5kHz on Comms ports
		SANS 61000-4-4	Class 4	4kV, 5kHz (power port) 2kV, 5kHz (I/O, data & control ports)
20	Electrostatic Discharge	IEC 60255-22-2 or SANS 61000-4-2	Class 3	6kV Contact Discharge, 8kV Air Discharge
21	Surge immunity	IEC 60255-22-5 or SANS 61000-4-5	- Class 3	2kV
22	Radiated Radio Frequency EM field immunity	IEC 60255-22-3 or SANS 61000-4-3	- Class 3	10V/m, 80MHz – 1GHz

Item	Test	Standard	Test Level	Compliance Criteria
23	Conducted Radio Frequency EM field immunity	IEC 60255-22-6 or SANS 61000-4-6	- Class 3	10Vrms, 150kHz – 80MHz

4.2.1 Non-standard tests

In addition to the type tests specified above, the following Eskom-specific type tests are to be conducted:

4.2.1.1 Ramping auxiliary d.c. test

This test standard has been adopted from an AREVA T&D EAI Stafford (formerly Alstom/GEC Alsthom) test[1].

This test simulates a failed station battery charger, which would result in the auxiliary voltage to the device slowly ramping down. The ramp-up section simulates the battery being recharged after discharging.

The relevant test levels are:

1min/cycle and 100min/cycle where 1 cycle is Nominal voltage – 0V – Nominal Voltage.

The pass criteria is that the device must power up cleanly and must not maloperate by either issuing a trip command or by chattering (rapidly switching off and on) when the boundary level of voltage is reached, for both the ramp down and ramp up test.

5. Marking, labeling and packaging

The device shall be packed in a high specification impact resistant corrugated cardboard box. The packaging shall be waterproof, and shall protect the contents from reasonable transport related wear and tear from the supplier's works to the end site.

6. Spares

Not applicable.

7. Authorization

This document has been seen and accepted by:

Name and surname	Designation
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Graeme Topham	SCOT Protection & Automation Study Committee Chairman

[1] Reference: AREVA Analysis and Protection of Power Systems (APPS) Course notes 7 March – 15 April 2005.

8. Revisions

Date	Rev.	Compiler	Remarks
March 2014	1	S J van Zyl	Document number changed to 240-75763120. Document reformatted on latest template. Document remains current and is republished without technical changes except that reference [14] was updated to reflect the latest version of the document.
Oct 2008	0	S J van Zyl	First issue of DSP 34-486.

9. Development team

The following people were involved in the development of this document:

- Paul Gerber Standards Implementation, Gauteng Operating Unit
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10. Acknowledgements

None.