CURRENT TRANSFORMER TESTING SWP

1. PURPOSE AND SCOPE

The purpose of this Standard Work Practice (SWP) is to standardise and prescribe the method for testing Current Transformers used for substation protection and indication systems.

The requirements for Revenue Metering applications are not included in this SWP.

2. STAFFING RESOURCES

Electrical Fitter/Mechanic and Competent Assistant with Switching and Access authorisations for the roles they are required to perform and be competent in, or instructed in, the operation of the test equipment to be used.

Required Training and Certificates

Current certification in modules contained in the Generic Field Induction applicable to the role of Transmission Electrical Fitter/ Mechanic.

3. DOCUMENTATION

CS000501F115. Daily/Task Risk Management Plan

ES000901R102. Health and Safety Risk Control Guide

SP0506 Substation Primary Plant and Secondary Systems Field Testing SWP

SP0507C01 Current Transformer Test Report

SP0507C02 Current Transformer Supplementary Test Report

SP0507C03 Current Transformer Testing Competency Assessment

SP0507C04 Current Transformer Inspection and Test Plan

SP0507R01 Current Transformer Testing Job Safety Analysis

AS 1675 – Current Transformers – Measurement and Protection.

AS 60044.1 – Instrument Transformers – Part 1: Current Transformers

Test Equipment Manual

Current Transformer Manual / Manufacturer's Drawings

4. KEY TOOLS AND EQUIPMENT

Standard PPE.

All Test Equipment shall be tested, tagged and within calibration date.

Typical equipment: Digital Voltmeter, Digital Ammeter, 200 amp clip on ammeter, 10 amp clip on ammeter, Standard CT, 240V Variac, 50 amp current source, 2KV Mag Test Transformer, Ohmmeter, Analogue Ammeter and 6 volt battery for polarity test, decade bridge or milli-ohmmeter, HV Test Set with dead man switch, Insulation Resistance Tester (minimum 5000volt), Ratiometer, Phase angle meter.

Safety Barriers.

Switching and Access Operating Equipment: PEDs, Live Line Tester, Class 0 gloves. All equipment to be inspected and confirmed within test date prior to use.

Additional PPE Required

Class 00 gloves, hearing protection, safety eyewear.

5. WORK PRACTICE STEPS

5.1 Carry out an on site risk assessment

Prior to performing this activity any hazards associated with prerequisite tasks at the worksite shall be identified and assessed with appropriate control measures implemented and documented in accordance with CS000501F115 Daily/Task Risk Management Plan and using reference document ES000901R102 Health and Safety Risk Control Guide.

If any risks cannot be managed or reduced to an acceptable level, do not proceed with the task and seek assistance from your Supervisor.

5.2 All work to be done with CT de-energised

All of the tests described in this SWP should be carried out with the CT de-energised and appropriate control measures in place (eg. barriers, matting) to prevent inadvertent contact with adjacent live plant or breaching exclusion zones. Furthermore, the P53 Operate the Network Process is applicable at all times for isolation and earthing.

Issue a Test Permit and follow the requirements of P53 Operate the Network Process.

As described in Substation Primary Plant and Secondary Systems Field Testing SWP SP0506, particular safety risks applicable to Current Transformers include:

- Contact with high voltage at CT primary connections.
- High fault current at CT primary connections.
- Open circuit CT secondary terminals.
- Unearthed CT secondary winding.
- Open DLA test terminal.

5.3 Record identification details

Manufacturer's name, manufacturer's type description and manufacturer's serial number.

Plant number.

Description, ie. post-type, bar-primary etc.

Rated voltage and insulation level.

Rated transformation ratios (multiple secondary cores).

Rated burden in ohms or VA.

Performance classification of all ratios, for example:

a) 0.5 M (Accuracy Classification 0.5, Class M)
Class M Metering CT, AS 1675

b) 0.5 ME 2 (Accuracy Classification 0.5, Class ME, Rated Accuracy Limit Factor 2)
Class ME Metering CT, AS 1675

c) 15 VA class 0.5 (Accuracy Class 0.5, Rated Output 15 VA)
Metering CT, AS 60044.1

d) 15 VA class 0.5 ext. 150% (Accuracy Class 0.5, Rated Output 15 VA, Extended Primary Current 150%)
Metering CT, AS 60044.1

e) 15 VA class 0.5 FS 10 (Accuracy Class 0.5, Rated Output 15 VA, Instrument Security Factor 10)
Metering CT, AS 60044.1

f) 10 P 150 F20 (Rated Composite Error 10%, Class P, Rated Secondary Reference Voltage 150 volts, Rated Accuracy Limit Factor 20)
Class P Protection CT, AS 1675

g) 0.05 PL 950 R3 (Maximum secondary exciting current 0.05 Amps when excited at the knee point voltage, Class PL,

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Rated Knee Point Voltage 950 volts, maximum Secondary Winding Resistance 3 ohms.
Class PL Protection CT, AS 1675

h) 30 VA class 5P 10 (Accuracy Class 5P, Rated Output 30 VA, Accuracy Limit Factor 10)
Class P Protection CT, AS 60044.1

i) 30 VA class 5PR 10 (Accuracy Class 5PR, Rated Output 30 VA, Accuracy Limit Factor 10)
Class PR Protection CT, AS 60044.1

j) 30 VA class 5PX 10 (Accuracy Class 5PX, Rated Output 30 VA, Accuracy Limit Factor 10)
Class PX Protection CT, AS 60044.1(Class PX replaces Class PL)

It is important to record the ratio at which the performance classification is stated, eg. 10 P 150 F20 at 200/5, since the performance of the CT is different at different ratios.

5.4 Visual inspection of CT condition

Inspect the CT for any sign of oil leaks both externally and in the CT secondary connection box. Confirm oil level/gas pressure is correct before testing commences.

Inspect the external surfaces and ensure the CT is clean and dry.

Check primary and secondary connections for adequate labelling. The connections should be legibly and adequately marked.

Check that the DLA test tap cover is in place (if applicable).

5.5 Measure primary and secondary winding insulation resistance

Test voltages as defined in the Maintenance Acceptance Criteria document are to be used when measuring the insulation resistance of the primary CT winding.

Insulation resistance tests as listed below are to be applied for one minute duration each:

- Primary (HV) to Secondary plus Earth. All secondaries to be connected together and earthed. It may be necessary to guard out surface leakage current with a guard located halfway down the HV insulator in order to achieve an acceptable IR value. A lower value is permitted if the CT is internal to a transformer and is being influenced by the transformer core and bushing insulation.
- Secondary to Earth @ 1kV. All secondaries to be connected together. No guard.
- Secondary to Secondary @ 1kV. Each secondary to be tested to all of the other secondaries connected together in turn. No guard.

Plant and equipment should not be commissioned unless the test result meets the C4 or C3 criteria defined in the Maintenance Acceptance Criteria document. Plant may only be commissioned at P2 level with specific approval from the Senior Commissioning Engineer. Plant may not be commissioned at a P1 level.

5.6 Check secondary winding resistance

With a high precision ohmmeter, test the resistance in the secondary core. For multiple core CTs all ratios should be tested. Be sure to record the temperature at which the measurements are carried out and the lead resistance of the measuring device. Refer to 5.8 below for comments on measuring winding resistance from

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a marshalling box or intermediate terminals rather than the CT secondary terminals.

Alternatively, use a stable DC current source (typically 100 mA) to pass current through the entire secondary winding and measure the DC voltage drop across each tap at the CT secondary terminals. From the current and voltage, calculate the winding resistance.

Note: For protection CT's the secondary resistance measurement can be checked against the resistance stated on nameplate classification.

Winding resistance measurement is carried out prior to excitation current measurement so that any residual magnetism caused by DC testing will be removed.

5.7 Check ratio and polarity

Ratio and polarity tests can be carried out using either primary current injection or secondary voltage injection. For multiple ratio CT's, tests shall be carried out on all ratios as marked on the manufacturer's nameplate.

For primary current injection, a current is applied to the primary side of the CT and corresponding secondary current measurements are made at each tapping of each core. Polarity can be checked by the use of a phase angle meter.

For secondary voltage injection, a voltage can be applied to the secondary core tapings and a corresponding voltage measured on the primary. Polarity can be checked by the use of a phase angle meter.

Alternatively, a transformer ratiometer can be used to check the transformation ratios and polarities. Note that when using a ratiometer, the voltage output leads which are normally connected to the HV of a transformer are connected to the secondary of a CT, and the measurement leads which are normally connected to the LV of a transformer are connected to the primary (HV) of a CT.

The applied test voltage may have to be varied depending on the saturation characteristics of the core so as not to overload the test equipment due to excessive magnetising current.

AS1675/AS60044.1 specifies the primary currents to be used when verifying compliance with the specified accuracy class. For metering CTs, this is up to 120/125% of the rated primary current, for protection CTs this is up to the Accuracy Limit Current.

Note that due to field test equipment limitations it will often not be possible to inject sufficient current in the CT as specified in AS1675/AS60044.1, in these cases use an injection current as high as practicable but be aware that the test results obtained are a verification of ratio only and do not demonstrate compliance with composite error designation.

The 'flick test' may be used to determine the polarity of a CT:

Caution:
Due to the likely generation of sparks as the lead is brushed to the battery positive, ensure there are no flammable substances present during this test.

a) Connect the secondary terminal 's1' to the positive terminal of an analogue meter on the DC millivolt range.

b) Connect the secondary terminal 's2' to the negative terminal of the meter.

c) Using a six volt dry cell battery, connect the negative terminal to the primary connection 'P2'.

d) Connect the HV terminal 'P1' to the battery positive terminal with a short, sharp movement while watching the meter deflection on the analogue meter - the deflection on the meter should be in the positive direction.

e) A more definite deflection will normally be seen as the battery positive terminal is dis-connected from P1 (again with a short, sharp movement) after the CT has been charged for a short time - the deflection on the meter should be in the negative direction.

5.8 Measure secondary excitation current

A sinusoidal voltage is applied to the secondary of the CT and the excitation current of the CT measured. RMS reading instruments should be used during these measurements.

Note that some instruments such as a CPC100 use "mean rectified" values for a magnetisation curve. A waveform with a high harmonic component (such as caused by a CT approaching saturation) will have a mean rectified value significantly lower than the rms value. Since AS60044-1 defines rated knee point in terms of rms voltages and currents, the CPC knee point will be lower than the actual knee point (i.e. the CT could appear to fail even though it is okay).

Note: It is preferred to apply a voltage and measure the current rather than inject a current and measure the voltage because Class P, PX and PL CT performance is referenced to voltage.

Note: All other cores are open circuited, including the primary.

Note: A step up mag curve transformer may be required to produce sufficient applied voltage.

Note: It is permissible to measure winding resistance and excitation current from the CT marshalling box or intermediate terminals rather the CT secondary terminals. Allowance needs to be made for the additional secondary wiring resistance that is introduced in this process. If the CT fails to meet performance specifications when measured from the marshalling box, then a repeat test from the CT secondary terminals must be carried out.

The voltage used to excite the CT should be applied across the entire winding of a tapped secondary. When this voltage would exceed the capability of the test equipment, a lower voltage may be applied across a portion of the winding. For example, a 400/300/1 CT of class 2.5 P 1000 F 20 at 400/1 would require in excess of 1000 volts to test, it may be more practicable to apply the excitation voltage to the 300/1 tapping which requires 75% of the voltage.

Note that the autotransformer effect would still generate 133% of the applied voltage on the 400/1 tapping; hence care must be taken not to overstress the insulation of this tapping (considered to be 2 kV maximum for 1 minute unless otherwise stated).

Prior to measuring the excitation current, increase the applied voltage from zero to a value to saturate the core (i.e. the excitation current increases significantly with only a minor change in applied voltage).

Over a period of 1 minute, reduce the applied voltage to zero, taking care to avoid any steps in the voltage as zero is approached. The excitation characteristic is measured as the voltage is decreased. Slowly reducing the voltage in this manner demagnetises the core.

The secondary excitation current is measured when 100, 75, 50, 25 and 10% of the voltage below is applied to the CT secondary winding:

$V_{applied} = VA / I_{sn} \times F$
(for metering CTs to AS1675 or AS60044.1)

or = $U_{sn} + F \times I_{sn} \times R_s$
(for class P CTs to AS1675)

or = $VA / I_{sn} \times F + F \times I_{sn} \times R_s$
(for class P and PR CTs to AS60044.1)

or = Rated Knee Point Voltage (for class PL CTs to AS1675 or class PX CTs to AS60044.1)

where: VA = Rated Burden in VA;

U_{sn} = Rated Secondary Reference Voltage;

I_{sn} = Rated Secondary Current;

F = Rated Accuracy Limit Factor;

R_s = Secondary Winding Resistance.

The secondary exciting current at 100% of the applied voltage described above should not exceed:

I_{max} = F x I_{sn} x e/100 (for metering CTs to AS1675 or AS60044.1, and class P CTs to AS1675 or AS60044.1 and class PR CTs to AS60044.1)

or = Maximum Secondary Exciting Current (for class PL CTs to AS1675 or class PX CTs to AS60044.1)

where F = Rated Accuracy Limit Factor and
I_{sn} = Rated Secondary Current and
e = Composite Error in percent

For example, a 400/5 CT of class 2.5 P 100 F 20 with 1 ohm winding resistance will have a maximum excitation current of Imax = 20 x 5 x 2.5 / 100 = 2.5 amps at 100 + (20 x 5 x 1) = 200 volts.

Similarly, a 1000/1 CT of class 0.05 PL 950 R3 will have a maximum excitation current of 50 mA at 950 volts.

A 100/5 CT of class 0.5 M 15VA would have a maximum excitation current of 5 x 0.5/100 = 25 mA when excited with 15/5 = 3 volts.

After readings have been taken, a Voltage vs. Current curve can be plotted. Note that some CTs use a combination of different types of core steel to improve performance at lower currents – this may appear as an additional non-linearity in the magnetising curve.

The knee point of the magnetising curve is defined as the point whereafter a 10% increase in voltage causes the secondary exciting current to increase by 50%.

5.9 Carry out DLA Tests

Measurement of dielectric dissipation factor (tangent delta) is not required unless specified by the client or Asset Manager. DLA testing is described in a separate SWP.

5.10 Carry out Partial Discharge Tests

Off-line partial discharge testing is required to be carried out on all current transformers in MV switchgear and all outdoor epoxy insulated current transformers.

The permissible PD level is given in the table below:

Type of earthing of the system	PD test voltage (r.m.s.) kV	Permissible PD level pC — Type of insulation: immersed in liquid	Permissible PD level pC — Type of insulation: solid
Earthed neutral system (earth fault factor ≤ 1,5)	U_m $1,2\ U_m / \sqrt{3}$	10 5	50 20
Isolated or non effectively earthed neutral system (earth fault factor > 1,5)	$1,2\ U_m$ $1,2\ U_m / \sqrt{3}$	10 5	50 20

NOTE 1 If the neutral system is not defined, the values given for isolated or non effectively earthed systems are valid.

NOTE 2 The permissible PD level is also valid for frequencies different from rated frequency.

On-line partial discharge testing is required to be carried out on all oil filled current transformers. At system voltage, there must be no partial discharge detected.

5.11 Carry out HV Testing

A CT shall withstand a power-frequency r.m.s. test voltage applied for 1 minute between the primary and all secondary terminals connected to earth.

All CTs should be subjected to the above test as part of the manufacturer's routine testing; otherwise the test must be carried out on site.

Where switchgear hv insulation is partly or wholly assembled on site (eg. installing recloser bushings), then 100% of the test voltages in the table below are to be used.

80% of the test voltages in the table below are to be used when the test is a repeat of routine testing at the manufacturer's works unless express permission is obtained from the manufacturer to use a higher voltage.

75% of the test voltages in the table below are to be used when aged or refurbished plant is tested.

The requirements of the test are satisfied if no disruptive discharge occurs.

Following the HV test, repeat the Primary to Secondary plus earth insulation resistance measurement to confirm insulation integrity.

Nominal voltage of system (Un) kV r.m.s.	Highest Voltage for equipment (Um) kV r.m.s.	Rated Short term Power-frequency withstand voltage (PFWV) KV r.m.s.
<1.1		2.5
3.3	3.6	16
6.6	7.2	20
11	12	28
22	24	50
33	36	70

Where Un > 33kV, refer to AS2650 for applicable test values.

5.12 Schedule of Tests

The table below details the circumstances in which different tests are carried out:

Test	New CT	Aged or refurbished CT
Insulation Resistance	On-site test required	On-site test required
Ratio / Polarity	Workshop or on-site test required at discretion of Commissioning Engineer*	Workshop or on-site test required
Excitation Current	On-site test required	On-site test required
Winding Resistance	Workshop or on-site test required at discretion of Commissioning Engineer*	Workshop or on-site test required
High Voltage Withstand	Workshop or on-site test required at discretion of Commissioning Engineer*	Workshop or on-site test required
PD	On-site test required	On-site test required
DLA	Only required if client or asset manager requests test.	

*otherwise review manufacturer's results only.

5.13 Measure Secondary Loop Resistance

Prior to energisation, the loop resistance of the CT secondary circuit should be measured across an open test link as close to the CT as possible. This loop includes the CT secondary winding, marshalling box wiring, cabling, panel wiring and relay /transducer/meter resistance and is only carried out for the in-service ratio. Note that backfeeds through other phases must be avoided when measuring loop resistance or an open circuit neutral could be masked – remove all three phase links then measure the loop resistance one phase at a time. Also note that if CTs are summed (eg. breaker and a half schemes) each CT loop resistance is measured with the other CTs disconnected.

5.14 Primary Injection

Primary injection is the subject of a separate SWP, however it is noted that primary injection should be carried out for any balance type protection (eg transformer differential, restricted earth fault, bus differential). Primary injection is not normally carried out for plain overcurrent/earthfault protection unless requested by the customer.

5.15 Complete pre-commissioning checklist

CTs being placed in service for the first time require that the following items are checked prior to energisation:

a) Check DLA link closed, DLA tap cover in place;

b) Check primary connections correct;

c) Check bonding connection from primary terminal to CT cap is in place if required;

d) Check gas pressure / oil level;

e) Check earth connection to CT base and marshalling box;

f) Set ratios;

g) Short and earth any unused cores at marshalling box;
h) Check that there is only a single earth on any star connections;
i) Check nameplate is in place;
j) Check that secondary circuits are continuous and correct as per AC schematic;
k) Check that all secondary terminals are tight;
l) Check that core allocation is correct, i.e. protection cores are used for protection functions.