TRANSFORMER PRIMARY INJECTION TESTING SWP

1. PURPOSE AND SCOPE

The purpose of this Standard Work Practice (SWP) is to standardise and prescribe the method for carrying out a primary injection test on a power transformer. Primary injection is used to verify:

- CT ratio;
- CT polarity;
- Secondary wiring connections;
- Transformer vector group;
- Relay ratio, polarity, star point, vector group and zero sequence compensation settings.

2. STAFFING RESOURCES

Adequate staffing resources with the competencies to safely complete the required tasks as per MN000301R165: 8 Level Field Test Competency.

These competencies can be gained from, but not limited to any or all of the following:

- Qualifying as an Electrical Fitter Mechanic
- Qualifying as a Technical Service Person
- Training in the safe use of relevant test equipment.

Requirement for all live work:

- Refer to Live Parts Safe Work Method Statement

All resources are required to:

- Have appropriate Switching and Access authorisations for the roles they are required to perform and have the ability to assess and maintain relevant exclusion zones from exposed live electrical apparatus.
- Hold current licences for any vehicles and equipment they may be required to operate.

Required Training

Staff must be current in all Regulatory Training relevant for the task.

Current certification Working Safely On or Near Electrical Network Infrastructure - 2941492.

Contractors must have completed Ergon Energy's Generic Contractor Worker Induction.

3. DOCUMENTATION

AS2374.1.2 – Power transformers - Minimum Energy Performance Standard (MEPS) requirements for distribution transformers.

AS2374.3.0 – Power transformers - Insulation levels and dielectric tests - General requirements.

Electrical Safety Rules 2022 - 6503074

HazChat - On-Site Hazard Assessment

P53 Operate the Network Enterprise Process

SP0506 Substation Primary Plant and Secondary Systems Field Testing SWP

SP0507 Current Transformer Testing

SP0508 Voltage Transformer Testing

SP0511C03 Test Tool - Primary Injection

Test Equipment Manuals.

Transformer Manual / Manufacturer’s Drawings.

4. KEY TOOLS AND EQUIPMENT

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

Additional PPE as required: Leather work gloves, class 00 gloves, hearing protection, safety eyewear. All PPE to be inspected and confirmed within test date (where applicable) prior to use.

Sun protection to be used when working outdoors.

Safety barriers and warning signs. Insulating mats.

High current injection leads and isolation switch.

HV leads, LV leads and non-conductive string.

Generator, capacitor units, variac, multi-tap transformer.

Shorting leads capable of carrying anticipated current.

Multimeters, including flexible tong for primary current measurement and mA tong for secondary current measurement.

5. TASK 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 HazChat on-site risk assessment.

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

All of the tests described in this SWP should be carried out with the transformer 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 Electrical Safety Rules 2022 - 6503074 is applicable at all times for isolation and earthing.

Issue a Test Permit and follow the requirements of Electrical Safety Rules 2022 - 6503074.

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

- Contact with high voltage at the transformer primary connections.
- High fault current at the transformer primary connections.
- Unearthed CT and VT secondary winding. Refer to SWP SP0507 and SP0508 for more information associated with current transformers and voltage transformers respectively.
- Open circuit CT secondary terminals.
- Open DLA test terminal on transformer bushing.
- Induced voltages and currents from nearby energised / loaded plant.
- Stored energy in capacitors.
- Working at height hazards.

5.2. Preliminary steps

Use spreadsheets Test Tool – Primary Injection to calculate the voltage required and series capacitors required to obtain sufficient injection current. All electronic relays have a threshold current below which it is impossible to verify correct operation. This threshold current varies between relay types and current ratings, however generally 50 mA secondary current is the lowest value at which accurate results can be obtained. 10 mA is considered the

lowest value at which any meaningful data may be obtained, given that noise will generally be 1 mA or more.

Identify transformer to be tested.

In a substation, ensure the transformer to be tested is de-energised, tested and proved dead and earthed. Erect safety barriers and warning signs and issue Test Permit if applicable. In workshops, testing should be within designated test bays or barricaded and warning signed test areas.

5.3. Isolate protection

During the primary injection, sufficient current may be injected to cause protection to operate. This protection may be related to the transformer protection scheme under test (for example transformer differential protection) or it may be another protection scheme that is unrelated to the scheme under test but uses CT's that will see current during the primary injection (for example bus differential protection). Any such protection should be isolated using an isolation sheet.

5.4. Isolate/short CT secondaries not required for test

In some cases, it may be necessary to pass current through CT cores that are not required for the scheme under test – for example high impedance bus differential protection. In this case it is not appropriate just to short the CT secondaries since this would disable the protection, instead the CT core must be isolated from the scheme for the duration of the primary injection and reinstated afterwards. On load tests should be completed after the CT is re-connected to ensure the connections are correct. Any such temporary works should be completed using an isolation sheet.

All CT's that will have primary current passing through them must have a continuous secondary circuit. For new work being commissioned, this is verified by measuring the secondary circuit loop resistance as described in SP0507.

5.5. Connect primary injection source and apply short circuit

Use the Test Tool to determine the appropriate connection for the injection source (ie phase to phase or phase to neutral) and the short circuit (ie phase to phase or phase to neutral). These connections have been determined to ensure that positive and zero sequence connections are verified.

Connect the injection source to the transformer via a suitably rated isolating switch and lead. The injection source may be a station service supply or a generator.

When connecting to a transformer neutral bushing, ensure that the neutral is not connected to earth or residual current protection (safety switch) may operate. If the neutral bushing is earthed, the injected current may find multiple parallel paths back to the source.

CAUTION: Ensure that the isolating switch is rated to break capacitive/inductive current particularly if series capacitors are used. An under-rated switch may have contacts welded closed during an opening operation. If possible arrange the primary injection leads so the load current can be broken with one of the primary plant HV CBs.

A suitably rated variac may be used to give control of the injection current. Alternatively, a multi ratio step up transformer may be used to control the injection current.

If series capacitors are used, ensure that they are rated for the voltage rise that will occur during testing. Some capacitors (eg single bushing capacitors) need to be insulated from earth, for example on an insulated mat.

CAUTION: Series capacitors are used to cancel out some of

the inductive reactance of the transformer under test and may give rise to high voltages.

Example 1 – no capacitors.

A 240 volt source injecting into a 100 ohm transformer gives 2.4 amps injection current.

Example 2 – 35 uF (90 ohm) capacitors.

The net impedance is now 100 – 90 = 10 ohms, with a resultant current of 240 / 10 = 24 amps. The voltage seen at the transformer terminals is however 24 x 100 = **2400 V**.

The voltage across the capacitor is 24 x 90 = 2160 V.

Refer to Test Tool – Primary Injection for calculated voltages.

CAUTION: The associated voltages will also be induced on the test leads including phase to phase voltages for 3 phase testings. Use appropriately rated test leads or ensure that sufficient air clearance is maintained between leads and other phases/earth using non-conductive string or similar.

The dielectric strength of air is 3kV/mm but the applied clearance should be such that it accounts for any movement in the leads during test for wind or other weather conditions. As a minimum, apply standard 11kV clearances, eg 160mm ph-g and 185mm ph-ph, if the test voltage is under 11kV.

CAUTION: Ensure any capacitors are discharged before contact.

The conductor used for shorting one winding of the transformer must be suitably rated for the anticipated current. The following ratings can be used for copper stranded insulated conductor.

Conductor Size (mm^2)	Rating (Amps)
2.5	27
4	36
6	46
10	62
25	110
35	140
70	230
95	280

5.6. Carry out primary injection

It is preferable to slowly increase the injection current from zero using a variac until the target current is reached. This is to avoid undue stress on equipment if the injection current is higher than anticipated.

Nominal tap of the transformer should be used for all injections, unless resonance problems as described below cause excessive current on nominal tap. In this case, use a tap as close to nominal as possible.

For each configuration in the Test Tool in turn, apply the injection voltage and confirm:

- Correct primary currents in the transformer windings using a hot tong, flexible tong or similar.
- Correct secondary currents in all CT's using a mA tong or similar.
- Correct primary and secondary metered values in all protection relays, SCADA and metering.

CAUTION: Earthing transformers often have low continuous current ratings. Ensure that this rating is not exceeded during the primary injection.

Note that if series capacitors are used and the capacitive reactance is very close in value to the inductive reactance of the transformer, then the injection current will change significantly as the transformer tap changes due to change in the transformer reactance. Always commence the injection on a tap position to minimise the current and change taps one step at a time until the target current is reached.

When testing the balance of high impedance transformer differential schemes, note that a high impedance scheme, if not balanced, can cause CT secondary measurements to look inaccurate. Similarly, you can expect a few mA to disappear exciting any idle CT's in high impedance schemes.

CAUTION: If a high impedance scheme is not balanced the out of balance current will flow through the differential relay. This relay will probably not be rated for continuous application of this current. It is therefore necessary to short/isolate the relay prior to commencing injection.

The impedance of some multimeters when on a low current range can significantly alter the current in a CT secondary circuit. It is preferred therefore to use a higher range (ie “Amps” not “mA”) so that accurate readings are obtained albeit at a lower resolution. A clip on mA tong can provide better accuracy in some situations.

It is necessary to prove any “balance” type scheme such as differential or restricted earth fault in both the balanced and unbalanced state. This is because a zero reading in the balanced state may be due to a wiring or application error, not a true balanced condition. It may be necessary to temporarily reverse or short out CT secondaries or disconnect them from the circuit in order to simulate the unbalanced state. Always check (by measurements) that any temporary connection has been properly reversed afterwards. Normally a better result is obtained by reversing the CT connections, since this will give twice the “operate” current compared to the “restrain” current.

Record all measurements in the Test Tool form. Use a separate form for each test configuration. There is no need to repeat similar measurements between tests – for example when completing test “1a” only record the measurements that have changed from test “1”.

5.7. Return plant to normal on completion of tests

Disconnect and remove all injection equipment.

Check all CT secondary connections are left in the correct state.

Reverse any isolation sheets.

Reverse HV isolation.