

Document No: SMI 103

Amendment No: 8

## Substation Maintenance Instruction

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# Testing of in-service insulating oil

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## Substation Maintenance Instruction

### PRIMARY SYSTEMS

|               |   |            |
|---------------|---|------------|
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### SMI 103      TESTING OF IN-SERVICE INSULATING OIL

#### CONTENTS

|            |                                                                                      |           |
|------------|--------------------------------------------------------------------------------------|-----------|
| <b>1.0</b> | <b>PURPOSE.....</b>                                                                  | <b>3</b>  |
| <b>2.0</b> | <b>SCOPE .....</b>                                                                   | <b>3</b>  |
| <b>3.0</b> | <b>REFERENCES.....</b>                                                               | <b>3</b>  |
| <b>4.0</b> | <b>DEFINITIONS AND ABBREVIATIONS.....</b>                                            | <b>4</b>  |
| <b>5.0</b> | <b>ACTIONS.....</b>                                                                  | <b>5</b>  |
| <b>5.1</b> | <b>General .....</b>                                                                 | <b>5</b>  |
| <b>5.2</b> | <b>Oil tests .....</b>                                                               | <b>5</b>  |
| <b>5.3</b> | <b>Power transformers.....</b>                                                       | <b>5</b>  |
| 5.3.1      | <i>Oil quality tests .....</i>                                                       | 6         |
| 5.3.2      | <i>Dissolved gas analysis (DGA) tests .....</i>                                      | 7         |
| 5.3.3      | <i>Furans tests.....</i>                                                             | 9         |
| <b>5.4</b> | <b>Instrument transformers .....</b>                                                 | <b>9</b>  |
| 5.4.1      | <i>Oil quality tests .....</i>                                                       | 9         |
| 5.4.2      | <i>Dissolved gas analysis tests .....</i>                                            | 10        |
| <b>5.5</b> | <b>All other transformers .....</b>                                                  | <b>10</b> |
| 5.5.1      | <i>Oil quality tests .....</i>                                                       | 10        |
| 5.5.2      | <i>Dissolved gas analysis tests .....</i>                                            | 11        |
| <b>5.6</b> | <b>Oil sampling .....</b>                                                            | <b>11</b> |
| <b>6.0</b> | <b>AUTHORITIES AND RESPONSIBILITIES.....</b>                                         | <b>11</b> |
| <b>7.0</b> | <b>DOCUMENT CONTROL .....</b>                                                        | <b>12</b> |
|            | <b>Annexure 1: Transformer categorisation based on tap changer arrangement .....</b> | <b>13</b> |
|            | <b>Annexure 2: Report format.....</b>                                                | <b>14</b> |
|            | <b>Annexure 3: Process of DGA analysis .....</b>                                     | <b>15</b> |

## 1.0 PURPOSE

To set out the minimum requirements for testing of insulating oil within equipment that has been in service for a minimum period of two (2) weeks after initial commissioning.

## 2.0 SCOPE

This instruction defines the minimum routine maintenance requirements for testing of insulating oil in equipment that has been in-service.

This instruction is to be read in conjunction with Substation Maintenance Instruction SMI 100 – Minimum requirements for maintenance of transmission and zone substation equipment.

**Note:** Insulating oil in new equipment that has not been in-service is not covered in this instruction. In special circumstances, the Network Substations Manager may seek additional tests.

## 3.0 REFERENCES

Board Policy (Health and Safety) 3.0 – Work Health and Safety  
 Board Policy (Environment) 4.0 – Environment  
 Company Policy (Network) 9.9.1 – Network Asset Maintenance  
 Company Procedure (Environment) GPE 0009 – Contaminated land project management  
 Company Procedure (Environment) GPE 0069 – Polychlorinated biphenyl management  
 Company Procedure (Environment) GPE 0075 – Storage, handling and transport of oil and oil-filled equipment  
 Company Procedure (Health & Safety) GSY 0003 – Hazardous manual tasks  
 Company Procedure (Health & Safety) GSY 1066 – Worksite Hazard and Risk Assessment  
 Division Procedure (Network) GNV 1093.1 – Oil Laboratory Processes: Testing of insulating oil  
 Division Procedure (Network) GNV 1093.3 – Oil Laboratory Processes: Sampling of insulating oil  
 Branch Form (Regional) FRG 1924 – Insulating Oil Test Report (Chemical Electrical)  
 Environmental Management Standard EMS 008 - Environmental incident response and management  
 Environmental Management Standard EMS 007 – Waste management  
 Equipment Technical Specification ETS 0029 – Regenerated mineral insulating oil  
 Substation Maintenance Instruction SMI 100 – Minimum requirements for maintenance of transmission and zone substation equipment  
 Substation Maintenance Instruction SMI 101 – Minimum requirements for maintenance of distribution equipment  
 Electrical Safety Rules  
 Network Management Plan December - 2013 Review  
*Electricity Supply Act 1995 (as amended)*  
*Work Health and Safety Act 2011*  
*Work Health and Safety Regulation 2011*  
 AS 1767.1:1999 – Insulating liquids – Specification for unused mineral insulating oils  
 AS 1883: 1992 – Guide to Maintenance and supervision of insulating oils in service  
 AS 1767.2.3:1999 – Test methods of sampling dielectrics  
 IEC 61620:1998 – Insulating liquids – Determination of the dielectric dissipation factor by measurement of the conductance and capacitance – Test method  
 IEC 60156:1995 – Insulating liquids – Determination of the breakdown voltage at power frequency – Test method  
 IEC 60247:2004 – Insulating liquids – Measurement of relative permittivity, dielectric dissipation factor and dc resistivity  
 IEC 60422:2013 – Mineral insulating oils in electrical equipment – Supervision and maintenance guidance  
 IEC 60567:2011 Oil-filled electrical equipment – Sampling of gases and analysis of free and dissolved gases – Guidance

IEC 60599:2007 – Guide to the interpretation of dissolved and free gases analysis

IEC 60814:1997 – Insulating liquids – Oil impregnated paper and pressboard – Determination of water by automatic coulometric Karl Fischer titration

IEEE Std C57.106:2006 – IEEE guide for Acceptance and Maintenance of Insulating oil in equipment

ENA National Electricity Network Safety Code (Doc 01-2008)

#### 4.0 DEFINITIONS AND ABBREVIATIONS

##### **Autotransformer**

A distribution transformer in which at least two windings have a common part

##### **CT**

Current transformer

##### **Communicating OLTC**

Some oil and/or gas communication (including leaking) is possible between the OLTC compartment and the main tank or between the respective conservators.

##### **DDF**

Dielectric dissipation factor

##### **DGA**

Dissolved gas analysis

##### **Ellipse**

company's asset database

##### **Furans testing**

Analysis to determine the condition of paper insulation

##### **In service**

Equipment that has been on load for a period of at least two (2) weeks after initial commissioning.

##### **Non-communicating OLTC**

No oil and/or gas communication is possible between the OLTC compartment and the main tank or between the respective conservators.

##### **PCB**

polychlorinated biphenyls

##### **Power transformer**

A transformer used in a transmission or zone substation.

##### **PPM**

Parts per million

##### **Regulating transformer**

A transformer used to adjust the voltage (or phase angle) within specified limits.

##### **VT**

Voltage transformer

## 5.0 ACTIONS

### 5.1 General

Monitoring and maintaining oil quality of in-service equipment is essential for the reliable operation of oil-filled electrical equipment. If a certain amount of oil deterioration (by degradation or contamination) is exceeded, there is a higher risk of failure in the equipment.

The main purpose of testing in-service oil is to use it as a monitoring tool to assess the condition of the equipment. Additionally, dissolved gas analysis (DGA) and furans tests on power transformer oil are also used as a diagnostic tool.

Power transformers are the only assets that require oil testing on a regular basis. Oil in all other equipment is only tested under special circumstances.

The oil test limits for the equipment are presented in this document as a guide only. Specific asset management strategies for each item of equipment will dictate the action to be taken when limits are exceeded. Polychlorinated biphenyl (PCB) tests are conducted only on request and must be recorded in Ellipse.

Sampling and testing of insulating oil is specialist work and requires special equipment. Oil sampling and testing is to be carried out by suitably qualified, trained and authorised employees. All the test results, including test equipment print outs and manual records, must be maintained for future reference.

Power transformer oil test results must be recorded in the MS Access database at G:\Oildata\Transformers Oil Database and a hard copy of test results must be maintained. All other oil test results must be recorded in the following network drive: G:\Oildata. Test results for other equipment must be recorded on the latest available Branch Form (Regional) FRG 1924 – Insulating Oil Test Report (Chemical Electrical) in a manner that complies with the report contents as specified in section 5.3. Where oil is tested in an external laboratory (such as PCB, inhibitors, passivator and particle count), the test results must be maintained for future reference.

### 5.2 Oil tests

The frequency of routine oil tests is stipulated in Substation Maintenance Instruction SMI 100 – Minimum requirements for maintenance of transmission and zone substation equipment. Oil samples must be tested within 10 days of sampling. If this requirement is not met, the oil-testing technologist must notify the respective Regional Operations Manager and seek new samples. Oil testing must be done in accordance with Division Procedure (Network) GNV 1093.1 – Oil Laboratory Processes: Testing of insulating oil.

### 5.3 Power transformers

The oil quality, DGA and furan tests are carried out on power transformers. The acceptable limits are based on:

- AS 1883: 1992 – Guide to Maintenance and supervision of insulating oils in service;
- IEC 60422:2013 – Mineral insulating oils in electrical equipment – Supervision and maintenance guidance;
- IEEE Std C57.106:2006 – IEEE guide for Acceptance and Maintenance of Insulating oil in equipment; and
- industry practice.

Primary Systems will analyse the oil test results for power transformers as soon as results are made available. Action to be taken in each instance will be based on the transformer life management strategy for that location.

Tap changer oil will **not** be tested under normal conditions. However, under certain circumstances, it may be necessary to test the condition of tap changer oil. In these instances Primary Systems will specify the tests required and assess the results.

### 5.3.1 Oil quality tests

The following tests will be carried out routinely to determine whether the condition of the oil is adequate for continued operation and to suggest the type of corrective action required, where applicable.

**Table 1: Power Transformer –Oil quality (Application and interpretation of tests)**

| Test description                                                                                                                                                                                    |                                                                | Operating voltage | Limit                                                   | Test method                |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------|-------------------|---------------------------------------------------------|----------------------------|
| <b>Colour classification</b>                                                                                                                                                                        |                                                                | All               | <3<br>(colour code)                                     | ISO 2049/<br>ASTM D1500    |
| <b>Breakdown voltage (kV)</b>                                                                                                                                                                       |                                                                | 132kV             | >50                                                     | IEC 60156                  |
|                                                                                                                                                                                                     |                                                                | 66kV and below    | >40                                                     |                            |
| <b>Moisture content</b>                                                                                                                                                                             | <b>Moisture at 20 °C (ppm)</b>                                 | 132kV             | <15                                                     | ASTM D1533<br>/IEC 60814   |
|                                                                                                                                                                                                     | 1.1.1 Oil sample temp $\geq 20^{\circ}\text{C}$<br>See note #1 | 66kV and below    | <25                                                     |                            |
| <b>Dielectric dissipation factor at 90 °C</b>                                                                                                                                                       |                                                                | All               | <0.04                                                   | IEC 60247                  |
| <b>Conductivity (pS/m) at 20 °C</b>                                                                                                                                                                 |                                                                | All               | < 15                                                    | IEC 61620                  |
| <b>Acidity – neutralisation value (mg KOH/g)</b>                                                                                                                                                    |                                                                | All               | < 0.1                                                   | IEC 62021-1<br>IEC 62021-2 |
| <b>Interfacial tension (mN/m)</b>                                                                                                                                                                   |                                                                | All               | > 18                                                    | ASTM D971                  |
| <b>Inhibitor</b> for inhibited oil (Wt%) <sup>1</sup><br><i>This test is carried out only on transformers that have inhibitors in the oil</i>                                                       |                                                                | All               | 0.1% to 0.3%                                            | IEC 60666                  |
| <b>Metal passivator</b> for oil containing metal passivator <sup>1</sup><br><i>This test is carried out only on transformers that have passivator in the oil, which will be notified by Manager</i> |                                                                | All               | > 50 mg/ kg and not decreasing at rate of 10 mg/kg/year | IEC 60666-Annexure B       |

<sup>1</sup> The newly commissioned transformer will be tested annually for inhibitor (for inhibited oil) and passivator (for oil containing metal passivator), until warranty period expires. After warranty period the frequency of these tests will be as per SMI 100.

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |  |  |  |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--|--|
| Substations, Primary systems                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |  |  |  |
| <p><b>Notes:</b> Measured moisture content (ppm) will be reported with the oil sample temperature.</p> <p>#1 Oil samples are to be taken at temperature <math>\geq 20^{\circ}\text{C}</math>. If the oil sample temperature (at the time of sampling) is above <math>20^{\circ}\text{C}</math>, the following correction formula from IEC 60422 will be used to calculate the corrected moisture content at <math>20^{\circ}\text{C}</math>.</p> $\text{Corrected moisture content} = \text{Measured water content} \times 2.24 e^{(-0.04 \times \text{oil sample temp})}$ |  |  |  |

### 5.3.2 Dissolved gas analysis (DGA) tests

DGA tests are performed to determine the dissolved gas components in oil filled in-service power transformers in order to detect and evaluate faults. Certain combinations and quantities of generated gases are frequently the first indication of a possible malfunction that may eventually lead to failure if not corrected.

The accumulation of gases within a power transformer depends, to some extent, on the location and sealing arrangement between the tap changer compartment and the transformer main tank. The transformer can be placed into three categories as described in Annexure 1 – Transformer categorisation based on tap changer arrangement.

The following nine (9) dissolved gases will be measured:

- Hydrogen  $\text{H}_2$ ;
- Methane  $\text{CH}_4$ ;
- Carbon monoxide  $\text{CO}$ ;
- Carbon dioxide  $\text{CO}_2$ ;
- Ethylene  $\text{C}_2\text{H}_4$ ;
- Ethane  $\text{C}_2\text{H}_6$ ;
- Acetylene  $\text{C}_2\text{H}_2$ ;
- Oxygen  $\text{O}_2$ ; and
- Nitrogen  $\text{N}_2$ .

The dissolved gas analysis of power transformers will be based on:

- trends in the accumulation of gases;
- rate of increase in gases;
- transformer category;
- load conditions;
- recent faults on the system;
- moisture levels;
- gas ratios;
- relationships between gases;
- confirmation indicators; and
- transformer temperature.

The process of DGA analysis specified in Annexure 3 – Process of DGA analysis along with the limits for the typical values of gas concentrations and limits for their rate of increase are presented in Table 2 and 3 respectively. This process will be utilised by Primary Systems to analyse the dissolved gases to identify the potential problems with power transformer and advice on a management strategy for each identified problem.

**Table 2: Power Transformer –Typical values of gas concentrations (DGA limits)<sup>2</sup>**

| Dissolved gases: Typical Values<br>Test method ASTM D3612-02 |                               | Non-communicating<br>OLTC Limit (ppm)<br>(TX ≤ 10 years old ) | Communicating OLTC<br>Limit (ppm)<br>(TX > 10 years old <sup>3</sup> ) |
|--------------------------------------------------------------|-------------------------------|---------------------------------------------------------------|------------------------------------------------------------------------|
| Hydrogen                                                     | H <sub>2</sub>                | 50                                                            | 100                                                                    |
| Methane                                                      | CH <sub>4</sub>               | 10                                                            | 25                                                                     |
| Carbon monoxide                                              | CO                            | 500                                                           | 600                                                                    |
| Carbon dioxide                                               | CO <sub>2</sub>               | 1350                                                          | 6800                                                                   |
| Ethylene                                                     | C <sub>2</sub> H <sub>4</sub> | 5                                                             | 75                                                                     |
| Ethane                                                       | C <sub>2</sub> H <sub>6</sub> | 20                                                            | 20                                                                     |
| Acetylene                                                    | C <sub>2</sub> H <sub>2</sub> | 2                                                             | 200                                                                    |

**Note:** Normally CO<sub>2</sub>/CO ratio is more than 3. When CO<sub>2</sub>/CO ratio is <3, excessive paper degradation is suspected. A Furanic compounds analysis in accordance with Table 5 may be required.

**Table 3: Power Transformer –Typical Rate of increase of gas concentrations<sup>2</sup>**

| 1.1.2 Rate of increase of<br>dissolved gases:<br>Test method ASTM D3612-02 |                               | Non-communicating<br>OLTC Limit<br>(ppm/year)<br>(TX ≤ 10 years old ) | Communicating OLTC<br>Limit (ppm/year)<br>(TX > 10 years old <sup>3</sup> ) |
|----------------------------------------------------------------------------|-------------------------------|-----------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Hydrogen                                                                   | H <sub>2</sub>                | 40                                                                    | 50                                                                          |
| Methane                                                                    | CH <sub>4</sub>               | 5                                                                     | 10                                                                          |
| Carbon monoxide                                                            | CO                            | 140                                                                   | 200                                                                         |
| Carbon dioxide                                                             | CO <sub>2</sub>               | 500                                                                   | 2350                                                                        |
| Ethylene                                                                   | C <sub>2</sub> H <sub>4</sub> | 2                                                                     | 22                                                                          |
| Ethane                                                                     | C <sub>2</sub> H <sub>6</sub> | 8                                                                     | 6                                                                           |
| Acetylene                                                                  | C <sub>2</sub> H <sub>2</sub> | 1                                                                     | 50                                                                          |

<sup>2</sup> The typical gas concentration values and typical rate of increase of gas concentration values are the 90th percentile of gas concentration and rate of increase of gas concentration values respectively from the past DGA test data in company's transformer oil database. These 90th percentile values are recommended by Cigre (reference TB -296) for the thresholds of determining the possible fault in transformer (in-service).

<sup>3</sup> Statistically, company's transformers greater than 10 years old from the date of commissioning have oil/gas leaking between the OLTC compartment and main tank.

### 5.3.3 Furans tests

Furans' testing is used as a condition assessment tool for solid paper insulation of power transformer. The furans analysis may also be used to estimate life of power transformer.

|              | Test method           |
|--------------|-----------------------|
| Total Furans | ASTM D 5837/IEC 61198 |

The following five (5) main derivatives of furans and total furans will be measured as shown in Table 5:

**Table 5: Power Transformer -furan analysis**

| Furanic compound              | Description                                                                                            |
|-------------------------------|--------------------------------------------------------------------------------------------------------|
| 2-furaldehyde                 | Indicates general overheating of cellulose (or may be present as the result of a past fault condition) |
| 2-furyl alcohol               | Indicates high moisture in the solid insulation                                                        |
| 5-hydroxymethyl-2-furaldehyde | Indicates oxidation of the solid insulation                                                            |
| 2-acetyl furan                | Indicates high electrical stress, for example lightning strike.                                        |
| 5-methyl-2-furaldehyde        | Indicates excessive localised overheating (hot spot)                                                   |

In special circumstances, the Network Maintenance Manager may seek additional tests.

## 5.4 Instrument transformers

The in-service oil of instrument transformers is not tested regularly. The in-service oil in some instrument transformers will be tested for diagnostic purposes. The following oil quality tests and the limits are specified as a guide for assessment of the oil and the equipment, where required.

### 5.4.1 Oil quality tests

**Table 6: Instrument Transformers –oil quality (Application and interpretation of tests)**

| Test description                       |                                                                   | Operating voltage | Limit                | Test method              |
|----------------------------------------|-------------------------------------------------------------------|-------------------|----------------------|--------------------------|
| Colour classification                  |                                                                   | All               | < 3<br>(colour code) | ISO 2049/<br>ASTM D1500  |
| Breakdown voltage (kV)                 |                                                                   | 132kV             | > 50                 | IEC 60156                |
|                                        |                                                                   | 66kV and below    | > 40                 |                          |
| Moisture content                       | Moisture at 20 °C-(ppm)<br>Oil sample temp ≥ 20 °C<br>See note #3 | All               | < 15                 | ASTM D1533<br>/IEC 60814 |
| Dielectric dissipation factor at 90 °C |                                                                   | All               | <0.04                | IEC 60247                |
| Conductivity (pS/m) at 20 °C           |                                                                   | All               | < 15                 | IEC 61620                |
| Acidity – neutralisation value         |                                                                   | All               | < 0.2                | IEC 62021-1              |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |  |  |             |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--|-------------|
| (mg KOH/g)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |  |  | IEC 62021-2 |
| <p><b>Notes:</b> Measured moisture content (ppm) will be reported with the oil sample temperature.</p> <p><b>#3</b> Oil samples are to be taken at temperature <math>\geq 20^{\circ}\text{C}</math>. If the oil sample temperature (at the time of sampling) is above <math>20^{\circ}\text{C}</math>, the following correction formula from IEC 60422 will be used to calculate the corrected moisture content at <math>20^{\circ}\text{C}</math>.</p> $\text{Corrected moisture content} = \text{Measured water content} \times 2.24 e^{(-0.04 \times \text{oil sample temp})}$ |  |  |             |

#### 5.4.2 Dissolved gas analysis tests

Dissolved gas analysis for CTs or VTs may be carried out only if it is suspected to be faulty, for example, type faults, oil leaks, and unusual noise. In such cases, testing must only be performed with the approval of the Network Maintenance Manager. Test results must be returned to the Network Maintenance Manager for assessment.

### 5.5 All other transformers

These include auxiliary transformers, auto-transformers (excluding power transformers), regulating transformers and oil filled reactors.

The in-service oil of other transformers is not tested regularly. The in-service oil in some transformers other than power transformers will be tested for diagnostic purposes. The following oil quality tests and the limits are specified as a guide for assessment of the oil and the equipment, where required. Test methods are as specified under power transformer oil quality and DGA tests (refer clauses 5.3.1 and 5.3.2 above).

#### 5.5.1 Oil quality tests

**Table 7: All Other Transformers –oil quality (Application and interpretation of tests)**

| Test description                             |                                                                           | Operating voltage | Limit               | Test method                |
|----------------------------------------------|---------------------------------------------------------------------------|-------------------|---------------------|----------------------------|
| Colour classification                        |                                                                           | All               | <3<br>(colour code) | ISO 2049/<br>ASTM D1500    |
| Breakdown voltage (kV)                       |                                                                           | 132kV             | > 50                | IEC 60156                  |
|                                              |                                                                           | 66kV and below    | > 40                |                            |
| Moisture content                             | Moisture at 20 °C- (ppm)<br><i>Oil sample temp ≥ 20 °C</i><br>See note #5 | 132kV             | < 15                | ASTM D1533<br>/IEC 60814   |
|                                              |                                                                           | 66kV and below    | < 25                |                            |
| Dielectric dissipation factor at 90 °C       |                                                                           | All               | <0.04               | IEC 60247                  |
| Conductivity (pS/m) at 20 °C                 |                                                                           | All               | < 15                | IEC 61620                  |
| Acidity – neutralisation value<br>(mg KOH/g) |                                                                           | All               | < 0.2               | IEC 62021-1<br>IEC 62021-2 |
| Interfacial tension (mN/m)                   |                                                                           | All               | > 18                | ASTM D971                  |

**Notes:** Measured moisture content (ppm) will be reported with the oil sample temperature.

**#5** Oil samples are to be taken at temperature  $\geq 20^{\circ}\text{C}$ . If the oil sample temperature (at the time of sampling) is above  $20^{\circ}\text{C}$ , the following correction formula from IEC 60422 will be used to calculate the corrected moisture content at  $20^{\circ}\text{C}$ .

$$\text{Corrected moisture content} = \text{Measured water content} \times 2.24 e^{(-0.04 \times \text{oil sample temp})}$$

### 5.5.2 Dissolved gas analysis tests

**Table 8: All Other Transformer –Typical values of gas concentrations (DGA limits)**

| Dissolved gas levels | Limit in ppm |
|----------------------|--------------|
| Hydrogen             | 50           |
| Methane              | 50           |
| Carbon monoxide      | 300          |
| Carbon dioxide       | 3000         |
| Ethylene             | 100          |
| Ethane               | 100          |
| Acetylene            | 2            |

## 5.6 Oil sampling

Sampling of oil for testing is based on:

- AS 1767.1:1999 – Insulating liquids – Specification for unused mineral insulating oils
- IEC 60567:2011 Oil-filled electrical equipment – Sampling of gases and analysis of free and dissolved gases – Guidance;
- industry practice; and
- manufacturers' recommendations.

The oil sampling must be carried by trained oil sampling technologist in accordance with the Division Procedure (Network) GNV 1093.3 – Oil Laboratory Processes: Sampling of insulating oil.

## 6.0 AUTHORITIES AND RESPONSIBILITIES

**Chief Engineer** has the authority and responsibility for approving this instruction.

**Manager Primary Systems** has the authority and responsibility for making recommendations to the Chief Engineer in respect to this instruction.

**Network Maintenance Manager** has the authority and responsibility for:

- analysing test results to identify potential problems and taking appropriate action; and
- keeping the content of this instruction up to date.

**Regional transmission managers** have the authority and responsibility for:

- confirming that company employees engaged to perform the work have appropriate qualifications;
- confirming that the testing of in-service insulating oil is carried out in accordance with this instruction; and
- maintaining records of all the test results, including test equipment print outs and manual records.

**Endeavour Energy employees and contractors** have the authority and responsibility for:

- confirming that the requirements of this instruction are met;
- working in accordance with local and statutory requirements;
- managing public safety so that it is not compromised; and
- working in accordance with Endeavour Energy's Electrical Safety Rules.

**Oil sampling technologists and contractors** have the authority and responsibility for:

- obtaining oil samples in accordance with section 5.6;
- verifying that the oil is handled, stored, disposed of and transported in accordance with Endeavour Energy procedures listed in section 3;
- delivering oil samples to Endeavour Energy's testing laboratory as soon as possible (definitely within five (5) days); and
- updating the Ellipse to indicate that an oil sample was taken and tested.

**Oil testing technologists** have the authority and responsibility for:

- testing oil samples received at the laboratory in accordance with this instruction;
- testing oil samples within ten (10) days of the sample being taken;
- verifying that the oil is handled, stored, disposed of and transported in accordance with Endeavour Energy procedures listed in section 3;
- identifying potential problems with equipment;
- entering test results into the testing laboratory database;
- issuing test reports in a prior approved format or according to annexure 2 of this instruction;
- maintaining all test records for future reference; and
- entering test results in the Ellipse database where oil is tested in an external laboratory.

## 7.0 DOCUMENT CONTROL

**Documentation Content Coordinator** : Network Maintenance Manager

**Documentation Distribution Coordinator** : Branch Process Coordinator

**Annexure 1: Transformer categorisation based on tap changer arrangement****Category 1**

The selector and diverter switches are contained in a completely separate compartment outside the transformer main tank and the transformer and tap changer have separate conservator tanks.

**Category 2**

The selector and diverter switches are located in separate compartments within the main tank of the transformer and they share the same conservator, which has a felt seal that separates the tap changer oil from the main tank.

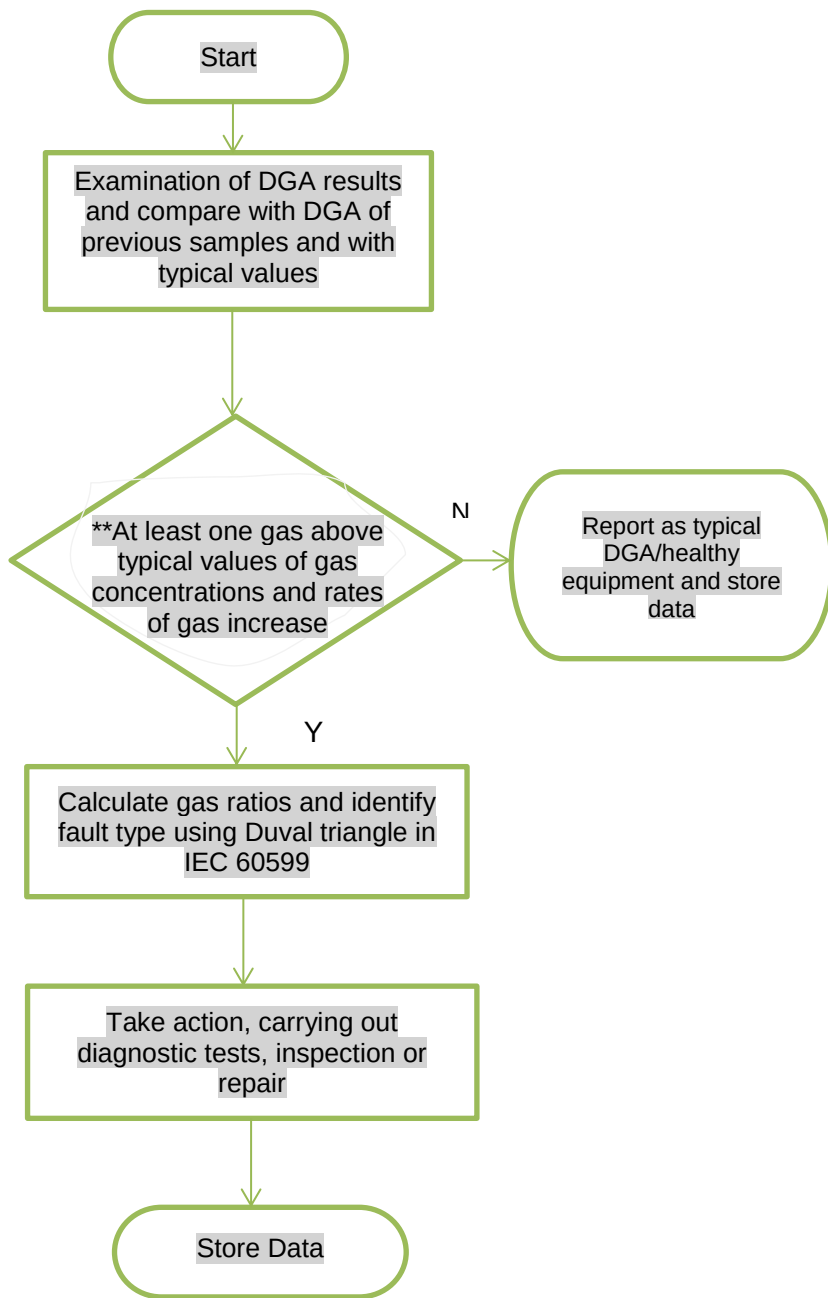
**Category 3**

The selector and diverter switches are located in separate compartments within the main tank of the transformer, but do not have a common conservator.

**Annexure 2: Report format**

The following minimum details must be required in oil test reports.

| OIL TEST RESULT                         |                     |                              |  |
|-----------------------------------------|---------------------|------------------------------|--|
| <b>ASSET DATA</b>                       |                     |                              |  |
| Location of substation                  |                     | Equipment voltage (kV)       |  |
| Equipment/Model no.                     |                     | Equipment type               |  |
| Manufacturer's serial no.               |                     | Equipment No                 |  |
| Age                                     |                     |                              |  |
| <b>SAMPLING DATA</b>                    |                     |                              |  |
| Workplace Instruction number            |                     | Sample time                  |  |
| Sample date                             |                     | Ambient temperature (°C)     |  |
| Sample location                         |                     | Weather condition            |  |
| Sample temperature                      |                     |                              |  |
| Top oil temperature for transformers    |                     |                              |  |
| <b>OIL TEST DATA</b>                    |                     |                              |  |
| Test date                               |                     | Average oil temperature (°C) |  |
| Test log file/reference no.             |                     | Laboratory                   |  |
| <b>OIL TEST RESULTS</b>                 |                     |                              |  |
| <b>Quality tests</b>                    | <b>Tested value</b> | <b>Limit</b>                 |  |
| Colour clarification (ASTM code)        |                     |                              |  |
| Dielectric strength (kV/2.5mm)          |                     |                              |  |
| Neutralisation number (mgKOH/g)         |                     |                              |  |
| Interfacial tension (mN/m):             |                     |                              |  |
| DDF at 90 °C                            |                     |                              |  |
| Conductivity pS/m                       |                     |                              |  |
| Moisture (ppm)                          |                     |                              |  |
| <b>Dissolved gas analysis (ppm)</b>     |                     |                              |  |
| Hydrogen H <sub>2</sub>                 |                     |                              |  |
| Oxygen O <sub>2</sub>                   |                     |                              |  |
| Nitrogen N <sub>2</sub>                 |                     |                              |  |
| Methane CH <sub>4</sub>                 |                     |                              |  |
| Carbon monoxide CO                      |                     |                              |  |
| Ethane C <sub>2</sub> H <sub>6</sub>    |                     |                              |  |
| Carbon dioxide CO <sub>2</sub>          |                     |                              |  |
| Ethylene C <sub>2</sub> H <sub>4</sub>  |                     |                              |  |
| Acetylene C <sub>2</sub> H <sub>2</sub> |                     |                              |  |
| Total combustibles CG                   |                     |                              |  |
| <b>Furan analysis (ppm)</b>             |                     |                              |  |
| 2-furaldehyde                           |                     |                              |  |
| 2-furyl alcohol                         |                     |                              |  |
| 5-hydroxymethyl-2-furaldehyde           |                     |                              |  |
| 2-acetyl furan                          |                     |                              |  |
| 5-methyl-2-furaldehyde                  |                     |                              |  |
| Total furans                            |                     |                              |  |
| <b>Comments</b>                         |                     |                              |  |

**Annexure 3: Process of DGA analysis**

| Fault Types (defined by Duval triangle in IEC 60599) |                                                                                |
|------------------------------------------------------|--------------------------------------------------------------------------------|
| PD                                                   | Partial Discharges                                                             |
| D1                                                   | Discharges of low energy                                                       |
| D2                                                   | Discharges of high energy                                                      |
| T1                                                   | Thermal fault, $t < 300\text{ }^{\circ}\text{C}$                               |
| T2                                                   | Thermal fault, $300\text{ }^{\circ}\text{C} < t < 700\text{ }^{\circ}\text{C}$ |
| T3                                                   | Thermal fault, $t > 700\text{ }^{\circ}\text{C}$                               |

**Note: \*\***In some cases the typical values of gas concentrations may not be higher than the limits, however if the trend indicates rate of gas increase is significantly rapid, the transformer will be investigated further to detect any possible fault condition (recommendation from Transformer Maintenance Guide by S.D.Myers).