Transformer Winding Resistance Test
Purpose of Testing

In the factory:

• proper manufacturing

• calculate conductor losses

  — Calculations of the $I^2R$ component of conductor losses.
  — Calculation of winding temperature at the end of a temperature test cycle.

• As a base for assessing possible damage in the field.

Measuring the resistance of the windings assures that the connections are correct and the resistance measurements indicates that there are no severe mismatches or opens.
Purpose of Testing

On site:

• evaluate possible winding damage, such as short circuits between windings or between turns,

• open circuits

• contact problems

• condition of the tap changer.
Principles of Operation

• The basic idea is to inject a DC current through the winding to be measured, and then read the voltage drop across that winding.

• Refer to formula for DC voltage across the transformer

\[ V = I \times R \]

where,
\( v_{dc} = \text{voltage across transformer winding} \)
\( I = \text{DC current through transformer winding} \)
\( R = \text{resistance of the transformer winding} \)
When We Run the Test

At Installation

- Risk of damage is significant whenever a transformer is moved
- Damage will often involve a current carrying component such as the LTC, DETC or a connector
- Serves as a verification of the manufacturers work
- Installation measurements should be filed for future reference

Routine (Scheduled) Transformer Maintenance

- To verify operating integrity and to assure reliability
When We Run the Test

At Unscheduled Maintenance/Troubleshooting

- To detect damage to the transformer.
- To determine if it is safe to re-energize.
- To determine if corrective action is necessary.
- To establish priority of corrective action.

At Internal Transformer Inspections

- Internal inspections are expensive due primarily to the cost of oil processing. When such opportunities do present themselves the inspection should be planned and thorough.
It is recommended DC resistance measurements be made on all on-load and off-load taps to detect problems and verify operating integrity of the DETC and LTC.

The winding resistance test is very useful in identifying and isolating the location of suspected problems.
Test Safety Precautions

• Ensure the test leads are securely attached to the winding's terminals.

• Do not operate any instrument control which would open the measured circuit while DC current is flowing. **DISCHARGE** the winding first.

• Do not disconnect any test leads while DC current is flowing. Ensure the winding is **DISCHARGED** first.

• When terminating the test, wait until the discharge indicator goes off before removing the current leads.
  • When testing larger transformers it may take **30 seconds or more** to discharge the winding.
Test Preparation

Selecting the Proper Current Range

- Xmfr manufacturers typically recommend that the current output selected should not exceed about 10% of the rated winding current.
  - Cause erroneous readings due to heating of the winding
  - Always choose the highest current output possible for the expected resistance value.
  - Typical ranges are 0.1-10 % of rated winding current.
Test Preparation

• The temperature of the windings shall be assumed to be the same as the temperature of the insulating liquid.

• It should not be assumed that the windings are at the same temperature as the surrounding air.

• For star connected winding, the resistance shall be measured between the line and neutral terminal.

• For delta connected windings, measurement of winding resistance shall be done between pairs of line terminals.
Test Preparation

As in delta connection the resistance of individual winding can not be measured separately, the resistance per winding shall be calculated with the following formula:

\[
\text{Resistance per winding} = 1.5 \times \text{Measured value}
\]

The resistance is measured at ambient temperature and then converted to resistance at \textit{75°C or 85°C} for all \textbf{practical purposes} of comparison with specified design values, previous results and diagnostics.

Winding Resistance at reference temperature of 75°C or 85°C

\[
R = R_m \frac{234.5 + \text{Ref. Temp}}{234.5 + \text{Meas. Temp}}
\]
Resistance calculations Delta Side

Average of the (3) Phase measurements multiplied by 9/2 or 4.5. This is the 3-phase sum resistance at the temperature the resistance was measured.

- Resistance measured: H1-H3 = 0.665, H2-H1 = 0.664, H3-H2 = 0.666 at an oil temperature of 26°C.
- The average resistance of the (3) phases is 0.665. This (0.665) multiplied by 4.5 equals 2.993. The unit is a 55/65 rise transformer, therefore to correct the resistance to the reference temperature 75°C, use the correction formula:

\[
\frac{234.5 + 75}{234.5 + 26} = 1.1881
\]

So the corrected 3-phase sum resistance is

\[
2.993 \times 1.1881 = 3.554 \text{ ohms}
\]

- Working backwards from the test report: HV position 3 resistance reported on the test report is 3.554. Determine oil temperature of transformer at time of resistance measurement (say its 26°C again).

\[
\frac{3.554}{1.1881} = 2.991
\]

\[
2.991 \div 4.5 = 0.665
\]

The measured resistance between two bushings (one phase) should be approx. 0.665 ohms.
Resistance calculations Wye Side

If measuring between L-N, then add each of the L-N measurements together. This is the 3-phase sum resistance at the measured temperature. The resistance needs to be corrected the same as for the Delta connection above.

If measuring a Wye connection L-L, then add each of the L-L measurements and divide by 2. This is the 3-phase sum resistance at the measured temperature. Correct resistance to reference temperature as above.

Measuring (L-N):
Resistance measured between X1-XO = 0.0394, X2-XO = 0.0393, X3-XO = 0.0397 at an oil temperature of 26°C. The 3-phase sum is:

\[ 0.0394 + 0.0393 + 0.0397 = 0.1184 \]

Corrected to 75°C:

\[ 0.1184 \times 1.1881 = 0.1407 \text{ ohms} \]
Resistance calculations Wye Side

Measuring (L-L):
Resistance measured between X1-X2 = 0.0782, X2-X3 = 0.0783, X3-X1 = 0.0785 at an oil temperature of 26°C. The 3-phase sum is:

\[
\frac{(0.0782 + 0.0783 + 0.0785)}{2} = 0.1175
\]

Corrected to 75°C:

\[
0.1175 \times 1.1881 = 0.1396 \text{ ohms}
\]

The 3-phase sum of the resistance between the L-N and L-L measurements are slightly different because the L-N measurement has the XO lead cable in the circuit.
Interpretation of Measurements

Measurements are evaluated by:

- Comparing to original factory measurements
- Comparing to previous field measurements
- Comparing one phase to another
- **Industry standard** (factory) permits a maximum difference of $\frac{1}{2}$ percent from average of three phase windings.
- **Field readings** may vary slightly more than this due to the many variables. If all readings are within **one percent** of each other, they are acceptable.
Interpretation of Measurements

Variation from one phase to another or inconsistent measurements can be indicative of many different problems:

- Shorted turns
- Open turns
- Defective DETC or LTC
- Poor connections (brazed or mechanical)

The winding resistance test is very useful in identifying and isolating the location of suspected problems.
Confusion Factors

Temperature change

- The DC resistance of a conductor (hence winding) will vary as its temperature changes, for copper windings 0.39 % per degree C.

A measuring error

- A wrong connection or poor connection
- A defective instrument or one requiring calibration
- An operating error
- A recording error