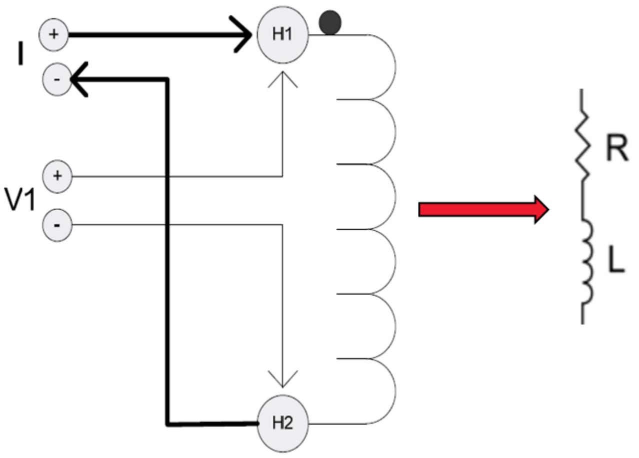
Transformer Winding Resistance Measurement

Why Measure Winding Resistance?

The measurement of winding resistance is useful in detecting a number of types of fault in a transformer.

- Malfunctioning tap changer mechanisms
- Partial or dead short-circuited turns
- Loose connections – improper crimping
- Broken strands
- Poor efficiency - I^2R component of conductor losses
- Measurement of winding temperature
- Calculate the winding temperature at the end of a heat run

Principle of Measurement



$$V = I*R + L*di/dt$$

$$R = \frac{V}{I}$$

To remove the effect of inductance (L), the change in current needs to be zero. There are two requirements to achieve this:

- Transformer core saturation, Ø = E * t (seconds)
- Current must be stable

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The larger the winding (inductance), the greater the difficulty in achieving current stabilization.

(On) Load Tap Changers

Reactive Type

The reactive LTC utilizes a reactor or preventive autotransformer to limit the circulating current when in the bridging position. They can be designed to operate at high speeds (0.3 - 0.7 seconds) or at relatively slow speeds (1 - 3 seconds).

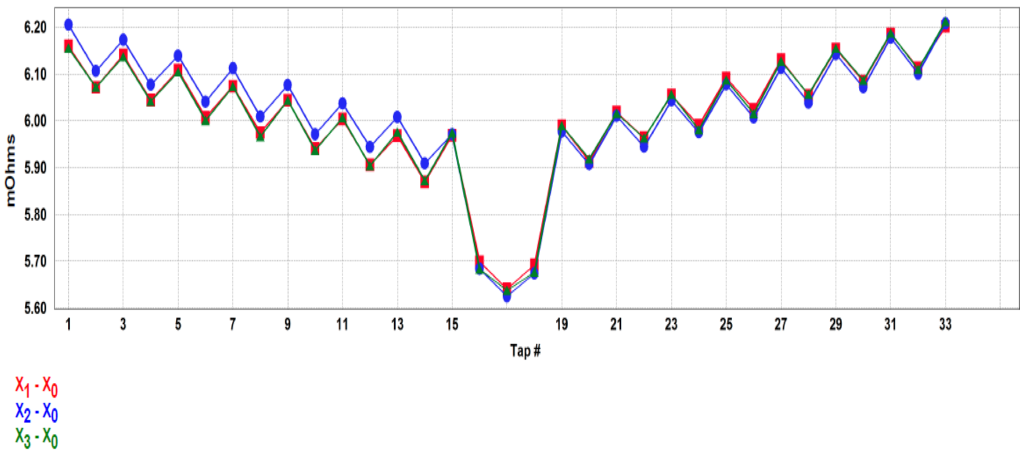
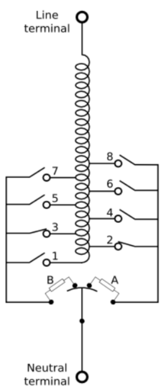


Figure 1: Graph of Reactive LTC with Preventive Auto

Resistive Type



The resistive LTC utilizes transition resistors to limit the circulating current during a tap change.

The bridging position is NOT a normal stopping tap position for a resistive LTC.

Resistive types are typically designed to arc either at the selector switch or the transfer (diverter) switch and operate at higher speeds (0.3 - 0.7 seconds).

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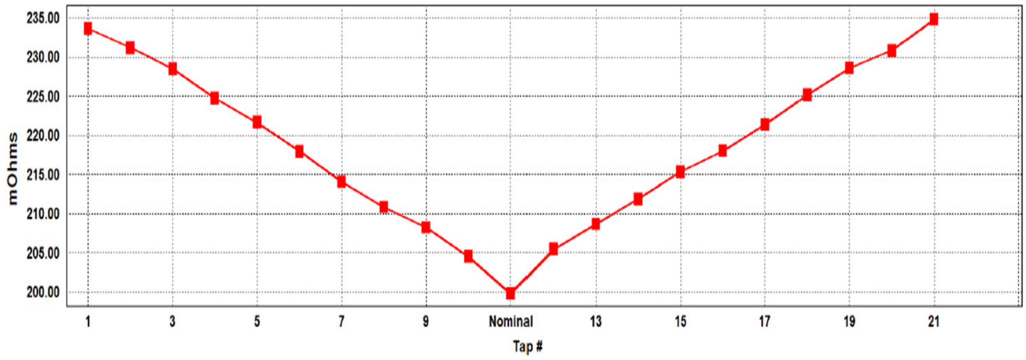

Figure 2: Graph of a Resistive Type LTC with Reversing Switch

Detecting Break Before Make (BBM) Condition

Under BBM conditions, current in the circuit drops and is monitored. If the current drops to a threshold value (10%) for a defined time, duration is used to detect BBM condition. Depending upon the age, number of operations, and type of LTC, one can select the sensitivity for BBM criteria.

Open Circuit Voltage

Open circuit voltage from the test set defines the time required for voltage to be applied to generate enough magnetic flux to saturate the transformer core.

$$\phi = \text{volts x seconds } (E^*t)$$

The time needed would also be dependent upon number of windings being tested simultaneously and prior level of core magnetization. This is contrary to a common belief that current saturates the core. Current magnitude does help to stabilize low resistance windings with high rated currents (>1000A).

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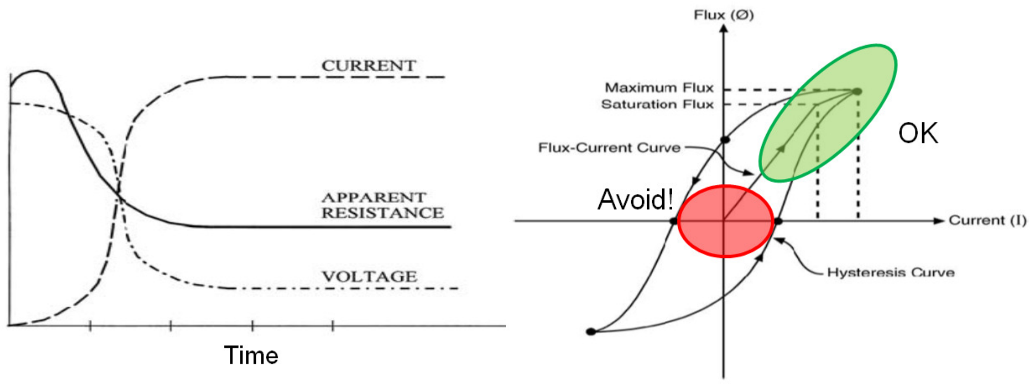
Principal relationship between applied voltage, resistance and core saturation



Selecting Test Current Range

- One should always try to inject above **1%** of rated current, but do not exceed **15%** rating (15% as per IEC/ANSI standards)
- Typical test currents range from 0.1% - 15% of rated current of winding – 0.1% to <1% becomes more difficult to maintain stability
- When test current is < 1% transformer rated current, measured resistance may not be consistent and/or time for stability may increase to an unreasonable time

Applying Large Test Currents

Higher test currents can have an adverse effect on the measurements:

- One can saturate the transformer core to a significant level such that residual flux (magnetization) causes protective relay to trip when re-energizing transformer (if not demagnetized properly)

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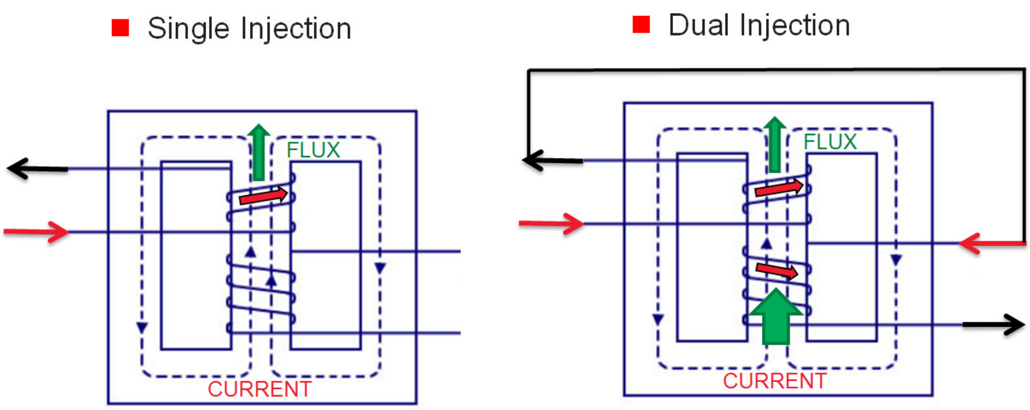
- When testing high side windings, large test currents may increase the test time unnecessarily
- High test currents (>15% rated current of winding) will change the winding resistance values over time during testing due to heating

Dual Injection Testing

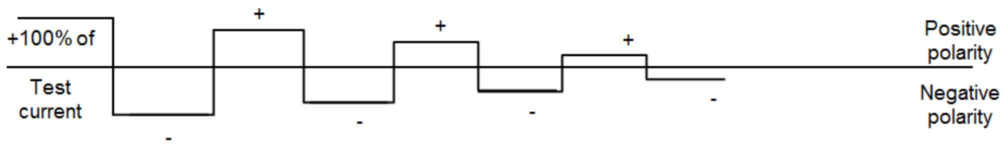
It can be an advantage to inject test current in the high voltage and low voltage windings simultaneously. This increases the flux in the core so the core saturates more quickly. This is particularly the case for transformers with a low voltage delta winding where the phase being measured saturates quickly, but the other 2 phases are in parallel and are only slowly saturated with 50% of the voltage.



Core demagnetization

The transformer core may remain magnetized as a result of DC measurements of winding resistance. This can lead to issues when re-energizing the transformer or when performing frequency response analysis.

Today's test equipment has a demagnetization feature. The user can demagnetize the core of the transformer at the completion of the test.



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Summary: WRM is NOT a simple test

- Not just an Ohm's law test R= V/I…. there is a lot more to it
- V= I*R +L*dI/dt, inductance of the winding
- Saturation of the core (volts*sec)
- Transient state before steady state is reached
- Stabilization of DC current
- Time constant of the circuit L/R
- Delta windings
- Make before break operation of (O)LTC's
- Return winding to original state - demagnetization