

11.2.2 Hot-resistance measurements

- a) The time from the instant of shutdown, i.e. time zero, shall be recorded for each hot resistance measurement.
- b) For *distribution transformers*, a hot resistance measurement shall be made on each terminal pair, and a series of hot resistance measurements shall be made on at least one terminal pair under test. For *power transformers*, a series of hot resistance measurements shall be made on each terminal pair under test; all terminal pairs shall be tested at maximum MVA nameplate rating. A series of hot resistance measurements may be made on only one terminal pair under test at lower nameplate ratings. The terminal pair used for those tests shall be the one found by prior testing to have the greatest winding temperature rise.
- c) The first hot resistance data point used to determine the time zero hot resistance of the winding shall be taken as quickly as possible after shutdown and after the inductive effects disappear and in any case, no later than 4 minutes after shutdown. In order to achieve core saturation in a short time period, the DC power supply voltage should be large enough to saturate the cores in a short time.

The DC source should be selected such that it can also provide sufficient current to keep the core saturated without causing excessive heating of windings. A series resistor added to the circuit will decrease time to stabilization.

When a transformer has a winding connected in delta, all involved core legs shall be saturated unless the delta is open during shutdown, for stable and accurate readings. When performing winding resistance measurements on a transformer that utilizes series transformers for load tap changing, care is required to ensure that the whole circuit, consisting of the main and series transformer windings, is saturated before stable readings of the combined winding resistances can be obtained.

- d) The hot resistance versus time data shall be used as the basis for correction to time zero. The cooling curve format shall consist of a series of measured hot resistance points beginning with the first hot resistance data point in accordance with c) and ending with a hot resistance data point taken no sooner than 10 minutes from shutdown. All hot resistance data points taken within the 10-minute period after shutdown shall be recorded at no longer than 30-second intervals for *distribution transformers* and no longer than 15-second intervals for *power transformers*.
- e) The hot resistance-time data collected in d) shall be extrapolated to the instant of shutdown using a computerized curve fitting program to determine the hot resistance-time cooling curve. The hot resistance-time data collected shall be fitted to an exponential decay curve using the method of least squares.

NOTE 1 - Comparative to large power transformers, the time constant of small distribution transformers may be short due to transformer thermal characteristics and measuring equipment which may affect the appropriateness of an exponential decay curve.

NOTE 2 - The mean oil temperature surrounding the winding and the actual location of the winding may result in top and bottom oil temperatures not giving the intended average winding oil temperature which could affect the appropriateness of the exponential decay curve.

NOTE 3 -The Working Group is initiating an investigation to define appropriate curves concerning notes 1 and 2 for a future modification to this clause.

- f) When the series of hot resistance measurements on only one terminal pair under test, the resistance-time data obtained on one phase of a winding shall be used to determine the correction to shutdown for the other phases of the same winding, provided the first measurement of each of the other phases has been taken within 4 min after shutdown.