$$\Delta\vartheta_{t} = (\Delta\vartheta_{U} - \Delta\vartheta_{i})\left[1 - \exp^{\frac{-t}{\tau}}\right] + \Delta\vartheta_{i} \qquad (14)$$

$$\vartheta_{HS} = \Delta\vartheta_{t} + \vartheta_{a} \qquad (15)$$

where

$\Delta\vartheta_{i}$ is the initial hot-spot temperature rise at some prior load I_{n}, expressed in Kelvins (K);

$\Delta\vartheta_{t}$ is the hot-spot temperature rise in Kelvins (K) at time t after changing the load;

$\Delta\vartheta_{U}$ is the ultimate hot-spot temperature rise in Kelvins (K) if the per unit overload I_{U} continued until the hot-spot temperature rise stabilised;

t is the time, in minutes (min);

τ_{R} is the time constant in minutes (min) for the transformer at rated load;

τ is the time constant in minutes (min) for the transformer at a given load;

ϑ_{HS} is the hot-spot temperature in degrees Celsius (°C);

ϑ_{a} is the ambient temperature in degrees Celsius (°C).

5.10 Determination of winding time constant

5.10.1 General

The concept of a transformer time constant is based on the assumption that a single heat source supplies heat to a single heat sink and that the temperature rise of the sink is an exponential function of the heat input. The time constant is defined as the time for the temperature rise over ambient to change 63,2 % after a step change in load. Typically the temperature stabilises after 5 time constants. Hot-spot temperature calculations for loading should be made on both the low-voltage and high-voltage windings since published test data indicates that the time constants may be different. Insulation system temperature classes for the two windings may also be different.

The time constant should be calculated or determined by test on the transformer after agreement between supplier and purchaser.

5.10.2 Time constant calculation method

The time constant of a winding at rated load, τ_{R}, is:

$$\tau_{R} = \frac{C\left(\Delta\vartheta_{HS,r} - \vartheta_{e}\right)}{P_{r}} \qquad (16)$$

where

C is the effective thermal capacity of winding, in watt-minutes per K (Wmin/K),

= (15,0 × mass of aluminium conductor in kilograms (kg)) + (24,5 × mass of epoxy and other winding insulation in kilograms (kg)), or

= (6,42 × mass of copper conductor in kilograms (kg)) + (24,5 × mass of epoxy and other winding insulation in kilograms (kg));

or

PS 916-12:2010 IEC 60076-12:2008