Using Overload Early Warning

T-PRO Transformer Protection Relay

Overview

Overload Early Warning is invaluable to help a system control (load dispatch) operator take action that reduces load on the transformer before it enters an overload condition.

Background: IEEE Specifications

This feature automatically follows all guidelines in the 'IEEE Guide for Loading Mineral-Oil-Immersed Transformers,' C57.91-1995: (quoting from the guide)

1. planned loading beyond nameplate rating
2. long-time emergency loading
3. short-time emergency loading

These IEEE specifications are based on the following premise:

- It is equally acceptable to overload a transformer lightly for a long time, as it is to overload heavily for a short time.

Basic Principle

Different overload scenarios should result in the same loss of life (of cellulose insulation) for any one overload occurrence.

Quoting from the guide

"The length of time for a transformer to operate in the [specified range] should be determined by loss of insulation life calculations…"

The equation recommended:

$$F_{AA} = e^{(15000/383 - 15000/(\theta H+273)}$$

where F_{AA} is the 'rate of aging,' sometimes called 'rate of loss of life' relative to normal, and θH is the hot spot temperature in degrees Celsius.

The normal or design condition is a hot spot temperature of 110°C, at which temperature the life of the cellulose insulation is 180,000 hours or 20.5 years. Incidentally, the reason that the actual lifetime of transformers is longer than 20.5 years is that they are usually loaded well below 110°C in the early part of their installed life, as well as at night.

T-PRO Implementation of the Overloading Guide

Figure 1 shows the Inverse-time Overload Characteristic for this T-PRO feature. The curves are based on equation (1).

Determining Hot Spot Temperature

As illustrated in Figure 1, the T-PRO relay determines hot spot temperature, either from sensed ambient temperature (probe available from ERLPhase), or sensed top oil temperature. The sensor is 0-1 mA or 4-20 mA. A second temperature channel input is also available.

Figure 1: Temperature input to the T-PRO relay.

If ambient temperature is sensed, both top oil and hot spot temperature are calculated using the C57 Guide equations (Clause 7). If the top oil temperature is sensed, only the hot spot temperature needs to be calculated. This is slightly more accurate, but the trade-off is the need to install a top oil sensor with an electrical signal output. See examples in Figures 2a and 2b.

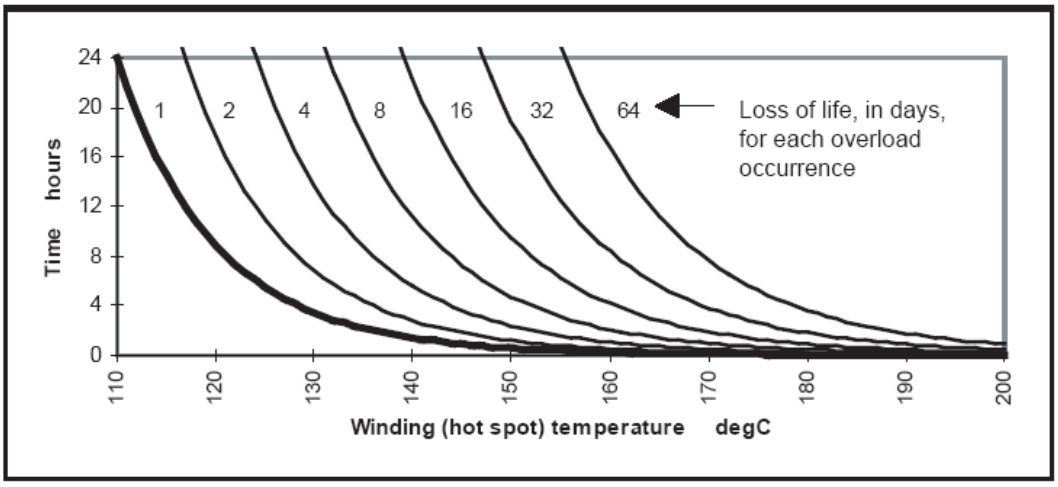

Figure 2a: Inverse-time Overload Characteristic.

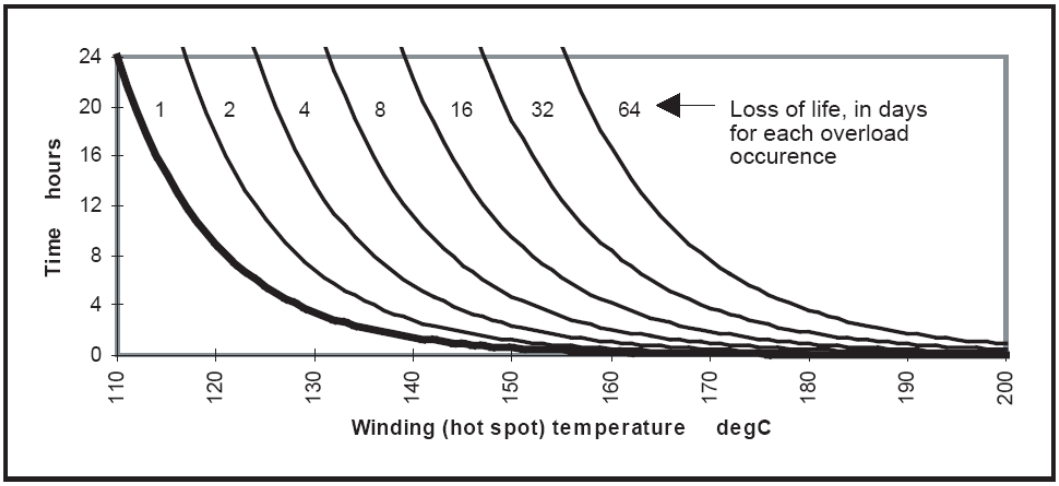

Figure 2b: If the hot spot temperature were constant at 140°C, then 4 times normal loss would occur in about 5.5 hours.

Suppose the curve labeled '4' has been selected. If the hot spot temperature were constant at 140°C, then 4 times normal loss of life would occur in about 5.5 hours. Trip or alarm (user decides) would occur at that time. Of course, during a sudden overload condition, the hot spot temperature is certainly not constant. Its behavior would be like that shown in Figure 3.

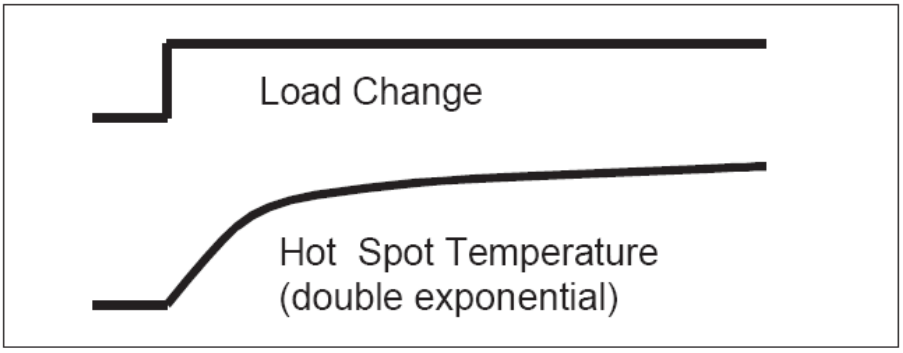

Figure 3: Hot spot temperature response to a sudden load change.

The relay algorithm works by integrating the rate-of-loss-of-life, once a settable threshold has been exceeded. Thus the elapsed loss-of-life is correct, regardless of whether the temperature is varying or not.

Overload Early Warning

If the overload condition is set for TRIP (or possibly ALARM), then it is highly desirable to know in advance when this condition occurs. Thus in T-PRO there is an EARLY WARNING feature. Again using equations from the C57 Guide, and assuming at any instant in time that the loading and ambient temperature will not change (since they aren't predictable), the time-to-trip is continuously calculated. As soon as this time drops below 30 minutes, an early warning alarm sounds. An over-riding maximum hot spot temperature can be OR'd with the above, and included in the warning calculation.

Summary

With this information, system control (load dispatch) operators can take action early to reduce load on the transformer to prevent the overload condition.