# Protecting Against Transformer Overload

## T-PRO Transformer Protection Relay


### Overview

In addition to all the "usual" features of transformer protection relays (differential protection, overcurrent protection, overvoltage protection), the T-PRO relay also has several features that protect against overheating:

- early warning of an overheating condition
- load shedding triggered by overheating
- adaptive pickup current for the overcurrent inverse-time function

These functions, in effect, monitor the health of paper (cellulose) insulation found in most power transformers. Insulation deteriorates when overheated, and the deterioration is cumulative: many minor overtemperature events can have the same effect as a single severe overtemperature event. Note that although an overloading (i.e. overcurrent) condition in a transformer can cause insulation over-heating (i.e. overtemperature), there are other factors to consider. For instance, the temperature of the insulation is dependent not only on the I2R losses due to loading, but also on the ambient temperature (see typical data below):

| Ambient | Loading | Hot Spot Temperature (steady-state) |
|---|---|---|
| 30°C | 100% | 110°C (normal full-load condition) |
| 40°C | 90% | 110°C |
| 0°C | 120% | 110°C |

Also, it can take an hour or so before a step change in loading causes a significant rise in the insulation temperature.

### Insulation Loss of Life – What is it and How is it Calculated?

When the hot spot temperature in a transformer is 110°C, the insulation deteriorates at a "normal" rate. At this rate, the transformer insulation strength will drop to one-half of its original value in 20 years, and has reached the end of its useful life (as described by present IEEE Standard, which is based on years of experience and testing). Note that this doesn't mean that the average transformer lasts only 20 years. Transformers aren't run at 100% load under 30°C ambient conditions 24 hours a day! The calculation of the "rate of loss of life" (of the insulation) is rather complex, but here's a rule-of-thumb:

**The "rate of loss of life" doubles for every 7°C rise in the "hot spot temperature".**

The T-PRO relay calculates the "rate of loss of life" every three minutes (and from this the accumulated loss of life is calculated continuously). Therefore, the effect of past overload conditions, especially repetitive ones, is known.

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In case of inconsistencies between documents, the version at www.erlphase.com will be considered correct. (D02836 R02)

## What is the Transformer Overload Early Warning System (TOEWS)?

TOEWS uses differential equation theory to predict – up to 30 minutes in advance – that a severe hot spot temperature condition will occur if something is not done to reduce load on the transformer.

110°C normal

117°C twice normal

124°C four times normal

## What is the Overtemperature-Sensitive Load Shedding System?

This feature is an improvement on the usual load shedding scheme, where loads are dropped (based on a priority scheme) as a function of excessive current in the transformer supplying those loads. As explained above, it's really the hot spot temperature that should be the deciding factor. In the T-PRO scheme, hot spot temperature is the major load drop decision-making factor. In other words, if the hot spot temperature is getting too high, keep dropping load (at a controlled rate) until the temperature is under control.

## What is the Adaptive Current Pick-up System?

The "pick-up" setting for an inverse-time overcurrent element is the current above which the relay operates to remove a transformer from service if that value of current has been exceeded for a long time (many minutes). There are some elements, such as a tap-changer, where this is a valid criterion, but if a T-PRO user opts for insulation loss of life as the criterion, then the ambient temperature is also a factor. With this scheme activated, the pick-up current automatically tracks the ambient temperature and adjusts the pick-up current upwards in cold weather and downwards in hot weather.

## Summary

The T-PRO relay includes several special features that help customers monitor transformer health: early warning of an overheating condition, load shedding triggered by overheating, and adaptive pickup current.