Guidelines on Draw-Lead Application

Draw-lead cable loading

The following guidelines can be used when bushings are used in a draw-lead application mode.

Bushing current rating

The maximum continuous current rating of the bushing in the draw-lead mode is limited to the rating specified on the bushing nameplate. The maximum continuous current rating of the draw-lead cable is determined by the size and type of the cable supplied by the transformer manufacturer. Since the draw-lead cable is an integral part of the transformer, the current rating specified on the transformer nameplate determines the rating of the draw-lead cable. When a draw-lead conductor is supplied with the bushing by the bushing manufacturer the rating of the draw-lead conductor is stated on the bushing nameplate.

Factors influencing the draw-lead cable(s) rating

The current rating of the draw-lead cable is dependent upon several factors. These are:

- Cable cross section, material, number of strands and type
- Insulation thickness, type, and the temperature limit
- Overall length of the bushing
- Top oil temperature
- Oil level in the transformer
- Oil level in the bushing central tube

The current carrying capacity of a cable is dependent upon the cross section of the cable as well as conductivity of the material. The temperature rise of the cable is dependent upon the thickness of the cable insulation. As the insulation thickness increases, it impedes the flow of heat through the paper and results in an increase in temperature of the cable. The temperature rise limit of the cable is dependent upon the type of insulation used on the cable. For example, thermally up grated insulation would have a higher temperature limit than a non-thermally up grated insulation. Aramid and treated Kraft paper insulation would fall into the thermally up grated category.

The overall length of the bushing has an effect on the rating of the cable. For the same sized cable and the same temperature rise, the current rating of the cable would be lower for longer high voltage bushings. The longer the bushing, the more difficult it is for the heat to dissipate and therefore the cable rating must be de-rated.

The temperature of the oil in the transformer as well as the bushing immersion level influences the temperature rise of the cable. The higher the top oil temperature, the higher would be the cable temperature. Similarly, higher the lower end oil immersion level, higher would be the cable temperature. Also, the oil level in the bushing central tube influences the temperature rise of the cable. If the tube is completely filled with oil, the hottest spot temperature of the cable would be lower when compared to oil level at

the mounting flange or lower. On the other hand, the temperature of the bushing central tube would be higher when the tube is completely filled with oil.

Factors influencing the draw-lead conductor rating

The current rating of the draw-lead conductor supplied with the bushing by the bushing manufacturer is dependent upon several factors. These are:

- Conductor cross section and material
- How the conductor is connected to the top terminal of the bushing, threads or multi-spring contacts
- If the conductor is two-piece, the type of joint used, bolted or threads
- Top oil temperature
- Oil level in the transformer
- Oil level in the bushing central tube
- Ambient air temperature

The actual rating of the specific design of the draw-lead conductor shall be determined by temperature rise test as described in C57.19.00 under the section “Design Tests”

Draw-lead cable/bushing loading

The rating of the draw lead cable is determined by the size and type of the cable used by the transformer manufacturer. The rating is limited to rating specified on the transformer nameplate.

When applying bushings in the draw-lead mode, the bushing manufacturer should be consulted for guidelines on draw-lead sizes, ratings, and loading. To minimize cable insulation loss of life during overloads, it would be preferable to choose a cable with current rating of at least 20% above the rated current of the transformer. If higher overloads are anticipated, then cables with even greater margin should be considered.

Although specific guidelines should be obtained from bushing or transformer manufacturers, following general guidelines can be used for rating draw lead cables with thermally up grated 65°C insulation.

Maximum ambient 40°C
Maximum cable hottest spot temperature rise above ambient air at rated current 80°C
Maximum cable hottest spot temperature rise above ambient air under overload condition 100°C

The 80°K rise limit agrees with the maximum winding hottest spot temperature rise for 65°K rise transformer as per C57.12.00 – 2000.

The 100°C hottest spot temperature rise limit is based on maximum temperature limit of 140°C with maximum ambient air temperature of 40°C. Operation at hottest spot temperatures above 140°C may cause gassing in oil and solid insulation.

Temperature Rise Test on Draw-Lead Bushings

A temperature rise test on a draw lead bushing can be carried out similar to the procedure described in C57.19.00 under the section “Design Tests”. In addition, the following guidelines may be useful when carrying out such a test.

- Attach the thermocouples to the draw-lead cable or conductor 20 – 30 cm (8 – 10 inch) apart
- When possible, attach thermocouples on the condenser bushing winding tube. This will be useful in getting temperature rise information on the central tube that is in contact with condenser insulation. For this a special test bushing would be required.
- For bushing designs supplied with a draw-lead conductor that has a joint a thermocouple should the attached to the joint as this will be the most likely location of the hottest spot on the conductor.
- The test should be done with transformer oil level within 50 mm of the bushing mounting flange with the tube partially or completely filled with oil as per the application.
- The top oil temperature rise should be 65°C above ambient air or as per the rating of the transformer
- The test can be done at the following currents for determining the thermal constants. 0.0, 0.7, 1.0, and 1.25 PU load current
- Calculate the thermal constants, using the method described in section xx.xx, “Derivation of Model Constants” These constants will be useful in estimating the cable temperature rise at different loads.

Written by

Keith Ellis
Trench Limited USA

Note that much of the text was copied from the proposal from Pritpal Singh

October 13, 2004