Bushing Overload Task Force

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Tuesday, March 27, 2018

4:45 PM – 6:00 PM

Call for Patents

“If any individual believes that Patent Claims might be Essential Patent Claims, that fact should be made known to the entire working group and duly recorded in the minutes of the working group meeting.”

Scope of Bushing Overload Task Force

Review existing guides, standards, and practices and determine the industry need for a guide (for users and manufactures to choose a bushing to meet transformer overload requirements) or does the industry need bushing overload requirements added to the bushing standard. (Or do nothing.)

IEEE C57.12.00-2015 - General Requirements for Liquid-Immersed Distribution, Power and Regulating Transformers

4.2 Loading at other-than-rated conditions

IEEE Std. C57.91™ [B12] is a guide that provides guidance for loading at other-than-rated conditions including the following:

- a) Ambient temperatures higher or lower than the basis of rating
- b) Short-time loading in excess of nameplate kVA with normal life expectancy
- c) Loading that results in reduced life expectancy

IEEE C57.12.00-2015 - General Requirements

4.2 Loading at other-than-rated conditions – Continued.

IEEE Std. C57.91 [B12] is an IEEE guide, and as such, it does not specify mandatory requirements…….

The guide discusses limitations of ancillary components other than windings that may limit the capability of transformers.

When specified, ancillary components and other construction features (such as cables**, <u>bushings</u>**, tap changers, insulating liquid expansion space, etc.) shall be supplied in a manner that **<u>will not limit the loading</u>** to less than the specified capability of the windings.

Transformer Overloading

Many Transformer users plan to overload their transformers at some point in a transformers life and IEEE C57.91-2011 Guide for Loading Mineral Oil Transformers, has suggestions for different types of loading.

Four types of loading are discussed in the guide.

1) Normal life expectancy loading
2) Planned loading beyond nameplate rating
3) Long-time emergency loading **(Two or three occurrences over the normal lifetime of the transformer where each occurrence may last several months)**
4) Short-time emergency loading **(One or two occurrences over the lifetime of the transformer**

Transformer Short-Time Emergency Loading

Table 8 of the transformer loading guide IEEE C57.91-2011 suggests temperature or loading limits above nameplate with a maximum loading of 200%, which may cause transformer and bushing loss of life.

Table 8—Suggested limits of temperature or load for loading above nameplate power transformers with 65 °C rise

Top-oil temperature	110 °C
Hottest-spot conductor temperature	180 °C
Maximum loading	200%

Notes:

a) The Guide does not provide a time limit for 200% loading for Power Transformers, where as for distribution transformers and voltage regulators, a 30 minute time limit is suggested for 200% loading.)

b) IEEE C57.19.100-1995 contained the 200% loading maximum until 2012 when it was removed.

Bushing Types

There are several types of bushing technologies.

1) Oil- impregnated paper-insulated (OIP), capacitance-graded bushings
2) Resin impregnated, paper insulated – oil-free, dry bushings
3) Resin bonded, paper insulated
4) Resin impregnated synthetic bushings
5) Solid insulation bushings
6) etc…..

IEEE C57.19.100-2012 - Guide for Application of Power Apparatus Bushings

The **IEEE C57.19.100** guide uses a bushing loading model developed for oil-impregnated, paper-insulated, capacitance-graded power apparatus bushings to make recommendations when installed on power transformers.

Similar loading models could be developed for other bushing constructions.

(Are there loading models for other bushing types publically available?)

OIP Bushings Loading Beyond Nameplate

IEEE Standards do not have bushing overload ratings, therefore each bushing's capability must be evaluated individually for each application.

To calculate OIP bushing loss of life, first need the steady-state bushing hottest-spot rise over ambient. Obtained from IEEE C57.19.100-2012 4.2.1 Steady-state hottest-spot temperature calculations.

$$\Delta\Theta_{HS} = K_1 I^n + K_2 \Delta\Theta_0 \qquad (1)$$

where

$\Delta\Theta_{HS}$	is the steady-state bushing hottest-spot rise over ambient (°C)
$\Delta\Theta_0$	is the steady-state immersion oil rise over ambient (°C) (transformer top oil rise)
I	is the per unit load current based on bushing rating
n, K_1, and K_2	are constants that can be determined as described in 4.3

To calculate bushing hot-spot rise over ambient requires the transformer top oil rise and constants particular to each bushing.

OIP Bushings Loading Beyond Nameplate-Continued

Once the steady-state bushing hottest-spot rise over ambient is obtained, then use Equation (B. l) in IEEE C57.91 to determine the bushing loss of life. Each user must determine what an acceptable loss of life is and provide that limit to the transformer manufacturer.

$$Log_{10}(LIFE) = \left[\frac{6972.15}{\Theta_{HS} + 273} - 14.133 \right] \qquad \text{(B.1)}$$

where

$LIFE$ is the life of bushing insulation, h

Θ_{HS} is the bushing insulation hottest-spot temperature, °C

Equation (B. l) indicates that bushings operated at rated current and rated insulation hot-spot temperature have a predicted life less than that of the transformer insulation.

The following parameters are needed by both bushing and transformer manufacturers to size bushings properly

1) Transformer overload requirements.
2) Transformer top oil temperature before and after overload.
3) Ambient temperature.
4) Temperature of metallic hotspot in contact or not in contact with bushing insulation **(Bushing mounting flange connection, lead, …)**
5) Allowable bushing loss of life.

(Should both the user and bushing manufacturer have input on allowable bushing loss of life?)

Discussion Questions:

1) Does the Task Force have sufficient information to answer the questions proposed in the Task Force scope of work?

2) If not, what additional information is needed to be able to answer the questions in the Task Force Scope of work?

3) Are the existing bushing standards and guides and the transformer standards and loading guide sufficient for choosing OIP bushings to meet transformer overload requirements?

4) Does the Task Force want to recommend that a guideline be created for other bushing types (similar to the OIP guide) to help users and transformer manufacturers to size bushings to meet transformer overload requirements?

Appendix

Overload limits for coordination of bushings with transformers:

IEEE C57.91-2011 Guide for loading mineral oil Transformers, Annex B, B.1 Bushings.

The following overload limits are established for coordination of OIP bushings with transformers:

Ambient air	40 °C maximum
Transformer top-oil temperature	110 °C maximum
Maximum current	2 times rated bushing current
Bushing insulation hottest-spot temperature	150 °C maximum

C57.19.100 Guide – Effect on Bushing when Operating above Bushing Temperature Limits

Operating a transformer beyond nameplate current can result in bushing temperatures above manufacturers guidelines, which can cause bushing loss-of-life.

Possible bushing overload effects include the following:
– Internal pressure build-ups
– Aging of gasket materials
– Unusual increases in power factor from thermal deterioration
– Gassing caused by hottest-spots in excess of 140 °C
– Thermal runaway from increased dielectric losses at high temperatures
– Heating in metallic flanges due to stray magnetic flux

For other bushing types, consult with the manufacturer for loading guidelines.

IEEE C57.91-2011 Guide for Loading Mineral oil Transformers

9.7 Loading information for specifications

If the maximum load capacity that a transformer user plans to utilize on a planned or emergency basis is included in the specifications at the time of purchase, the following information should be given:

a) Load

1) Two step load cycle approach Prior steady-state load, percent of maximum nameplate rating

– Maximum load, percent of maximum nameplate rating

– Duration

2) Load cycle over a 24 h period

b) Ambient temperature, °C

1) Constant for load cycle approach [see item a)1)]

2) Variable over the load cycle for load cycle approach [see item a)2)]

c) Type of loading, planned or emergency, long-time or short-time

d) Limiting top-oil temperature

e) Limiting hottest-spot temperature

f**) Statement that ancillary components not limit the loading capability**

More than one set of loading conditions may be used.