

IEEE Guide for Application of Power Apparatus Bushings

Sponsor

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Abstract: Guidance on the use of outdoor power apparatus bushings is provided. The bushings are limited to those built in accordance with IEEE Std C57.19.00-1991. General information and recommendations for the application of power apparatus bushings, when incorporated as part of power transformers, power circuit breakers, and isolated-phase bus, are provided.

Keywords: circuit breakers, isolated-phase bus, power apparatus bushings, transformers

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Introduction

(This introduction is not part of IEEE Std C57.19.100-1995, IEEE Guide for Application of Power Apparatus Bushings.)

In August 1968, the ANSI C76 committee decided to separate ANSI C76.1 into three parts: The first (C76.1, presently IEEE Std C57.19.00-1991) part was to cover the general requirements and test procedures; the second (C76.2, presently IEEE Std C57.19.01-1991), to cover explicit ratings and dimensions; and the third (C76.3), to be an application guide. This document, IEEE Std C57.19.100-1995, is the application guide.

When the ANSI C76 committee was developing the first draft of the application guide, it was decided that the loading guide portion of the guide should be published for trial use before completion of the application guide. This would allow experience with its use and possible modifications prior to publication within the application guide. The trial-use loading guide was approved but not published before the disbanding of the ANSI C76 committee.

The Working Group on Bushing Application Guide was established by the Bushing Subcommittee of the IEEE Transformers Committee to take over the development and completion of the application guide so that it could be submitted for IEEE Standards Board approval and publication. IEEE published the trial-use loading guide in July 1989 as IEEE Std C57.19.101-1989. It was upgraded to a full-use guide on June 18, 1992, and designated as IEEE Std C57.19.101-1992. The current guide, IEEE Std C57.19.100-1995, is the application guide in its entirety, which includes the loading guide (clause 4), and hence, supersedes IEEE Std C57.19.101-1992.

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Guide for Application of Power Apparatus Bushings

1. Overview

1.1 Scope

Guidance on the use of outdoor power apparatus bushings is provided in this document. The bushings are limited to those built in accordance with IEEE Std C57.19.00-1991.¹

1.2 Purpose

The purpose of this guide is to present general information and recommendations for the application of power apparatus bushings when incorporated as part of power transformers, power circuit breakers, and isolated-phase bus. The loading model developed in this guide is based on oil-impregnated, paper-insulated, capacitance-graded bushings. Similar loading models could be developed for other bushing constructions.

2. References

The following standards form a part of this guide to the extent specified in this document:

IEEE Std 1-1986 (Reaff 1992), IEEE Standard General Principles for Temperature Limits in the Rating of Electric Equipment and for the Evaluation of Electrical Insulation (ANSI).²

IEEE Std 4-1978, IEEE Standard Techniques for High-Voltage Testing (ANSI).³

IEEE Std 100-1992, The New IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI).

IEEE Std C37.04-1979 (Reaff 1988), IEEE Standard Rating Structure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis (ANSI).

¹Information about references can be found in clause 2.

²IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

³IEEE Std 4-1978 has been withdrawn; however, copies can be obtained from the IEEE Standards Department, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

IEEE Std C37.010-1979 (Reaff 1988), IEEE Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis (including Supplement IEEE Std C37.010d) (ANSI).

IEEE Std C37.010b-1985, Supplement to IEEE Std C37.010-1979.

IEEE Std C37.010e-1985, Supplement to IEEE Std C37.010-1979.

IEEE Std C37.23-1987 (Reaff 1991), IEEE Standard for Metal-Enclosed Bus and Calculating Losses in Isolated-Phase Bus (ANSI).

IEEE Std C57.12.00-1993, IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers (ANSI).

IEEE Std C57.19.00-1991, IEEE General Requirements and Test Procedures for Outdoor Apparatus Bushings (ANSI).

IEEE Std C57.19.01-1991, IEEE Standard Performance Characteristics and Dimensions for Outdoor Apparatus Bushings.

IEEE Std C57.92-1981 (Reaff 1991), IEEE Guide for Loading Mineral-Oil-Immersed Power Transformers Up To and Including 100 MVA with 55 °C or 65 °C Winding Rise (ANSI).

3. Definitions

For definitions of terms used in this standard, see IEEE Std C57.19.00-1991 and IEEE Std 100-1992.

4. Thermal loading above nameplate rating for bushings applied on power transformers

4.1 General

The thermal loading capability of bushings varies with the way they are loaded, the way they are designed, and the ambient conditions in which they are applied.

4.1.1 Basis of rating and rationalization of thermal requirements rating

Capacitance-graded, paper-insulated bushings that, at rated current, meet the requirements of IEEE Std C57.19.00-1991 and earlier versions of that standard may be applied in either 55 °C or 65 °C rise transformers. IEEE Std C57.19.00-1991 and IEEE Std C57.12.00-1993 state that the temperature of the oil in which the lower end of the bushing is immersed shall not exceed 95 °C when averaged over a 24 h period. Transformer loading shall conform to IEEE Std C57.92-1981.

4.1.1.1 Operation above normal temperature

When operating a bushing at rated current in conjunction with a 65 °C average winding rise rated transformer, the hottest-spot temperature of the bushing is limited to a 65 °C rise over ambient or a 105 °C total temperature because of the use of temperature index 105 insulating paper for the bushing condenser. If it should be determined that a transformer develops a top oil rise of 65 °C at rated current when operating in a 40 °C ambient, the hottest-spot temperature of the bushing can be expected to exceed 105 °C. In addition, transformers can be expected to have bushing temperatures above 105 °C when loaded in accordance with IEEE Std C57.92-1981. In each instance, the normal life expectancy of the bushing will be shortened by the

higher operating temperatures. The loss-of-life of a bushing will, like transformers, be a function of the actual temperature and the time operating at that temperature.

The severity of loss-of-life in a bushing can be minimized by installing bushings that have nameplate ratings greater than the transformer current ratings or by using bushings with special high-temperature insulation. An alternative is to operate the bushing with the higher inherent temperatures and accept a moderate degree of accelerated aging, as it is presently recognized for transformers. Refer to 4.4 to correlate bushing paper insulation aging with the bushing conductor hottest-spot temperature.

4.1.1.2 Factors influencing bushing aging

There are several factors that tend to decrease the severity of bushing aging. These are as follows:

- a) The top oil rise of many transformers is significantly below 65 °C when the transformer is operated at nameplate loading. This is most likely to occur on forced oil-cooled (FOA) transformers.
- b) Bushings are totally sealed from the atmosphere at the time of manufacture, thus preserving their dielectric and thermal integrity.
- c) Bushing insulation is generally processed to a greater degree of dryness than transformer insulation, thus providing a lower power/dissipation factor, lower dielectric losses, and consequently prolonged life at any temperature.
- d) The end-of-life of cellulose insulation in transformers may be governed by its ability to withstand mechanical forces that are associated with fault currents through the transformers. Cellulose insulation in bushings is not subjected to similar forces.
- e) Although end-of-life of insulating materials is typically based on a given change in mechanical or chemical properties, no similar relationship for dielectric characteristics has been established. However, considering increased insulation power/dissipation factor and capacitance as important criteria, well-dried bushing cellulose material is probably equal in life expectancy to thermally upgraded (65 °C) transformer insulation.
- f) The use of bushings with current ratings greater than the transformer current ratings as described in 4.1.1.1 reduces the temperature rise inside the bushing at rated transformer current.

4.1.2 Overload concerns

When a bushing is loaded above nameplate, it is exposed to the risks described in 4.1.2.1–4.1.2.5.

4.1.2.1 Pressure buildup

When load current through a bushing exceeds the nameplate rating, internal pressures can develop that could cause one or more of the sealing gaskets to leak or fail. This pressure increase is caused by the expansion of the insulating oil within the bushing. The rate of oil expansion is normally considered to be approximately 0.0725–0.0755% per °C temperature increase for temperatures ranging from 0–100 °C.

4.1.2.2 Gasket seals

Gasket materials will age according to the temperature adjacent to the gasket surface and the duration at that temperature. Usually gaskets will perform well at elevated temperatures; however, progressive changes in physical properties will occur when excessive temperatures are maintained for long durations. These changes could result in loss of seal and consequent loss of dielectric strength. Therefore, repeated occurrences at high temperature will require inspection for oil leaks and corrective actions where necessary.

4.1.2.3 Power/dissipation factor and capacitance

There are many reasons why insulation power/dissipation factor and/or capacitance may increase over the life of a bushing. In fact, some slight increase of power/dissipation factor can be tolerated. However degradation of that portion of the insulation that operates at greatly elevated temperature could result in a substantial increase in power/dissipation factor. An unusual increase in power/dissipation factor may become an indica-