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IEEE Guide for Loading Mineral-Oil-Immersed Transformers and Step-Voltage Regulators

IEEE Power & Energy Society

Sponsored by the
Transformers Committee

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Abstract: General recommendations for loading 65 °C rise mineral-oil-immersed distribution and power transformers are covered.
Keywords: distribution transformer, IEEE C57.91, loading, mineral-oil-immersed, power transformer

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Introduction

This introduction is not part of IEEE Std C57.91-2011, IEEE Guide for Loading Mineral-Oil-Immersed Transformers and Step-Voltage Regulators.

This guide is applicable to loading 65 °C mineral-oil-immersed distribution and power transformers. Guides for loading, IEEE Std C57.91-1981 (prior edition), IEEE Std C57.92™-1981,[a] and IEEE Std C57.115-1991 (redesignated as IEEE Std 756) are all combined in this document as the basic theory of transformer loading is the same, whether the subject is distribution transformers, power transformers 100 MVA and smaller, or transformers larger than 100 MVA. In recognition of different types of construction, special considerations, and the degree of conservatism involved in the loading of this equipment, specific sections are devoted to power transformers and distribution transformers. In the previously referenced information, the guide for units larger than 100 MVA referenced the IEEE Std C57.92-1981 loading guide for units up to and including 100 MVA.

This update to the work done in 1995 expands the scope to include step-voltage regulators and replaces Annex A with an improved discussion on bubble evolution. Subclause 8.4 was added for step-voltage regulators. In addition, the formula notations were changed to reflect the updated IEEE style and a number of typographical errors were fixed. Both Clause 7 and Annex G calculation procedures remain in place. Clause J was removed as out-of-date information and is expected to be re-introduced in the future in a new standard on transformer monitoring systems. Annex C and Annex G were changed from normative to informative.

As IEEE Std C57.12.00-2010[b] has adopted an insulation life of 180 000 hours at 110 °C, Table 2 of this guide has been moved to Annex I for historical reference.

In previous guides, different insulation aging curves were used for power transformers and distribution transformers. This was caused by the different evaluation procedures used. The distribution transformer curve was based on aging tests of actual transformers. The power transformer curve was based on aging insulation samples in test containers to achieve 50% retention of tensile strength. Investigation of cellulosic insulating materials removed from transformers that had long service life has led knowledgeable people to question the validity of the 50% criteria. One newer criteria suggested is 25% retention. This guide will permit the user to select the criteria most acceptable to their need, based on percent strength retention, polymerization index, etc. An insulation aging factor may thus be applied.

A per unit life concept and aging acceleration factor are provided in this loading guide. The equations given may be used to calculate percent loss of total insulation life, as has been the practice in earlier editions of the transformer loading guides. The relationship between insulation life and transformer life is a question that remains to be resolved. It is recognized that under the proper conditions, transformer life can well exceed the life of the insulation.

The assumed characteristics used in previous guides contained tables of loading capability based on assumed typical transformer characteristics. These assumed characteristics were recognized as not being those of actually built units, which may have a wide range of characteristics. In this guide these tables were removed since computer technology permits calculation of loading capability based on specific transformer characteristics.

Two methods of calculating temperatures are given in this guide. Clause 7 contains temperature equations similar to those used in previous editions of this guide. These equations use the winding hot spot rise over tank top oil and assume that the oil temperature in the cooling ducts is the same as the tank top oil during overloads. Recent research using imbedded thermocouples and fiber optic detectors indicates that the fluid

[a] IEEE Std C57.92-1981 has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel. (303) 792-2181 (http://global.ihs.com/).

[b] Information of references can be found in Clause 2.

flow occurring in the windings during transient heating and cooling is an extremely complicated phenomena to describe by simple equations. These recent investigations have shown that during overloads, the temperature of the oil in the winding cooling ducts rises rapidly and exceeds the top-oil temperature in the tank. An alternate set of equations based on this concept is given in Annex G. The change of losses with temperature and liquid viscosity effects, and variable ambient temperature was incorporated into the equations. A computer program based on these equations is given for evaluation by the industry. Research in this field is ongoing at this time and may be incorporated into future revisions of this guide.

Changes in the guide, in addition to the consolidation, include information to more accurately load transformers operating down to a −30 °C ambient, this information concerns loss of diversity due to cold load pick-up or unusually low ambient temperatures.

Transformers rated 55 °C rise were generally replaced as a standard offering by most manufacturers about 1966. Their replacements were originally rated 55/65 °C and in 1977 the single 65 °C rated transformers became the industry standard offering. The higher temperature ratings are based on thermally upgraded oil-paper-enamel insulation systems. Loading of 55 °C insulation system transformers is covered in Annex D.

Suggestions for improvement gained in the use of this guide will be welcomed. They should be sent to the IEEE Standards Department.

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IEEE Guide for Loading Mineral-Oil-Immersed Transformers and Step-Voltage Regulators

1. Overview

1.1 Scope

This guide provides recommendations for loading mineral-oil-immersed transformers and step-voltage regulators with insulation systems rated for a 65 °C average winding temperature rise at rated load. This guide applies to transformers manufactured in accordance with IEEE Std C57.12.00[1] and tested in accordance with IEEE Std C57.12.90, and step-voltage regulators manufactured and tested in accordance with IEEE Std C57.15. Because a substantial population of transformers and step-voltage regulators with insulation systems rated for 55 °C average winding temperature rise at rated load are still in service, recommendations that are specific to this equipment are also included.

1.2 Purpose

Applications of loads in excess of nameplate rating involve some degree of risk. It is the purpose of this guide to identify these risks and to establish limitations and guidelines, the application of which will minimize the risks to an acceptable level.

[1] Information of references can be found in Clause 2.