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IEEE Guide for the Interpretation of Gases Generated in Mineral Oil-Immersed Transformers

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IEEE Power and Energy Society

Developed by the
Transformers Committee

IEEE Std C57.104™-2019
(Revision of IEEE Std C57.104-2008)

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Abstract: Detailed procedures for interpreting Dissolved Gas Analysis results are described in this guide. The document details: 1) Overview of gas generation in transformer and DGA process; 2) The purpose and application of DGA; 3) DGA quality verification and DGA limitations; 4) DGA interpretation and norms; 5) Fault type definitions and identification; 6) Case studies and interpretation example. The intent is to provide the operator with useful information concerning the serviceability of the equipment. An extensive bibliography on gas evolution, detection, and interpretation is included.

Keywords: DGA, gas analysis, IEEE C57.104™, mineral oil, mineral oil-immersed transformers, transformers

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Introduction

This introduction is not part of IEEE Std C57.104-2019, IEEE Guide for the Interpretation of Gases Generated in Mineral Oil-Immersed Transformers.

IEEE Std C57.104™-1991 was officially withdrawn by IEEE based on recommendation by the Transformers Committee of the IEEE Power and Energy Society at the end of 2005. IEEE Std C57.104-2008 was issued with minor changes to address some of the most pressing issues identified from the 1991 version (such as correcting typos, factual errors, and the values listed in Table 1 of the 1991 version of the guide) for use by the industry.

Upon publication of the 2008 document, the working group immediately began the process of further revision to the guide to reflect additional advances in current knowledge and trends, and to incorporate relevant and new material presented during several meetings of both the IEEE Std C57.104 Working Group Task Force (WG TF) leaders and general IEEE Transformer Committee meetings. In addition, results from the analysis of more than a million pieces of laboratory DGA data has resulted in revision of several tables in this guide.

Changes in this revised guide are as follows:

— All clauses reviewed and updated.
— Reduction of Table 1 from four conditions to three DGA status based on 90th and 95th percentile values.
— Modification of Table 1 to include several subcategories and split between Table 1 (90th percentile) and Table 2 (95th percentile) based on results of a large statistical study (Annex A).
— Removal of TCG and TDCG interpretation and associated Table 2 and Table 3.
— Introduction of delta and rate tables: Table 3 and Table 4.
— New interpretation flowchart and methodology with illustrative examples (Annex B).
— Updated fault definitions in Annex C.
— Introduction of the Duval Triangle and pentagon interpretations methods in 6.2 and in Annex D and removal of the Doernenberg and key gas methodology from main text.
— Addition of case studies in Annex E.
— Addition of Normalized Energy Intensity (NEI) methodology in Annex F.
— Preservation of deleted material with historical values in Annex G.
— An updated bibliography in Annex H.

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IEEE Guide for the Interpretation of Gases Generated in Mineral Oil-Immersed Transformers

1. Overview

Over the years, since transformer dissolved-gas analysis (DGA) was first used in the 1960s, accumulated experience and new technology have led to significant improvements. Gas formation processes and severity assessment are now better understood. Chart-based methods and slide rules have been replaced by modern computer-based technologies that bring improved communications, data management, graphical and computational aids, analysis, and electronic reports. Instrument technology has advanced greatly, providing better laboratory instruments, as well as field-portable gas analyzers and on-line gas monitors.

The fundamental purpose of DGA is to discriminate between normal and abnormal conditions. More specifically, DGA aims to provide a reliable and economical method of detecting faults, which may present unacceptable possibility of damage or near-term failure. In transformers, a fault is revealed by the production of new gases. In many cases, active faults generate gases at such a high rate that detection and assessment do not require finesse. On the other hand, the gases generated by a subtle, incipient, or intermittent fault can sometimes be difficult to distinguish from the background of residual gases already present in the transformer during "normal" operation. This situation can arise because of normal variations in gas concentrations due to load and environmental conditions; unavoidable random "noise" from measurement uncertainty (method repeatability and reproducibility), as well as data quality issues arising from poor sampling technique, exposure of samples to air, or mislabeling of samples. As with any decision process based on data subject to "random" interference, a method must be developed to minimize the number of false positives while also minimizing the number of false negatives, i.e., failures to detect real abnormalities.

DGA is one of the most widely used diagnostic tools for transformer condition assessment because experience has proven it to be an effective tool.

Even so, DGA has limitations that warrant some precautions in interpretation, such as:

— Samples can be incorrectly collected, identified, or processed. The veracity of dissolved gas data should be checked before remedial or emergency action is undertaken (i.e., a confirmation sample).

— Unusual causes of gas formation can misdirect DGA diagnosis. For example, when a pattern consistent with "stray gassing" is observed, the possibility of that explanation should be carefully considered before further action is taken.

— Gas concentrations alone are not a sufficient indicator of transformer condition. An understanding of how the gases were produced, and at what rates, is usually needed for judging the significance of the gases found in a sample.

— Multiple phenomena occurring simultaneously, or at different times, can confuse analysis. Examination of changes in gas concentrations helps to reveal the active processes.

— Rates and accelerations of gas formation provide the best basis for evaluating process development, but proper determination of gas formation rates and accelerations requires several measurements over time.

— Characterizing the rate and pattern of gas formation is not always sufficient to identify the origin of gas generation. Comparison with historical information, industry trends, and documented case histories can be helpful. Additional diagnostic tools, such as on-line and off-line electrical, mechanical or acoustic testing, internal inspection and other insulating liquid testing, may be needed.

This guide is based on the collective experience of the industry in using the strengths of DGA and managing its limitations to detect abnormal gas formation, identify its most probable causes, and follow its development to assess the severity of a developing abnormality.

1.1 Scope

This guide applies to mineral oil-immersed transformers and addresses:

a) The theory of combustible gas generation in a transformer
b) The interpretation of gas analysis
c) Suggested operating procedures
d) Various diagnostic techniques, such as Key Gases, Rogers Ratios, Duval Triangle, and other methods
e) Case studies and examples
f) Evaluation criteria and guidelines
g) A bibliography of related literature

1.2 Purpose

The purpose of this document is to provide a guide for evaluating dissolved gases analysis results from mineral oil-immersed transformers using statistical based analytical tools and fault interpretation methods.

1.3 Limitations to use of this document

This guide is applicable to mineral oil-immersed transformers and reactors of all types, sizes, voltage classes, construction, and usages, except those excluded in 1.3.

This guide is not applicable to DGA samples taken during factory testing. For DGA samples taken during factory temperature rise tests, refer to IEEE Std C57.130™ [B105].[1]

[1] The numbers in brackets correspond to those of the bibliography in Annex H.