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IEEE Standard Practices and Requirements for Semiconductor Power Rectifier Transformers

STANDARDS

IEEE Power and Energy Society

Developed by the
Transformers Committee

IEEE Std C57.18.10™-2021
(Revision of IEEE Std C57.18.10™-1998)

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Approved 9 November 2021

IEEE SA Standards Board

Abstract: Practices and requirements for semiconductor power rectifier transformers for dedicated loads rated single-phase 100 kW and above and three-phase 100 kW and above are included. Static precipitators, high-voltage converters for dc power transmission, and other nonlinear loads are excluded. Service conditions, both usual and unusual, are specified, or other standards are referenced as appropriate. Routine tests are specified, and an informative annex provides several examples of load loss calculations for transformers when subjected to nonsinusoidal currents, based on calculations provided in the standard.

Keywords: eddy current losses, harmonic load losses, IEEE C57.18.10™, single-phase transformers, three-phase transformers, three-winding transformers, transformer load losses, two-winding transformers

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3 Park Avenue, New York, NY 10016-5997, USA

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Introduction

This introduction is not part of IEEE Std C57.18.10-2021, IEEE Standard Practices and Requirements for Semiconductor Power Rectifier Transformers.

Early editions of ANSI C57.18 were written for transformers used with pool cathode mercury arc rectifiers. The last revision date for ANSI C57.18 was 1964. That standard did not reflect the practices that have developed with the use of semiconductor rectifying or converting devices, nor did it reflect the latest transformer technology. As a result, much of it is inconsistent with current practices and with other related standards that deal with semiconductor converters. This new standard is the result of the decision to write a new rectifier transformer standard instead of revising the old standard. Suggestions for improvement of these practices will be welcomed.

Basic impulse level (BIL) ratings for windings connected to converters are not specified by this standard. There are many practical reasons why windings connected to converters need not have a BIL test or rating. These windings are often high-current, low-voltage windings that will not produce ANSI standard waveforms when tested. Interleaved windings cannot be impulse tested easily. Usually the converter and the transformer are close coupled in a throat connection and not subject to lightning strikes. The converter usually cannot withstand normal transformer BIL ratings for the winding voltages to which they are connected. These conditions aren't always true, however. If a user wishes to have a BIL rating or test, this may be arranged through commercial negotiations and technical specifications that may override this standard. This should also be acknowledged by the transformer manufacturer during the bidding process.

Hottest-spot winding temperatures are referred to in this standard. These are not tested values. Hottest-spot temperatures cannot be measured from a practical standpoint on production units. Therefore, average winding temperatures plus a hottest-spot increment may be used. There is continuing work in other standards groups on this matter.

The methods of rating the transformer kVA and currents in previous editions of ANSI C57.18 were based on the rms equivalent of a rectangular current wave shape based on the dc rated load commutated with zero commutating angle. This is the rms kVA and current method. All the tables in Clause 10 are based on this traditional method. A new approach is to base the transformer kVA and currents on the rms value of the fundamental current and kVA. This is the fundamental kVA and current method. The fundamental kVA method is in use in IEC standards. This approach needs to be reflected in other IEEE standards as well as in this standard. The traditional tables are retained in Clause 10 to maintain its method. Both kVA values will be shown on the nameplate to accommodate either method. Specifying engineers should clearly define whether they are specifying the traditional rms kVA or the fundamental kVA to avoid confusion. RMS kVA is beneficial to users who utilize their primary metering on the transformer to monitor load. The fundamental kVA is related directly to the real power used by the rectifier or convertor. The rms kVA can be determined when the fundamental kVA is given along with the harmonic spectrum for the load. The specifying engineer is always obligated to supply the harmonic spectrum to properly rate and design the transformer. The specifying engineer has overall system responsibility; definition of the harmonic spectrum is not the transformer manufacturer's responsibility. The difference between the two methods should result in only a small percentage error in kVA sizing, but, in some cases, it may be determined to be critical. Future coordination with other IEEE standards working groups should give a final direction regarding the kVA rating method.

Two cautionary notes are in order regarding testing.

First, errors may result when measuring losses on transformers with low power factors. Care must be exercised in making the loss measurements for rectifier transformers with high reactance and low losses. Test tolerances should be held to 3% throughout the ranges of reactance and losses so as to accurately measure stray losses for the harmonic calculations. There is ongoing work on this subject within the Loss Measurement Working Group of the Performance Characteristics Subcommittee.

Second, other errors regarding resistance readings for losses or temperature rise tests are possible on low-voltage, high-current windings having very low resistance, often with bolted joints. Connection losses may alter normal resistance measurements. Work on this topic should be undertaken in the future. The exact methodology for temperature rise testing using service losses enhanced with harmonics needs to be more fully developed. After this standard has been in use, it is expected that manufacturers and users will develop more detailed preferred methods. Experience will also provide insight as to whether there are any serious shortcomings in these methods. It is hoped that they will be found to be safely conservative. It is believed that some development time is necessary with the new approach before exact methods are prescribed.

This revision includes more details of the following: methods of interphase transformer testing, phase shifted windings for harmonic cancellation, electrostatic ground shields, and more precise methods of determining losses for thermal and magnetic capability using finite element analysis (more work is needed regarding FEA).