

IEEE Trial-Use Guide for Testing Permanent Magnet Machines

IEEE Power and Energy Society

Sponsored by the
Electric Machinery Committee

And the
IEEE Industry Applications Society

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New York, NY 10016-5997
USA

IEEE Std 1812™-2014

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IEEE Industry Applications Society

Approved 10 December 2014

IEEE-SA Standards Board

Abstract: Contained in this trial-use guide are instructions for conducting tests to determine the performance characteristics and machine parameters of permanent magnet (PM) machines. The tests described may be applied to motors and generators, as needed, and no attempt is made to partition this guide into clauses applying to motors and clauses applying to generators. It is not intended that this guide shall cover all possible tests, or tests of a research nature, but only those general methods that may be used to obtain the performance data and machine parameters. The schedule of factory and field tests, which may be required on new equipment, is normally specified by applicable standards or by contract specifications. This guide should not be interpreted as requiring any specific test in a given transaction or implying any guarantee as to specific performance indices or operating conditions.

The term specified conditions for tests as used in this guide will be considered as rated conditions unless otherwise agreed upon. Rated conditions apply usually to the quantities listed on the machine nameplate.

Keywords: characteristics, IEEE 1812™, permanent magnet machines, testing

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PDF: ISBN 978-0-7381-9469-1 STD20066
Print: ISBN 978-0-7381-9470-7 STDPD20066

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Introduction

This introduction is not part of IEEE Std 1812™-2014, IEEE Trial-Use Guide for Testing Permanent Magnet Machines.

The Motors Subcommittee of the Electric Machinery Committee of the IEEE Power and Energy Society proposed the project since permanent magnet machines are being employed for many industrial applications and there is no existing guide for testing these machines. The PAR P1812 was approved by IEEE-SA on December 09, 2009. On May 19, 2011, the IEEE Industry Applications Society became a co-sponsor of this working group and its activities.

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1. Overview

1.1 Scope

This trial-use guide contains instructions for conducting tests to determine the performance characteristics and machine parameters of permanent magnet (PM) machines. The tests described may be applied to motors and generators as needed, and no attempt is made to partition this guide into clauses applying to motors and clauses applying to generators. It is not intended that this guide shall cover all possible tests, or tests of a research nature, but only those general methods that may be used to obtain the performance data and machine parameters. The schedule of factory and field tests, which may be required on new equipment, is normally specified by applicable standards or by contract specifications. This guide should not be interpreted as requiring any specific test in a given transaction or implying any guarantee as to specific performance indices or operating conditions.

The term specified conditions for tests as used in this guide will be considered as rated conditions unless otherwise agreed upon. Rated conditions apply usually to the quantities listed on the machine nameplate.

1.2 Purpose

Instructions for conducting tests to determine the performance characteristics and machine parameters of PM machines are covered in this guide. Additional tests can be required by the customers and operators to satisfy specific performance indices.

1.3 Organization of the guide

This guide consists of seven clauses. By following the IEEE 2012 style guide, the first three clauses are mandatory clauses for all new standards. Clause 1 gives an overview of the entire guide using the scope approved by the IEEE Standards Board. Clause 2 lists the normative references. Clause 3 includes the definitions. Clause 3 through Clause 6 are written in two parts, by following the structure of IEEE Std 115TM^{1,2}.

Clause 3 through Clause 5 constitute Part I and describe the steady-state and transient performance test procedures. Clause 4 describes the condition and integrity tests, some of which may precede the performance testing described in Clause 5 and Clause 6. Many of these tests are performed to assess the overall health of the machine. Since the PM excitation is usually employed in the rotor, the stator construction is often similar to the stator of the wound-field synchronous machines. Therefore, many stator-specific tests can be applied to PM machines by following IEEE Std 115. Clause 4 describes the steady-state performance tests. The term steady-state is defined for these tests in 4.5.1. Clause 5 describes the transient tests. These tests include retardation and sudden short-circuit tests.

Clause 6 constitutes Part II of the guide and describes the machine operating characteristics, such as losses, efficiency, thermal capability, torque-speed characteristics, and torque ripple. In the initial ballot, a Clause 8 was included to describe the test procedures for determination of model parameters. The Working Group decided not to include this clause for this ballot since there are many issues for different rotor configurations that have not been fully resolved to recommend the tests to the user. The publication of this guide should encourage users to contribute to the future revisions to resolve the testing issues for parameters in PM machines of various rotor configurations. References [B2], [B6], and [B8]³ can be used as the basis for the next revision.

Where the test procedure for a PM machine is the same as that for a wound-field synchronous machine, reference to the test procedure in IEEE Std 115 is provided in lieu of duplicating the same information in this guide. Consequently, the use of IEEE Std 115 in conjunction with this guide is recommended.

1.4 Instrumentation

Appropriate instrumentation requirements are generally the same as outlined in IEEE Std 115.

WARNING

Many tests described in this guide subject the machine to thermal, dielectric, or mechanical stresses that could extend beyond normal operating limits. To reduce the risk of damage to the machine or operators, it is recommended that all tests be performed either under the manufacturer's supervision or in accordance with the manufacturer's recommendations.

Because of the excessive currents, voltages, and forces encountered, adequate safety precautions should be taken for all tests. No attempt is made here to list or review the numerous general safety precautions that are well established throughout the industry. However, this guide recommends special safety precautions applicable to the particular tests described. Knowledgeable and experienced personnel should perform all tests.

¹ Information on references can be found in Clause 2.

² IEEE publications are available from The Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (<http://standards.ieee.org/>).

³ The numbers in brackets correspond to those of the bibliography in Annex A.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ASTM-G182, Standard Test Method for Determination of the Breakaway Friction Characteristics of Rolling Element Bearings.⁴

IEEE Std 43™, IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery.⁵

IEEE Std 56™, IEEE Guide for Insulation Maintenance of Large Alternating-Current Rotating Machinery (10 000 VA and Larger).

IEEE Std 95™, IEEE Recommended Practice for Insulation Testing of Large AC Electric Machinery (2300 V and Above) With High Direct Voltage.

IEEE Std 112™, IEEE Standard Test Procedure for Polyphase Induction Motors and Generators.

IEEE Std 115™, IEEE Guide for Test Procedures for Synchronous Machines, Part I—Acceptance and Performance Testing; Part II—Test Procedures and Parameter Determination for Dynamic Analysis.

IEEE Std 118™ (withdrawn), IEEE Standard Test Code for Resistance Measurement.⁶

IEEE Std 433™, IEEE Recommended Practice for Insulation Testing of AC Electric Machinery with High Voltage at Very Low Frequency.

IEEE Std C57.13™, IEEE Standard Requirements for Instrument Transformers.

NEMA MG1, Motors and Generators.⁷

PART I—TEST PROCEDURES

3. Condition and integrity tests

A number of tests within this category are common to other types (non-permanent magnet) of machines and have been described in IEEE Std 112 and IEEE Std 115. However, some tests are specific to the PM machines. To perform these tests, various standards besides those noted above have been referenced where applicable. The tests for which there are no known standards are described in detail.

⁴ ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, USA (<http://www.astm.org/>).

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⁶ IEEE Std 118 has been withdrawn; however, copies can be obtained from The Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (<http://standards.ieee.org/>).

⁷ NEMA publications are available from the National Electrical Manufacturers Association, 1300 N. 17th St., Ste. 1847, Rosslyn, VA 22209, USA (<http://www.nema.org/>).

3.1 Resistance measurement

To obtain dc resistance of armature and field winding (if applicable) at specified temperature, see IEEE Std 118.

3.2 Phase sequence

3.2.1 General

Phase sequence of PM machines are tested in a similar manner to the methods adopted in IEEE Std 115 for testing synchronous machines. However, attention should be paid to the issues emphasized here. Following the test procedures in IEEE Std 115, the phase sequence can be tested using the following methods:

- Method 1: Phase-sequence indicators
- Method 2: Indication of differential voltage
- Method 3: Direction of rotation for machines that can be started on a power source

Comments on these tests are given below.

3.2.2 Method 1: Phase-sequence indicators

During this test, it is recommended to run the PM test machine at a shaft speed to produce 50 Hz or 60 Hz output voltage. If the output voltage magnitude is compatible with the neon-lamp indicator input voltage, the test machine output voltage is directly connected to the sequence indicator. Otherwise, the connection can be made using voltage transformers. When it is necessary to connect a phase-sequence indicator to the machine terminals through voltage transformers, extreme care should be exercised in observing the conventions for polarity markings of the voltage transformers. (See 4.8.1 of IEEE Std C57.13.)

3.2.3 Method 2: Indication of differential voltage

In performing this test on a PM machine, the output voltage of the voltage transformers connected to the system and the test machine should be close in magnitude. This can be achieved by choosing appropriate turns ratio for the voltage transformers on either side of the disconnect switch.

3.2.4 Method 3: Direction of rotation for machines that can be started on a power source

The test procedure is the same as that described in 3.7.4 of IEEE Std 115.

3.2.5 Voltage unbalance

Voltage unbalance is defined in different ways in different standards. These definitions may be found in NEMA MG1 and in the European standard EN 50160 [B9]. Reference [B1] also gives a good discussion of the voltage unbalance issue.

3.3 Insulation resistance

See IEEE Std 43, IEEE Std 56, IEEE Std 95, and IEEE Std 433 for tests to determine insulation resistance.

3.4 Dielectric and partial discharge tests

Relevant clauses from IEEE Std 115 can be followed for these tests.

3.5 Polarity tests for magnets

The difference in polarity of the PM field poles can be checked by means of a small permanent magnet mounted so that it can turn and reverse its direction freely when it is in close proximity of the rotor. The magnet indicates a change in polarity by reversing direction as it is passed from pole to pole. The test magnets should be checked to determine that its magnetism has not been lost or its polarity reversed by the field flux. The open-circuit voltage magnitude is also a good indication of the magnets' health.

An alternate means of checking magnet polarity is to use a Hall probe sensor. The Hall probe has the advantage that it will not demagnetize and that it gives an order of magnitude of flux so that it is possible to check the polarity of individual magnet segments along a rotor pole.

WARNING

Use properly designed tooling for the Hall probe sensor so that it can be moved safely around the periphery of the rotor without the possibility of pinching body parts between the magnets and the probe.

3.6 Shaft and bearing current

There are two main classifications for bearing currents:

- a) Classical bearing currents (sometimes referred to as sinusoidally driven): associated with line operated machines and involve high voltage sinusoidal waveform (i.e., a non-pulse width modulated or PWM). See IEEE Std 115.
- b) Inverter driven bearing currents: inverter driven machines can cause bearing currents due to fast rise time (dv/dt) and magnitude of common mode voltage (V_{cm}).

It is the magnitude of these currents that may cause damage to the bearings. Bearing damage caused by electrical currents in machines are pits or transverse flutes burnt in the bearing race.

Testing methodologies in IEEE Std 112 and IEEE Std 115 can be followed for the classical bearing currents. There is no known standard (which this WG is aware of), for measuring bearing currents in inverter driven motors.

3.7 Over-speed tests

Reference should be made to IEEE Std 115. One of the primary concerns associated with PM machines is the magnet containment during an over-speed condition. Normally, the over-speed test is performed with no magnetic field in the machine. Since this is not possible for PM machines, care must be taken to coordinate the design of the insulation system to allow the over-speed test to be performed without damage if the rated voltage of the machine is exceeded during the over-speed testing.