

114™

IEEE Standard Test Procedure for Single-Phase Induction Motors

Industry Applications Society

Sponsored by the
Electric Machines Committee



Published by
The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

24 May 2002

Print: SH94969
PDF: SS94969

Recognized as an
American National Standard (ANSI)

IEEE Std 114™-2001
(Revision of
IEEE Std 114-1982)

IEEE Standard Test Procedure for Single-Phase Induction Motors

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Electric Machines Committee
of the
Industry Applications Society

Approved 2 May 2002
American National Standards Institute

Approved 6 December 2001
IEEE-SA Standards Board

Abstract: Instructions are given for conducting and reporting the more generally applicable and acceptable tests to determine the performance characteristics of single phase induction motors. Electrical measurements, performance testing, temperature tests, and miscellaneous tests are covered.

Keywords: electric motor, induction, single phase, test

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

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Print: ISBN 0-7381-3080-X SH94969
PDF: ISBN 0-7381-3081-8 SS94969

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Introduction

(This introduction is not part of IEEE Std 114-2001, IEEE Standard Test Procedure for Single-Phase Induction Motors.)

This introduction provides some background on the rationale used to develop this standard and is meant to aid in the understanding and usage of this document.

This standard describes laboratory tests conducted to evaluate the performance of certain single-phase induction motors. It is intended for the following:

- Individuals or organizations who use electric motors and purchase electric motors from manufacturers.
- Individuals or organizations who acquire electric motors for resale to other individuals or organizations.
- Individuals or organizations who influence how electric motors are purchased from manufacturers.
- Manufacturers interested in providing high-quality electric motors to the consumer.

This standard is designed to help organizations and individuals:

- Incorporate quality considerations during the design, evaluation, selection, and acceptance of single-phase induction motors for operational use.
- Determine how single-phase induction motors should be evaluated, tested, and accepted for delivery to end users.

This standard is intended to satisfy the following objectives:

- a) Promote consistency among electric motor manufacturers in the performance evaluation of single-phase induction motors.
- b) Provide useful practices for evaluating performance during the design of electric motors.
- c) Provide useful practices for evaluating and qualifying manufacturer capabilities to meet user requirements.
- d) Provide useful practices for evaluating and qualifying manufactured electric motors.
- e) Assist individuals or organizations judging the quality of single-phase induction motors delivered to end users.

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IEEE Standard Test Procedure for Single-Phase Induction Motors

1. Overview

This standard test procedure is divided into 13 Clauses. This overview as well as the scope and purpose of this standard test procedure are presented in Clause 1. References to other standards that are useful in applying this standard test procedure as provided in Clause 2. This standard test procedure covers a broad range of basic models of single-phase induction motors; common types of single-phase motors and the tests that are applicable to each are specified in Clause 3. Requirements for test instrumentation and other general testing facilities are presented in Clause 4. General procedures for electrical, mechanical, and temperature measurements are presented in Clause 5. General test procedures and safety requirements are presented in Clause 6. A general discussion of loss is presented in Clause 7. Test methods for determination of motor efficiency and power factor are presented in Clause 8. Methods for determination of other performance are presented in Clause 9. Temperature tests are presented in Clause 10. Miscellaneous tests are described in Clause 11. Typical forms for the reporting the results of routine test, complete test, and a determination of efficiency are provided in Annex A. Bibliographic references are provided in Annex B.

1.1 Scope

This standard covers instructions for conducting and reporting the more generally applicable and acceptable tests to determine the performance characteristics of single-phase induction motors, including non-excited synchronous motors. It is not intended that this standard shall cover all possible tests used in production or tests of a research nature. The standard shall not be interpreted as requiring the making of any or all of the tests described herein in any given transaction.

1.2 Purpose

This standard test procedure is meant to provide tests for use in evaluating the performance of single-phase induction motors.

2. References

This standard shall be used in conjunction with the following standards. If the following standards are superseded by an approved revision, the revision shall apply.

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

IEEE Std 4TM-1995, IEEE Standard Techniques for High-Voltage Testing.

IEEE Std 43TM-2000, IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery.

IEEE Std 85TM-1973 (Reaff 1986), IEEE Test Procedure for Airborne Sound Measurements on Rotating Electric Machinery.³

IEEE Std 118TM-1978 (Reaff 1992), IEEE Standard Test Code for Resistance Measurement.

IEEE Std 119TM-1974, IEEE Recommended Practice for General Principles of Temperature Measurement as Applied to Electrical Apparatus.⁴

IEEE Std 120TM-1989 (Reaff 1997), IEEE Standard for Electrical Measurements in Power Circuits.

ANSI/NEMA MG 1-1998 (Revision 1, 2000), Motors and Generators.⁵

3. General tests

Single-phase induction motors are normally given a routine test. A routine test includes measurement of input power and input current at no-load, measurement of input current with locked rotor, and a high-potential test. Measurements of input power and input current at no-load and with locked rotor are obtained at rated voltage and frequency. A typical form for reporting the results of a routine test is shown in Form 1, Annex A.

Additional tests may be conducted for a determination of efficiency, power factor, starting torque, pull-up torque, breakdown torque, rated-load slip, and load temperature rise. A typical form for reporting these additional test data is shown in Form 2, Annex A. Tests to determine locked-rotor temperature rise, speed-torque characteristics, noise, and vibration may also be conducted.

3.1 Schedule of tests

Common types of single-phase induction motors are listed in Table 1 together with tests applicable to each motor type. Test types in Table 1 correspond to the following as defined in *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition :⁶

- a) Locked-rotor current
- b) Locked-rotor torque
- c) Pull-up torque

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²IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

³IEEE Std 85-1973 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/>).

⁴IEEE Std 119-1974 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/>).

⁵ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

⁶The numbers in brackets correspond to those of the bibliography in Annex B.

- d) Switching torque
- e) Pull-in torque
- f) Breakdown torque
- g) Pull-out torque
- h) Speed
- i) Power factor
- j) Efficiency
- k) Temperature rise

Tests for speed, power factor, efficiency, and temperature rise are usually conducted at rated load; however, these tests may be conducted at any load, as required.

Table 1—Tests applicable to single-phase motors

	Test types										
	Locked-rotor current	Locked-rotor torque	Pull-up torque	Switching torque	Pull-in torque	Breakdown torque	Pull-out torque	Speed	Power factor	Efficiency	Temperature rise
Capacitor (permanent split)	X	X	X			X		X	X	X	X
Capacitor (two-value)	X	X	X	X		X		X	X	X	X
Capacitor-start	X	X	X	X		X		X	X	X	X
Split-phase	X	X	X	X		X		X	X	X	X
Shaded-pole	X	X	X			X		X	X	X	X
Repulsion	X	X				X		X	X	X	X
Repulsion-induction	X	X	X			X		X	X	X	X
Repulsion-start-induction	X	X	X	X		X	X	X	X	X	X
Reluctance (synchronous)	X	X	X		X	X	X	X	X	X	X
Universal ^a	X	X						X	X	X	X

^aThe tests listed apply to operation on alternating current only.

3.2 Tests with load

Tests with load are made for the purpose of determining efficiency, power factor, speed, and temperature rise. Some of the miscellaneous tests outlined in Clause 11 are also made with load. For all tests with load, the motor shall be properly aligned and securely fastened. For readings to be used in performance determinations, the motor temperature rise shall be between 50% and 100% of rated temperature rise. The usual procedure is to take readings at higher loads first and follow with readings at lower loads.

3.3 Tests with rotor locked

It should be recognized that the testing of induction motors under locked-rotor conditions involves high mechanical stresses and high rates of heating. Therefore, the following precautions are necessary:

- a) The mechanical means of locking the rotor must be of adequate strength to prevent possible injury to personnel or damage to equipment.
- b) The direction of rotation must be determined prior to test so that methods of fastening and of measuring torque can be properly applied.
- c) The motor is at approximately ambient temperature before the test is started.

Current and torque readings should be taken as quickly as possible after voltage is applied. The period of time between application of voltage and current and torque readings shall not exceed 5 seconds. The motor temperature should not exceed the rated temperature rise plus 40 °C.

3.4 Precautions

Inasmuch as the performance of a single-phase motor depends not only upon the voltage and frequency, but also upon the wave shape of the voltage, correct data can be obtained only by careful measurement and the use of a suitable source of power (see 4.2).

CAUTION

Many of the tests described in these procedures subject the motor to thermal and/or mechanical stresses beyond normal operating limits. To minimize the risk of damage to the motor, it is recommended that all tests be performed either under the manufacturer's supervision or in accordance with the manufacturer's recommendations.

4. Testing facilities

4.1 Instrument selection

Calibrated, high-accuracy instrumentation and accessory equipment shall be used. Either analog or digital-type instruments may be used in testing. Factors affecting accuracy, particularly with nonelectronic analog instruments, are

- a) Range, condition, and calibration of the instrument;
- b) Loading of the signal source; and
- c) Lead calibration.

Since instrument accuracy is generally expressed as a percentage of full scale, the range of the instrument chosen shall be as low as practical.

The indicating instrument shall bear record of calibration, within 12 months of the test, indicating limits of the error no greater than $\pm 0.5\%$ of full scale for general testing and no greater than $\pm 0.2\%$ for a determination of efficiency. When several instruments are connected in the circuit simultaneously, additional corrections of the instrument indication may be required.

Electronic instruments are generally more versatile and have much higher impedances than passive (non-electronic) instruments. Higher input impedance reduces the need to make corrections for the current drawn by the instrument. However, high-input impedance instruments are more susceptible to noise.

Common sources of noise are

- a) Inductive or electrostatic coupling of signal leads to power systems;
- b) Common impedance coupling or ground loops;
- c) Inadequate common mode rejection; and
- d) Conducted interference from the power line.

Good practice requires the use of shielded twisted pairs for signal leads, grounding the shield at only one point, and keeping signal cables as far away as possible from power cables. All exposed metal parts of instruments should be grounded for safety.

Instrument calibration requirements are similar to those of nonelectronic instruments. When suitable automatic data acquisition systems or high-speed recorders are available, they may be used. Further information regarding the use of instruments is given in IEEE Std 120-1989.⁷

4.1.1 Instrument transformers

When current and potential instrument transformers are used, corrections shall be made for ratio errors in voltage and current measurements and for ratio and phase angle errors in power measurements. The use of instrument transformers shall be avoided if possible (see IEEE Std 120-1989).

The errors of the instrument transformers used shall not be greater than 0.5%.

4.2 Power supply

The power supply voltage shall closely approach a sinusoidal waveform. The voltage waveform deviation factor, as defined in IEEE 100™, shall not exceed 10%. The frequency shall be maintained within $\pm 0.5\%$ of the value required for the test being conducted, unless otherwise specified. Any departure from the assumed frequency directly affects the efficiency. For a determination of efficiency, the average frequency shall be within $\pm 0.1\%$ of the required test value.

4.2.1 Frequency stability

Rapid changes in frequency cannot be tolerated in input-output tests because such changes in frequency cause changes in speed and the variations are transmitted to the output-measuring device. Variations in frequency during a test shall not exceed 0.33% of the average frequency.

5. Measurements

5.1 Electrical measurements

5.1.1 RMS quantities

All voltage and current measurements are rms values, unless otherwise indicated.

⁷For information on references, see Clause 2.

5.1.2 Voltage

The line voltage shall be measured with signal leads connected to the motor terminals whenever possible. If local conditions will not permit such connections, the error introduced shall be evaluated and the readings shall be corrected.

Means should be provided whereby the voltage can be adjusted to the desired value. This control can be effected by the use of a continuously variable transformer or auto-transformer, by an induction regulator, or by a controlled motor-generator set.

5.1.3 Current

The line current shall be measured by an ammeter or current transducer. The preferred arrangement of meters is shown by the circuit diagram in Figure 1.

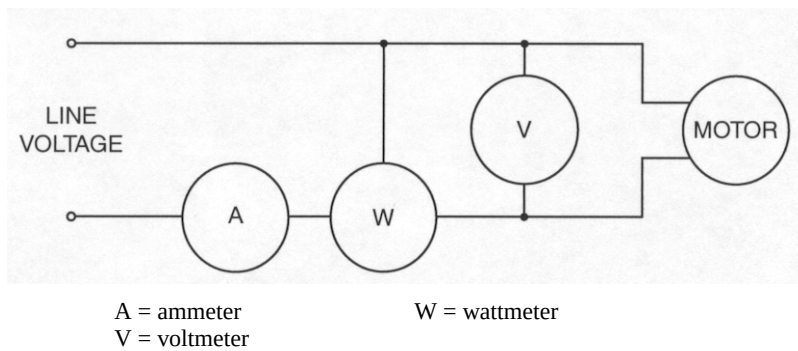


Figure 1—Preferred meter arrangement

The motor net current, I , is the true current input to the motor. It is obtained from the measured line current by subtracting the voltmeter and wattmeter shunt currents, and may be computed by using Equation (1):

$$I = \sqrt{I_A^2 - \frac{2P_W}{R_M} + \left(\frac{E}{R_M}\right)^2} \quad (1)$$

where

- I_A is the measured line current (A);
- P_W is the power indicated by wattmeter (W);
- E is the line voltage measured at the motor terminals (V);
- R_M is the resistance of the voltmeter and wattmeter voltage coils in parallel (Ω).

Alternatively, the motor net current may be computed by using Equation (2):

$$I = I_A - \frac{P_W}{I_A R_M} \quad (2)$$

provided the condition $I_A \geq 7E/R_M$ holds.

5.1.4 Power

A single-phase wattmeter or power transducer shall be used. The total watts read on the wattmeter, which shall be connected according to 6.1.1, shall be reduced by the amount of the power lost in the voltage circuit of the instruments. Where a properly selected power transducer is used, the transducer loss shall be shown to be negligible.

5.1.5 Resistance

The procedures given in IEEE Std 118-1978 should be used to obtain dc resistance measurements of the stator.

5.1.5.1 Reference ambient temperature

All performance determinations should be corrected to an ambient temperature of 25 °C.

5.1.5.1.1 Correction to a specified temperature

When the resistance of a winding has been determined by test at winding temperature t_t , the resistance may be corrected to a specified temperature t_s , as follows:

$$R_s = \frac{R_t(t_s + k)}{(t_t + k)} \quad (3)$$

where

- R_s is the corrected winding resistance (Ω);
- R_t is the measured winding resistance, (Ω), at temperature t_t ;
- t_s is the specified temperature for resistance correction (°C);
- t_t is the measured temperature of the winding (°C);
- k is a constant selected according to the wire type,
 k is 234.5 for 100% International Annealed Copper Standard (IACS) conductivity copper
 k is 225 for aluminum, based on a volume conductivity of 62%.

5.2 Mechanical measurements

5.2.1 Torque

The torque may be measured by dynamometer, with a brake or beam, with a rotating-shaft torque sensor, or by stator reaction.

5.2.2 Rotational speed

The instrumentation used to measure rotational speed shall not have an error greater than ± 1.0 r/min.

5.2.2.1 Stroboscopic methods

Stroboscopic methods are recommended when a motor of approximately 40 W or less is tested, due to the load added by the tachometer. Either an electronic or a mechanical stroboscope is satisfactory.

When measuring rotational speed using a stroboscope, the stroboscope should first be set at the synchronous speed of the motor under test and then reduced until the first sharp image is achieved. When the flash rate is set to zero and then increased, sharp images may be seen at rational intervals of the rotational speed.