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# Efficiency Test for Induction Motors with Agilent USB Data Acquisition (DAQ) Device

Application Note

Agilent Technologies

## Introduction

Motor efficiency remains one of the top issues for motor manufacturers. However, where efficiency is concerned, there are trade-offs. As cost is always an important factor, motor manufacturers need to find the right balance to increase motor output without driving up the cost.

Induction motors are considered the largest users of electrical energy among all motors. They are used in a wide range of commercial and industrial applications, including fans, compressors, pumps, conveyors, winders, mills, transports, elevators, home appliances, and office equipments.

This application note focuses on the IEEE 112 Method B test and how data acquisition can fulfill efficiency-test requirements.

### Efficiency Test Standards

There are three standards for the testing of induction motors.

One of the standards is the IEEE 112, which recognizes five methods for determining motor efficiency. Depending primarily on motor size, advantages of these methods include high accuracy, low cost, and ease of testing.

The IEEE 112 Method B test standard is the preferred method in the United States for poly-phase AC motors rated 1-125 HP, according to NEMA Standard MG 1-12.58.1. Other test standards include JEC 37 (Japanese) and IEC 34-2 (International).

Both test standards generally provide different values of efficiency compared to the IEEE 112 Method B test standard. Other countries may have a mix of the above-mentioned standards.

**Table 1** Methods of IEEE 112 test for determining motor efficiency

| Test | Test Method | Method Description |
|---|---|---|
| A | Brake | A mechanical brake is used to load the motor, and the reaction force is measured with limitations to fractional horsepower motors because of heat generated in the brake. |
| B | Dynamometer | A dynamometer loads the motor and output is measured by a scale or load cell and is easily controlled so that load points can be accurately set and remain stable while direct readings of torque and speed are taken. |
| C | Duplicate Machine | Two identical machines are coupled together and connected to two power sources - the frequency of one being adjustable. Rarely used except for large horsepower machines because it is time-consuming to set up and run. |
| D | Input Measurements | Input power is measured directly but motor output is calculated by deducting calculated losses from the input. Requires a separate test to measure stray load loss. |
| E | Equivalent Circuit | Can be used if no means of motor loading is available. The motor's equivalent circuit constants are determined from locked rotor, and no–load tests, and losses are calculated from the equivalent circuit. A separate test is required to determine stray load loss. |

## IEEE 112 Method B Test Standard

At this stage, it is important to note that the rated value of the motor efficiency is dependent on the test standard that it adheres to. This is because each standard adopts different methodologies and measurement procedures. However, similar methods can be derived from the information in this application note and used to measure the efficiency of the motor according to the specific requirements of the respective test standards.

The IEEE 112 Method B test standard is applicable for horizontal axis, polyphase, and squirrel-cage induction motors with power rating of less than 180 kW. This test method involves the following three tests.

- Rated load thermal test: The machine works at the rated load until the principal motor (stator winding, stator lamination core, and external frame) temperature deviation is within 1 °C, measured at 30 minutes. At the end of this test, the winding resistance is measured.
- No-load test: The motor, supplied with the rated voltage and frequency, runs without any mechanical load. A variable voltage test is performed when the bearings are stabilized between two consecutive measures with a 30-minute interval, and the input power does not increase by more than 3%.
- Variable load test: At rated conditions, when the steady state thermal condition is reached, the motor is loaded with six decreasing load torque values (from 150% to 25% of the rated motor torque). The winding temperature should not deviate more than 10 °C with reference to the rated one.

Method B is a direct measurement method that reads the input and output power directly from the motor shaft. The efficiency of the motor can be calculated as belows:

Efficiency

= Output/Input

= Output/(Output + Losses)

$$\frac{P_{mechanical}}{P_{electrical}}$$

$$= \frac{P_{mechanical}}{P_{mechanical} + \sum Losses}$$

Pmechanical represents the output power at the motor shaft, which is the electric power absorbed at the main power supply.

The losses (∑ Losses) that are associated with this method can be defined as follows:

- $P_{stator}$: Stator I²R loss at the specified temperature, as derived from the thermal load test
- $P_{friction + windage}$: Friction and windage loss, as derived from the no-load test
- $P_{core}$: Core loss, as derived from the no-load test, for the appropriate voltage
- $P_{stray}$: Stray load loss is calculated by $P_{stray} = P_{electrical} – P_{mechanical} – P_{conventional}$ . From the apparent total loss, stator I²R, core, friction, and windage losses are subtracted to obtain the stray load loss at that particular point.

The graph showing obtained squared load torque versus stray loss is plotted for the different loads.

The relationship between the squared load torque and stray loss is governed by the equation.

$$P_{stray} = AT_{shaft}^2 + B$$

, where A and B are constants determined from the graph.

A typical graph is shown below.

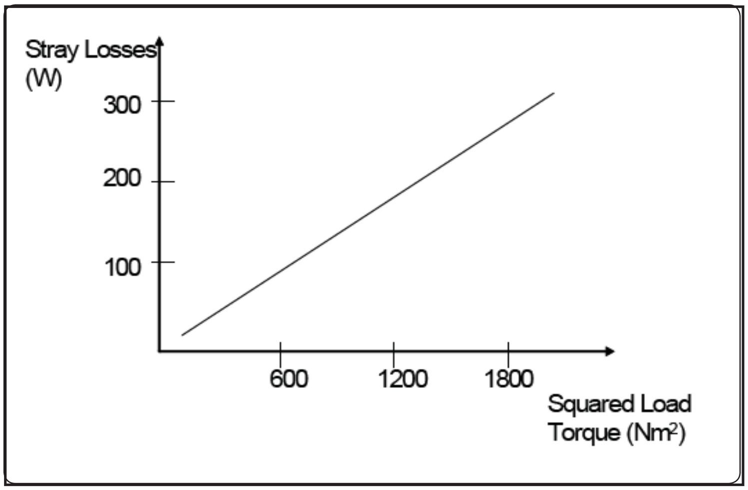

**Figure 1** Graph of squared load torque versus stray loss

Using these tests, it is possible to determine all contributed motor loss, and thereby to calculate motor efficiency. Conventional iron ($P_{conventional}$) and mechanical ($P_{mechanical}$) losses are evaluated by the no-load test. Through the load test, the stator and rotor Joule losses ($P_{Js}$ and $P_{Jr}$) are evaluated, whereas the stray losses are calculated by the variable load test data using the equation, $P_{stray} = (P_{electrical} – P_{mechanical}) – P_{conventional}$ .

The obtained stray-loss-versus-squared-load-torque curve is then plotted and smoothed using linear regression. If the slope of the linear regression line is negative or the correlation factor is less than 0.9, the worst point is deleted and the regression has to be repeated.
If this operation increases the correlation factor to 0.9 or higher, the second regression is considered valid. Otherwise, if the slope is still negative, the test is unsatisfactory and must be repeated.

For efficiency calculation, the standard IEEE 112 Method B test requires that some loss terms be corrected. In particular, the stray loss has to be considered zero at a null load.

The stator and rotor Joule losses have to be recorded at the same over-temperature measured in the tests, considering an ambient temperature of 25 °C. For the rotor Joule loss, this correction takes into consideration the slip value. The motor winding temperature can be measured using the embedded sensor method or by the resistive method (measurement of the stator winding resistance upon shutdown of the voltage supply).
t Electrical quantities need to be measured with an accuracy higher than 0.2%, a voltage stability of 0.5%, and a frequency tolerance of 0.1%. The absolute maximum speed error is 1 rpm.

## Measurement setup

To test the efficiency of the induction motor, Agilent Technologies proposes the setup shown in Figure 2.

The power transducer is used to measure the input power to the motor ($P_{electrical}$) while the torque and temperature sensors are used for $P_{mechanical}$ and temperature measurements, respectively. These three instruments are connected to the data acquisition (DAQ) device that transfers the data acquired to the PC for display and post analysis.

## Advantages of Agilent USB DAQ

Key advantages are as follows:

•Motor efficiency can be measured easily using appropriate sensors or transducers.

•For any additional measurement, like the start-up (inrush) current test, a current transducer is sufficient without having to get a new oscilloscope.

•A USB port is a common standard interface for PCs and no additional hardware is required.

•If the channel count is insufficient, the module can be fitted into a a chassis. For the U2300A Series DAQ devices, slotting into the U2781A USB instrument chassis can provide up to 384 single-ended channels.

## Conclusion

Efficiency testing for induction motors can be made with just one interface to the PC by using the Agilent USB DAQ device. The USB DAQ device is able to meet a broad range of test measurement requirements by employing the relevant sensors or transducers.

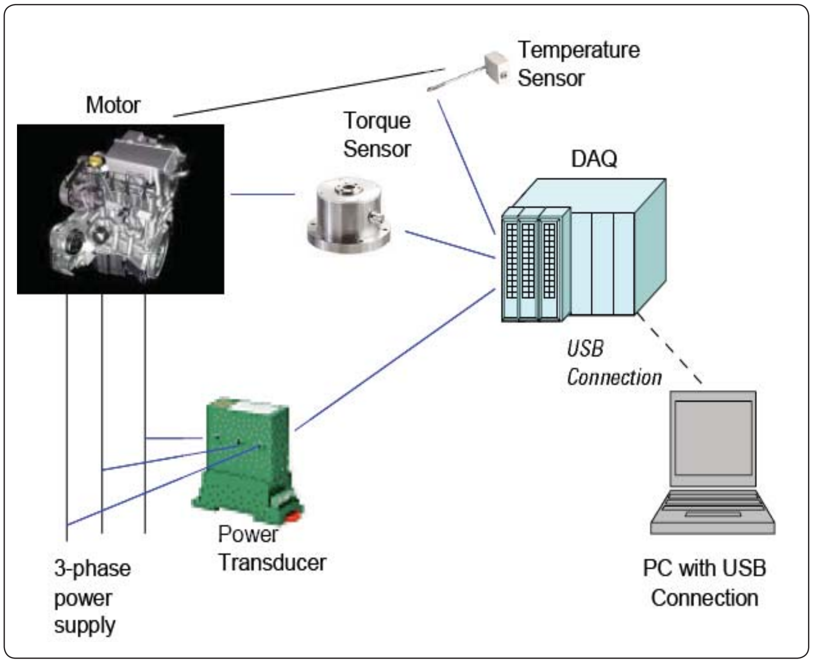

**Figure 2** Measurement setup using Agilent's USB DAQ device

## References

•Anibal T. de Almeida, Fernando T. E. Ferreira, John F. Busch, and Pierre Angers, 2001 IEEE, *Comparative Analysis of IEEE 112-B and IEC 34-2 Efficiency Testing Standards using Stray Load Losses in Low Voltage Three-Phase, Cage Induction Motors by*

•A. Boglietti, A. Cavagnino, M. Lazzari, M. Pastorelli, 2003 IEEE, *Induction Motor Efficiency Measurements in accordance to IEEE 112-B, IEC 34-2 and JEC 37 International Standards*

## Related Agilent Literature

•*System Developer Guide - Using USB in the Test and Measurement Environment,* literature number 1465-12

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