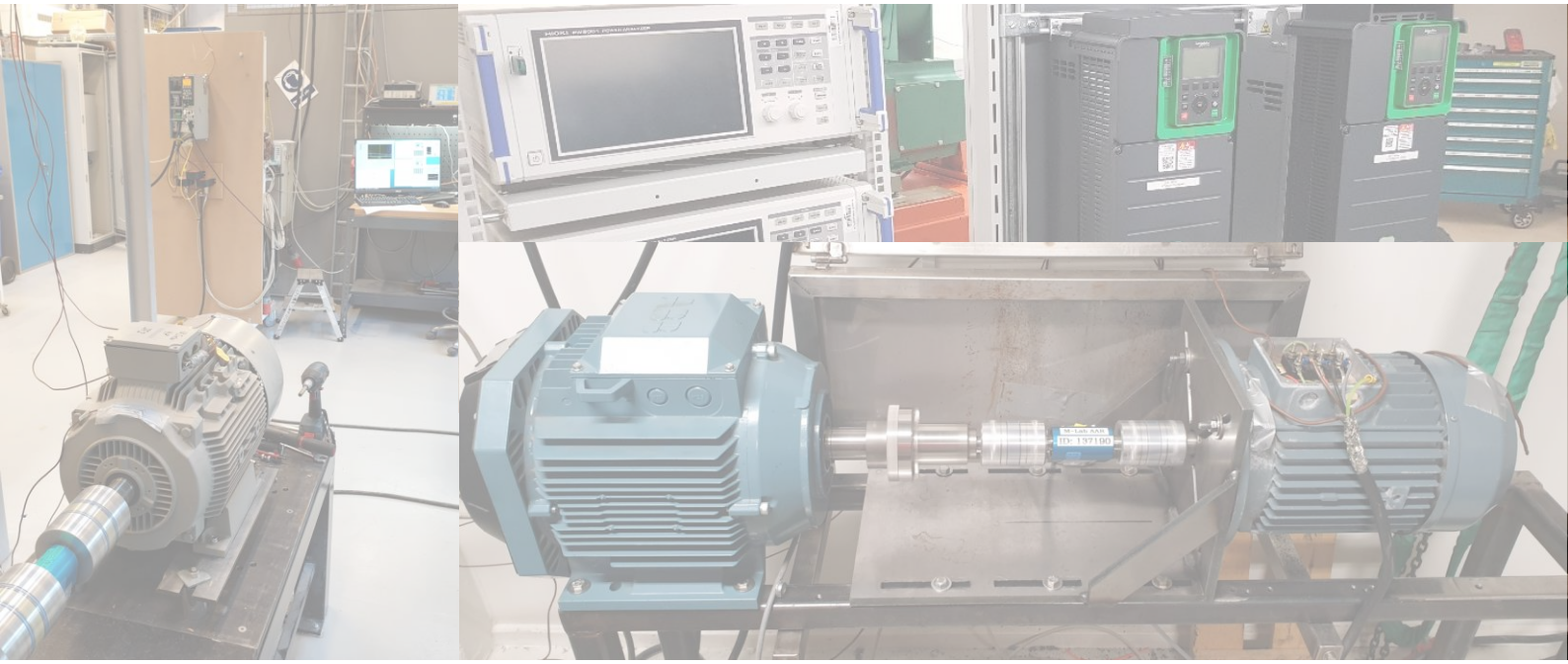
Electric Motor Systems
EMSA



Report on Test Standards for Advanced Motor Technologies

Elaborated by: Lawrence Berkeley National Laboratory

July 2020

Technology Collaboration Programme
by iea

Electric Motor Systems Annex – 2020

The report was prepared under the IEA Technology Collaboration Programme on Energy Efficient End-Use Equipment (4E) – **Electric Motor Systems Annex** (EMSA) program.

The report has been formally approved by the EMSA Members on their Meeting in May 2020.

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Acknowledgements to contributors and reviewers:

The authors are very much indebted to the following expert and organization, who generously supported the elaboration of the report with his significant technical knowledge, text and review contributions.

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Abstract:

The report identifies and compares existing test standards for selected advanced motor technologies. The input-output method seems to be a feasible and simpler test method, when applied with state of the art measurement equipment. Although this method is included in all test standards reviewed, the details of its implementation vary and could represent an opportunity for harmonization across standards for same equipment.

About the IEA 4E Electric Motor Systems Annex (EMSA):

Electric motor systems consume annually about 10 700 TWh worldwide and are responsible for 53% of the global electric energy consumption (2015). This corresponds approximately to the combined electricity consumption of China, the European Union (28 countries) and the USA. The goal of the Electric Motor Systems Annex EMSA is to increase energy efficiency and reduce greenhouse gas emissions worldwide by promoting highly efficient electric motor systems in the EMSA member countries, in industrialised countries as well as in emerging economies and developing countries.

Further information on EMSA is available at: www.motorsystem.org

About the IEA Implementing Agreement on Energy Efficient End-Use Equipment (4E):

The Technology Collaboration Programme on Energy Efficient End-Use Equipment (4E TCP), has been supporting governments to coordinate effective energy efficiency policies since 2008. Fourteen countries and one region have joined together under the 4E TCP platform to exchange technical and policy information focused on increasing the production and trade in efficient end-use equipment. However, the 4E TCP is more than a forum for sharing information: it pools resources and expertise on a wide a range of projects designed to meet the policy needs of participating governments. Members of 4E find this an efficient use of scarce funds which results in outcomes that are far more comprehensive and authoritative than can be achieved by individual jurisdictions. The 4E TCP is established under the auspices of the International Energy Agency (IEA) as a functionally and legally autonomous body.

Current members of 4E TCP are: Australia, Austria, Canada, China, Denmark, European Commission, France, Japan, Korea, Netherlands, New Zealand, Switzerland, Sweden, UK and USA.

The main collaborative research and development activities under 4E include the

- Electric Motor Systems Annex (EMSA)
- Monitoring, Verification and Enforcement (MV&E)
- Solid State Lighting (SSL) Annex
- Electronic Devices and Networks Annex (EDNA)
- Power Electronic Conversion Technology Annex (PECTA)

Further information on the 4E TCP is available from: www.iea-4e.org

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1. Background

With the market introduction of advanced motor technologies there is increased demand for reliable energy performance information. In addition, different countries have already developed different test procedures for similar equipment (e.g. AHRI 1210, IEC 61800-9-2). This document identifies existing test standards for selected advanced motor technologies and discusses opportunities for potential test procedure harmonization for each categories of equipment analyzed.

2. Scope

This document provides a brief review of existing test standards for the following equipment:

- Converter-fed motors – motor only (i.e. permanent magnet motors, switched reluctance motors, synchronous reluctance motors);
- Drives (converter, or complete drive module "CDM"); and
- Power drive systems ("PDS") (i.e. motor and drive combination).

3. Existing Test Standards

Table 1 provides a short summary of the metrics, methods, and test conditions used across the industry standards reviewed. Although Table 1 includes test standards for converted-fed motors, drives, and PDS; comparison should only be done across test standards for the same equipment category. The comparison focuses on the efficiency test portion of the test standards and on the equipment set-up and test conditions (i.e. the review does not include other aspects of the test standards such as measurement equipment accuracy requirements, etc.). Other test standards for these products exist but are not as widely used or were not recently updated and were not included (e.g. IEEE 1812-2014 for polyphase permanent magnet motors). Each of the test standard reviewed is relatively new and may require future revision to ensure repeatable and comparable results. The ongoing EMSA round robin project provides a good example of how additional laboratory tests can help inform the revision of a standard. [8]

3.1 Test method

Different methods are currently used to test the efficiency of advanced motor technologies (i.e. input-output, summation of losses, and calorimetric – see Table 1). However, one common test method across all test standards is the input-output method. It is a simpler, and typically less time consuming method but can yield to less accurate results when compared to the loss-segregation and calorimetric methods. However, with state of the art measurement equipment, the input-output method uncertainty can approximates the loss segregation method uncertainty and could be considered as a simpler alternative [6], [7]. The 2019 pre-release version of IEC 60034-2-3, includes method of test with a "comparable converter" (i.e. a standardized converter) based on an input-output test while its previous (2013) version used the summation of losses method when testing with a "comparable converter".

Table 1: Summary of Existing Test Standards

Test Standard	Equipment Tested	Metric	Method(s)	Equipment set-up	Test points	Notes
IEC 60034-2-3 (PRV) [1]	Converter-fed AC Motors Up to 1kV	Motor Efficiency / Losses • Compliance with the IE class is evaluated at rated torque and 90% rated speed[1]	• Input-output method; or • Summation of losses with specific converter; Also include two calculation / analytical tool approaches: • Alternate Determination Method • Determination of efficiency by calculation	• When using a "*comparable converter*", the drive is parametrized in accordance with the standard, or • When using the converter supplied with the motor, the drive is set-up according to manufacturer's instructions.	Seven speed/torque points[2] - some of which are also included in IEC 61800-9-2, [2]	• The summation of loss methods allow the determination of the additional harmonic losses resulting from a non-sinusoidal power supply in the final application (i.e. combined with the converter to be used in actual application) • The standard also includes an interpolation method to determine losses at any operating points.
IEC 61800-9-2 [2]	Drive (CDM) PDS	CDM and PDS Losses[3] • For CDMs, compliance with the IE class is evaluated at rated current and 90% rated motor stator frequency (single point). • For PDS, Compliance with an IES class is evaluated at rated torque and rated speed (single point).	• Input-output method; or • Calorimetric measurement. Also includes a loss calculation method which relies on a mathematical model and does not require testing.	• Drive is set at factory default settings • Motor selection is based on CDM output power	Eight frequency/torque producing current points (CDM) and speed/torque points (for PDS)[4]	EMSA Round Robin activity will inform revision of this test standard.
AHRI 1210/1211 ASHRAE 222 [3],[4]	Drive (CDM) Low voltage (<600V) Used in asynchronous motors [5]	PDS Efficiency The standard does not identify standardized operating point(s) to use when comparing the losses of different drives	• Input-output method	• Drive is set-up according to manufacturer's instruction • Uses a "test motor" described as a NEMA Design B 4-pole motor matching the drive voltage and horsepower.	Seven speed/torque points[6]	Intended to provide guidance to users and VFD specifiers – The test also includes a measurement of the motor "stress" (i.e. peak voltage and rise time) and total harmonic distortion.
CSA C838 [5]	PDS Low voltage (<750V) Three phase output	• CDM, Motor, and PDS efficiency. • Reporting of efficiency is done at three frequency/ torque/ power (% of the motor's rated values) points: (100;100;100);(75;56;42); and (50;25;12.5)	• Input-output method	• Drive is set at factory default settings. Any deviation must be documented.	Twenty frequency/torque points[7]	Annex A includes a method to determine the additional motor losses during the operation with a drive by using the losses under sinusoidal excitation as a reference

[1] IEC TS 60034-30-2 establishes efficiency classes for converter-fed motors (IE).
[2] Seven speed/torque point at (90,100),(50,100),(25,100),(90,50),(50,50)(50,25),and (25,25) of motor rated speed/torque.
[3] IEC 61800-9-2 establishes efficiency classes for CDMs (IE) and PDS (IES).
[4] Eight frequency/torque producing current points for CDM defined as follows: (0;25);(0;50);(0;100);(50;25);(50;50);(50;100);(90;50); and (90;100) percent of CDM rated frequency/torque producing current and eight speed/torque points for PDS defined as follows: (0;25);(0;50);(0;100);(50;25);(50;50);(50;100);(100;50); and (100;100) percent of motor rated speed/torque.
[5] Does not apply to integrated drives (only applies to standalone drives)
[6] Seven speed/torque points: (40;16);(50;25);(75;56);(40;100);(50;100);(75;100); and (100;100) percent of motor rated speed/torque.
[7] Twenty points: (100;100);(100;75);(100;50);(100;25);(100;10);(75;100);(75;75);(75;50);(75;25);(75;10);(50;100);(50;75);(50;50);(50;25);(50;10); (25;100);(25;75);(25;50);(25;25);(25;10) percent motor rated frequency/torque.

3.2 Equipment set-up and test points

Several challenges are associated with testing advanced motor technologies and comparing efficiency in a repeatable and meaningful way:

- Advanced motor technologies are sold in different configurations: as a motor only, an integrated motor-drive unit, or as a packaged motor and drive;
- In addition to identifying standardized operating point(s) to provide comparable efficiency figures, there is a need to characterize the efficiency of this equipment across its full range of operation to support the development of equipment-level performance metrics across a wide range of applications (e.g. pump, fan, etc.); and
- The drive user settings (e.g. switching frequency, amplitude modulation index) can influence the drive, motor, and PDS losses and could impact the efficiency/losses determination.

The test standards reviewed apply the following strategies to address these challenges:

- Specify standardized components parameters and settings: a “comparable converter” when testing a converter-fed motor (see IEC 60034-2-3) or instructions to select a motor when testing a drive (see IEC 61800-9-2 and AHRI 1210/1211);
- Specify standardized operating point(s) to allow comparison of efficiency figures;
- Specify several test points that can be used to interpolate the losses and efficiency of the equipment across its full range of operation and for a specific application; and
- Require to set the drive to its default factory settings or according to manufacturer instructions or specifying how to adjust the drive settings.8

Although these approaches are common across standards, the details of their implementation vary and could represent an opportunity for harmonization. For example: the motor selection approaches in IEC 61800-9-2 and AHRI 1210 do not follow the same requirements. Also, although AHRI 1210 is intended to provide ratings of drive, it relies on a PDS efficiency metric and uses motor characteristics to define operating points (speed and torque). The IEC 61800-9-2 method relies on a drive efficiency/losses metric and on characteristics of the drive (frequency and torque producing current).

4. Conclusion

When comparing the performance of different advanced motor technology equipment at standardized operating point(s), the input-output method seems to be a feasible and simpler test method, when applied with state of the art measurement equipment. Although this method is included in all test standards reviewed, the details of its implementation in terms of test points and equipment set-up vary and could represent an opportunity for harmonization across standards for same equipment (i.e. ASHRAE 1210/1211 and IEC 61800-9-2 for drives, CSA 838 and IEC 61800-9-2 for PDS).

[8] For example, IEC 60034-2-3 includes several requirements for the test drive, including the following: the switching frequency has to be fixed (4kHz at or below 90kW or 2 kHz above 90kW), and the slip compensation and current feedback must be deactivated).

5. References

[1]. IEC 60034-2-3:2019 (PRV) Rotating electrical machines - Part 2-3: Specific test methods for determining losses and efficiency of converter-fed AC induction motors. (Pre-Release Version) Available at https://webstore.iec.ch/publication/123 (Note: Final version is scheduled to be published in February 2020)

[2]. IEC 61800-9-2:2017 Adjustable speed electrical power drive systems - Part 9-2: Ecodesign for power drive systems, motor starters, power electronics and their driven applications - Energy efficiency indicators for power drive systems and motor starters. Available at https://webstore.iec.ch/publication/31527

[3]. AHRI 1210 (I-P) and AHRI 1211(SI) (2019) Performance Rating of Variable Frequency Drives. Available at http://www.ahrinet.org/search-standards

[4]. ANSI/ASHRAE Standard 222-2018 Standard Method of Test for Electrical Power Drive Systems https://webstore.ansi.org/standards/ashrae/ansiashraestandard2222018

[5]. CAN/CSA C838-2013 (R2018) Energy efficiency test methods for three-phase variable frequency drive systems. Available at https://store.csagroup.org

[6]. P. Angers, “Variable Frequency Drive Testing Standards Review” in Proceedings of the Motor Summit, Zurich, Switzerland, 2016, pp. 58-59.

[7]. H. Kärkkäinen, L. Aarniovuori , M. Niemelä, J. Pyrhönen, “Converter-Fed Induction Motor Efficiency: Practical Applicability of IEC Methods”, in IEEE Industrial Electronics Magazine, June 2017.

[8]. E. Agamloh, A. Baghurst, C. Brunner, S. Nielsen, A. Vezzini, “Round Robin of Converter Losses, Report of Results of Phase 1”, 4E Electric Motor Systems (EMSA) Zurich, Switzerland, 2019.