SEAD Policy Exchange Forum

Electric Motors and Motor Systems: Challenges and Solutions for Effective Energy Efficiency Regulation

2 April, 2019
12:00 PM - 2:00 PM (UTC)
Welcome, Introductions & Agenda

Lina Kelpsaite, CLASP
Who is on today’s call?

- **CLASP** - SEAD Operating Agent and SPEx coordinator
- Presentations from:
  - IEA 4E Electric Motor Systems Annex
  - European Commission
  - Laboratory for Electrical Machines and Drive Systems at Bern University of Applied Sciences
  - Regal Beloit, representing National Electrical Manufacturers Association
- Participants on today’s call include policy makers, industry representatives, civil society, consultants, international organizations
SPEx Call Agenda

• Welcome, Introductions, and Agenda Review
• Introduction and Overview of Electric Motor Technologies, Standards & Challenges
• Case Studies:
  – *The Energy Efficiency Policy for Motors in European Union*
  – Challenges and Requirements for Electric Motor Efficiency Testing
  – *Global Motor Energy Efficiency Program: Reduced Trade Barriers and Other Benefits*
• Q&A and Group Discussion
• Closing Remarks
Webinar Guidelines

• All on mute during the presentations
  – Submit questions via the webinar chat application
  – Raise Hand feature also available

• If you have questions:
  – Please introduce yourself (Name and Organization)
  – Clarifying questions can be asked after each presentation
  – Share discussion questions for Q&A and General Discussion session

• During Q&A and General Discussion session:
  – All participants will be unmuted
  – If not speaking, please mute your devices

• Record of discussions
  – Webinar is being recorded
  – Presentations and Summary of Discussions available on SEAD website
A Global Initiative:
SEAD governments work together to save energy
Foster Global Collaboration & Partnership

SEAD increases visibility of energy efficiency at the highest levels
Welcome to the SPEx!

A tool to engage with industry

Voluntary peer-to-peer collaboration

Share experiences & best practices

Strengthen relationships & improve coordination
Introduction and Overview of Electric Motor Technologies, Standards & Challenges

Maarten van Werkhoven – IEA 4E Electric Motor Systems Annex
Maarten van Werkhoven – Operating Agent, IEA 4E Electric Motor Systems Annex

Maarten is a consultant on Energy Efficiency & Sustainability with TPA Advisors, where he has worked since 2004 on both international activities and in The Netherlands.

Currently he serves as Operating Agent for IEA 4E EMSA: Electric Motors Systems Annex. He is also a member of IEC ACEE: Advisory Committee on Energy Efficiency - TG 6; and has worked internationally on industrial energy efficiency projects.

In The Netherlands, Maarten has worked on Green Deal on motor systems, Pilot Audit program for industrial motor systems and the Knowledge Network efficient electric motor systems.
Introduction and Overview of Electric Motors Technology, Standards & Challenges

SPEx webinar

2 April 2019

Maarten van Werkhoven
Global electricity consumption

- Motors: 53%
- Heating: 18%
- Lighting: 15%
- Appliances: 11%
- Electrolysis: 3%

Source: IEA World Energy Outlook 2016
Electric Motor Systems

Motor System

Motor Driven Unit

Variable Frequency Drive

Motor

Mechanical Equipment
Gear, belt, clutch, brake

Driven Application
Pump, fan, compressor, transport

Mains

Flow/Motion
Global electricity use: 53% motors

Source: IEA World Energy Outlook 2016
Global electricity use: 53% motors - Industry

MOTORS ACCOUNT FOR MORE THAN HALF OF TODAY’S ELECTRICITY CONSUMPTION

Source: IEA World Energy Outlook 2016
The majority of electric motors are still at lower efficiency levels

- The majority of electric motors are at the lower (IE0 or IE1) efficiency levels
- China dominates global electric motors energy use and will continue to do so

Energy consumption of electric motor systems by efficiency level (left) and regional breakdown of electric motor energy use (right)

Source: IEA Energy Efficiency 2018
Energy Efficiency - benefits

• Energy Efficiency alone can result in a peak before 2020 and fall to levels 12% lower than today by 2040
• Global GDP could double between now and 2040 for only a marginal increase in energy demand
Standards: Motor efficiency (IE-Code)

Electric motors: 4 pole, 50 Hz

Source: Impact Energy, based on IEC 60034-30-1, 2014
Rotating electrical machines - Part 30-1: Efficiency classes of line operated AC motors (IE code)

Scope of IE-code for motors:

• Output power 0.12 kW - 1000 kW
• 2-, 4-, 6-, 8-pole motors
• Low voltage < 1000 V
• 50 Hz and 60 Hz
• Nominal efficiency at 100% load (torque and speed)
• Classes for efficiency IE1, IE2, IE3 and IE4

• Efficiency based on testing method in IEC 60034-2-1
### Group of motor standards - *line operated AC motors*

<table>
<thead>
<tr>
<th></th>
<th>IEC 60034-1</th>
<th>IEC 60034-2-1</th>
<th>IEC 60034-30</th>
<th>IEC/TS 60034-31</th>
<th>IECEE e3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SCOPE</td>
<td>TESTING</td>
<td>EFFICIENCY CLASSES</td>
<td>GUIDE</td>
<td>CERTIFICATION</td>
</tr>
<tr>
<td>2</td>
<td>standard use conditions, only selected technologies in the scope</td>
<td>one preferred testing method, procedure prescribed in detail (accuracy, repeatability); check-testing!</td>
<td>4 major efficiency classes: IE1 &gt; IE2 &gt; IE3 &gt; IE4, open to advanced technology</td>
<td>background, application, context, system integration, tools?</td>
<td>conformity assessment, lab accreditation, expert training, round robin, global label</td>
</tr>
</tbody>
</table>

IECEE: System of Conformity Assessment Schemes for Electrotechnical Equipment and Components
### Motor MEPS* worldwide (Minimum Energy Performance Standards)

<table>
<thead>
<tr>
<th>Efficiency Levels</th>
<th>Efficiency Classes</th>
<th>Testing Standard</th>
<th>Performance Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-phase induction motors (Low Voltage &lt; 1000 V)</td>
<td>IEC 60034-30-1, 2014</td>
<td>IEC 60034-2-1, 2014</td>
<td>Mandatory MEPS*</td>
</tr>
<tr>
<td>Global classes IE-Code</td>
<td>incl. stray load losses</td>
<td>National Policy Requirement</td>
<td></td>
</tr>
<tr>
<td><strong>Super Premium Efficiency</strong></td>
<td>IE4</td>
<td>Preferred Method **</td>
<td>EU 28 ** (75 - 200 kW)</td>
</tr>
<tr>
<td><strong>Premium Efficiency</strong></td>
<td>IE3</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>High Efficiency</strong></td>
<td>IE2</td>
<td>Summation of losses with load test: Additional losses $P_{CL}$ determined from residual loss</td>
<td></td>
</tr>
<tr>
<td><strong>Standard Efficiency</strong></td>
<td>IE1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

28 03 2019
Impact Energy Inc. & TPA advisors © EMSA 2019

I) Output power: 0.12 kW - 1000 kW, 50 and 60 Hz, line operated
II) for 3-phase machines direct online, < 1 kW, *) Polyphase: eq. to IE3, single phase: IE2 levels or above
II) rated output power < 1000 kW
***) Tier1: per 19/7/21; Option IE2+VSD removed (0.75-375 kW)
III) Minimum Energy Performance Standard
Tier2: 1/7/2023, 1-phase >0.12 kW IE2: 0.75-75 / 200-1.000 kW IE3
****) IE3 per 30-8-2019; 0.12 - 370 kW
***** IE2 planned per Aug. 2018

Vietnam

Note: Efficiency Classes and Testing Standards vary depending on the country's specific regulations and standards.
Motor Minimum Energy Performance Standards worldwide

Efficiency Classes:
IEC 60034-30-1, 2014
Output power: 0.12 - 1000 kW
50 Hz and 60 Hz, line operated
2-, 4-, 6-, 8-poles

Motors: electricity use & efficiency development

Global industrial electricity consumption by motor efficiency class

- Motor electricity use almost doubles between now and 2040, but
- in 2040 more than 60% will come from IE3 motors and better (under IEA policy scenario NPS)

Source: IEA World Energy Outlook 2016
Summary

• Electric motors consume more than half of the global electricity production
• The biggest energy savings come from high efficiency electric motors, well integrated into motor systems for pumps, fans, compressors, machines
• Electric motors are globally traded
• Rolling stock is too old
• Harmonized IEC standards can be directly used as basis for Minimum Energy Performance Standards (MEPS)
  − IEC testing standards for motors, motors driven by converters and converters
  − IEC efficiency classes for motors and converters
EMSA Electric Motor Systems Annex

- 4E countries: 13 (+CA, CN, FR, KR, JP, SW, UK)
- EMSA countries: 7
- [www.motorsystems.org](http://www.motorsystems.org)
- Goal: help governments design & implement successful EE policies
Successful policy implementation, Sources

- IEA 4E EMSA publications
  Download: [www.motorsystems.org](http://www.motorsystems.org)

- UN Environment Program initiative United for Efficiency (U4E)
  - Policy Guide Energy Efficient Electric Motors and Motor Systems
  - Model Regulation for MEPS for electric motors
  Download: [www.united4efficiency.org/](http://www.united4efficiency.org/)
Ronald Piers de Raveschoot is a mechanical engineer (Université Catholique de Louvain) with a MSc in Environmental Management (Imperial College of London). After working in energy-related industries for seven years he moved to the public sector, first in the Brussels Capital Region administration for environment and energy, where he headed the energy sub-division, and then at the European Commission. In the period 2009-2016 he worked at the Joint Research Centre (JRC), the Commission's science and knowledge service. He was in charge of providing scientific support to several EU initiatives and projects in the field of energy and environment.

In 2017 he moved to DG ENER as Policy Officer in the field of product energy efficiency (Ecodesign and Energy Labelling), mainly focusing on electric motors and their applications such as pumps, fans and others.
SEAD Policy Exchange Forum (SPEx) on motors - webinar 2 April 2019

Electric Motors and Motor Systems: Challenges and Solutions for Effective Energy Efficiency Regulation

The Energy Efficiency Policy for Motors in European Union

Ronald Piers de Raveschoot
Policy Officer
Energy Efficiency
Directorate General for Energy
Content

I. Policy context

II. Electric motors

III. Extended products approach
I. Policy context
EU policy framework for energy efficiency

Energy Efficiency
Directive 2012/27/EU

Energy Performance of Buildings
New Directive 2018/844

Energy Labelling
New Regulation 2017/1369 (replacing Directive 2010/30/EU)

Ecodesign
Directive 2009/125/EC

Tyre Labelling
Regulation 2009/30/EU

Financing Energy Efficiency
European Structural Investment Fund; Horizon 2020; LIFE + funding; European Fund for Strategic Investments; Member State programmes; etc.

Revised as part of the 2016 'Clean energy for All package'
### Measures in place

**29 Ecodesign regulations**

<table>
<thead>
<tr>
<th>Regulation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1275/2008</td>
<td>Electric power consumption standby and off mode</td>
</tr>
<tr>
<td>107/2009</td>
<td>Simple set-top boxes</td>
</tr>
<tr>
<td>244/2009</td>
<td>Non-directional household lamps</td>
</tr>
<tr>
<td>245/2009</td>
<td>Fluorescent lamps</td>
</tr>
<tr>
<td>278/2009</td>
<td>External power supplies</td>
</tr>
<tr>
<td><strong>640/2009</strong></td>
<td><strong>Electric motors</strong></td>
</tr>
<tr>
<td><strong>641/2009</strong></td>
<td><strong>Circulators</strong></td>
</tr>
<tr>
<td>642/2009</td>
<td>Televisions</td>
</tr>
<tr>
<td>643/2009</td>
<td>Household refrigerating appliances</td>
</tr>
<tr>
<td>1015/2010</td>
<td>Household washing machines</td>
</tr>
<tr>
<td>1016/2010</td>
<td>Household dishwashers</td>
</tr>
<tr>
<td><strong>327/2011</strong></td>
<td><strong>Industrial fans</strong></td>
</tr>
<tr>
<td>206/2012</td>
<td>Airco and comfort fans</td>
</tr>
<tr>
<td><strong>547/2012</strong></td>
<td><strong>Water pumps</strong></td>
</tr>
<tr>
<td>932/2012</td>
<td>Household tumble dryers</td>
</tr>
<tr>
<td>1194/2012</td>
<td>Directional lamps</td>
</tr>
<tr>
<td>548/2014</td>
<td>Power transformers</td>
</tr>
<tr>
<td>617/2013</td>
<td>Computers and servers</td>
</tr>
<tr>
<td>666/2013</td>
<td>Vacuum cleaners</td>
</tr>
<tr>
<td>801/2013</td>
<td>Networked standby</td>
</tr>
<tr>
<td>813/2013</td>
<td>Space heaters</td>
</tr>
<tr>
<td>814/2013</td>
<td>Water heaters &amp; storage tanks</td>
</tr>
<tr>
<td>66/2014</td>
<td>Domestic ovens, hobs and range hoods</td>
</tr>
<tr>
<td>1253/2014</td>
<td>Ventilation units</td>
</tr>
<tr>
<td>2015/1095</td>
<td>Professional refrigeration</td>
</tr>
<tr>
<td>2015/1185</td>
<td>Solid fuel local space heaters</td>
</tr>
<tr>
<td>2015/1188</td>
<td>Local space heaters</td>
</tr>
<tr>
<td>2015/1189</td>
<td>Solid fuel boilers</td>
</tr>
<tr>
<td>2281/2016</td>
<td>Air heating products, cooling products, high</td>
</tr>
<tr>
<td></td>
<td>temperature process chillers and fan coil units</td>
</tr>
</tbody>
</table>

**15 Energy labelling regulations**

<table>
<thead>
<tr>
<th>Regulation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1059/2010</td>
<td>Household dishwashers</td>
</tr>
<tr>
<td>1060/2010</td>
<td>Household refrigerating appliances</td>
</tr>
<tr>
<td>1061/2010</td>
<td>Household washing machines</td>
</tr>
<tr>
<td>1062/2010</td>
<td>Televisions</td>
</tr>
<tr>
<td>626/2011</td>
<td>Air conditioners</td>
</tr>
<tr>
<td>392/2012</td>
<td>Household tumble dryers</td>
</tr>
<tr>
<td>874/2012</td>
<td>Electrical lamps and luminaires</td>
</tr>
<tr>
<td>811/2013</td>
<td>Space heaters</td>
</tr>
<tr>
<td>812/2013</td>
<td>Water heaters &amp; storage tanks</td>
</tr>
<tr>
<td>65/2014</td>
<td>Domestic ovens, hobs and range hoods</td>
</tr>
<tr>
<td>518/2014</td>
<td>Internet energy labelling</td>
</tr>
<tr>
<td>1254/2014</td>
<td>Residential ventilation units</td>
</tr>
<tr>
<td>2015/1094</td>
<td>Professional refrigeration</td>
</tr>
<tr>
<td>2015/1186</td>
<td>Local space heaters</td>
</tr>
<tr>
<td>2015/1187</td>
<td>Solid fuel boilers</td>
</tr>
</tbody>
</table>

**Voluntary agreements**

<table>
<thead>
<tr>
<th>Document</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>COM (2012) 684</td>
<td>Complex set top boxes</td>
</tr>
<tr>
<td>COM (2013) 23</td>
<td>Imaging equipment</td>
</tr>
<tr>
<td>COM (2015) 178</td>
<td>Game consoles</td>
</tr>
</tbody>
</table>

**Tyre labelling regulation**

<table>
<thead>
<tr>
<th>Regulation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1222/2009/EC</td>
<td>Labelling of tyres with respect to fuel efficiency and other essential parameters</td>
</tr>
</tbody>
</table>
The 2019 package of measures: 17 measures for 11 products!
All voted/agreed in Regulatory Committee / Expert Group in Dec 2019 – Jan 2019

<table>
<thead>
<tr>
<th>Product Group</th>
<th>New or (R)evie</th>
<th>Ecodesign</th>
<th>Energy labelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Domestic refrigeration</td>
<td>R</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>2. Lighting products</td>
<td>R</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>3. Electronic displays and TV</td>
<td>R</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>4. Dishwashers</td>
<td>R</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>5. Washing machines</td>
<td>R</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>6. Electric motors and VSDs</td>
<td>R</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>7. Power transformers</td>
<td>R</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>8. EPS (Electronic Power Supplies)</td>
<td>R</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>9. Commercial refrigeration</td>
<td>New</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>10. Welding equipment</td>
<td>New</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>11. Entreprise servers</td>
<td>New</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

‘Adoption’ of ecodesign measures expected mid 2019
Possible publication in the OJ: September 2019
Review process

**Pumps and circulators**
- Ecodesign Work Plan
- Review study
- Consultation Forum on draft measure
- Impact assessment + Opinion of RSB
- Inter-service consultation
- Notification To World Trade Organisation (60 days)

**Fans**
- 4 week Feedback mechanism

**Electric motors**
- Ecodesign (implementing acts) procedure
- Regulatory Committee (discussion and vote)
- Scrutiny European Parliament & Council
- Adoption by European Commission
- Publication in the Official Journal
II. Electric motors
Electric Motors


Scope: 3-phase induction motors, 2 to 6 poles - 0.75-370 kW
Current requirements: IE3 or IE2+VSD
Art 7: review clause (2016)
Review of 640/2009

- Text voted by Member States on 14 Jan available on Comitology Register
- Now under scrutiny by EP and council
- Expected adoption by mid-2019
- Repeals Regulations (EC) 640/2009
- Application date: 1 July 2021
- Includes variable speed drives
## Main changes

### Proposed scope

<table>
<thead>
<tr>
<th>AC induction motors ≤ 1000 V</th>
<th>Year and minimum efficiency requirements (2016 onwards)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.12-0.75 kW</td>
<td>2016: IE2, 2018...2020: IE2, 2021: IE2, 2022: IE2, 2023: IE2, onwards: IE2</td>
</tr>
</tbody>
</table>

### Variable speed drives

<table>
<thead>
<tr>
<th>Variable speed drives</th>
<th>Year and minimum efficiency requirements (2016 onwards)</th>
</tr>
</thead>
</table>

---

**Current requirements** (regulation 640/2009)
Main changes (continuation)

Also:

- Information requirements for both motors and drives, including efficiency at additional load points to enable extended product approach
- 7 years exemption for motors that substitute identical motors integrated in products (spare parts) + other reasoned exemptions
- Special measures facilitating enforcement for large motors
- Alignment on other eco-design measures (circumvention ...)
Substantial energy savings
III. Extended products approach: (preliminary reflexion)
Energy efficiency can be considered at several levels, e.g.

IV. System level

III. ‘Extended Product’ level (pumps, fans; compressors)

II. ‘Motor system’ level

I. Product / component level

Driven equipment

Hydraulic circuit

Electric Motor

Load machine e.g. Pump

Transmission e.g. coupling

Mains (Drive)

Desired work

ECODESIGN ?
Ecodesign and EPA

- EPA can be introduced at the level of the driven equipment regulations (pumps, fans, compressors ...)
- EPA and systems approach can deliver significant additional energy savings (ensure adequacy of components)
- Efficient motors and VSD are part of the building blocks of the EPA
- EPA means increased complexity
- Challenges, especially in terms of enforcement (market surveillance is done at Member State level, normally when the products are placed on the market)
- Ecodesign is a powerful instrument to regulate products, but not be suitable for a systems approach (application-specific requirements). It can enable the approach e.g. by requiring availability of the required metrics.
Thank you for your attention!

Ronald Piers de Raveschoot
Tel: +32(0)2 29 65182
Email: ronald.piers-de-raveschoot@ec.europa.eu

Website: http://ec.europa.eu/energy/efficiency/index_en.htm
Challenges and Requirements for Electric Motor Efficiency Testing

Prof. Dr. Andrea Vezzini - Bern University of Applied Sciences
Prof. Dr. Andrea Vezzini - Head of Laboratory for Electrical Machines and Drive Systems
Bern University of Applied Sciences, Switzerland

Since 1996, Prof. Dr. Andrea Vezzini has been a Professor for Industrial Electronics and Electrical Machines at Bern University of Applied Sciences. He is a member of various technical and research groups, including IEC TC2 WG 28 & WG 31 and IEC 22G WG18 since 2017 and the Federal Energy Research Commission (CORE) since 2015.

Prof. Dr. Vezzini has served as Head of the CSEM – BFH Energy Storage Research Center since 2014, and as Deputy Head of the Swiss Competence Center for Energy Research “Mobility” since 2013. Additionally, he is the Co-founder and Member of the Board of “Integrated Power Systems AG” since 2009, as well as Co-founder and Chairman of the Board of drivetek ag since 2002.

Last but not least, he has both invented and co-invented 8/23 patents in the field of electric motor design and lithium-ion battery technology.
Challenges and Requirements for Electric Motor Efficiency Testing

Prof. Dr. Andrea Vezzini, Bern University of Applied Sciences

Bern University of Applied Sciences, Institute for Energy and Mobility Research; Laboratory for Electric Machines and Drive Systems
Content

- Losses and Efficiency of Induction Motor
- Introduction to IEC standards on energy efficiency of power drive systems
- Induction machines: preferred testing methods
- Example setup of an automated efficiency testing test bench
- Measurement Accuracy
- Efficiency determination: workflow and example results
- Laboratory accreditation
- Conclusions
Motor Driven Unit definition

- A Motor Driven Unit converts electrical power into rotational mechanical power and may consist of the following individual components: variable frequency drive, electric motor, mechanical equipment (e.g. gear, belt, clutch, brake, throttle) and a driven application (e.g. pump, fan, compressor, transport).
Losses and Efficiency of Induction Motor

- Copper losses,
  - Stator Cu loss ($P_{s\theta}$)
  - Rotor Cu loss ($P_{r\theta}$)
- Core Losses ($P_{fe}$)
  - Hysteresis loss
  - Eddy current loss
- Mechanical losses ($P_{fw}$)
  - Friction loss
  - Windage loss
- Stray Losses ($P_{LL}$)

\[ P_T = P_{fe} + P_{fw} + P_{s\theta} + P_{r\theta} + P_{LL} \]

\[ \eta = \frac{P_{1,\theta} - P_T}{P_{1,\theta}} = \frac{P_2}{P_2 + P_T} \]
# Introduction to IEC standards

## Overview of IEC standards on energy efficiency of power drive systems and motor driven units

<table>
<thead>
<tr>
<th></th>
<th>Scope</th>
<th>Efficiency testing</th>
<th>Efficiency classification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>IEC TC2 WG28</td>
<td>IEC TC2 WG31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IEC TC2 WG28</td>
<td>IEC TC2WG31</td>
</tr>
<tr>
<td>3</td>
<td>VFD</td>
<td>IEC 61800-9-2: VFD Classification/Testing Edition 1: 2017-03</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>IEC SC22G WG18</td>
<td></td>
</tr>
</tbody>
</table>
IE efficiency classes for 4-pole motors at 50 Hz

- Electric motors with 2 to 8 poles and rated powers between 0.12 kW and 1000 kW are tested according to IEC 60034-2-1 and classified according to their efficiency into the efficiency classes IE1 to IE4 (IE code according to IEC 60034-30-1)

IE-Code for efficiency of electric motors: 4-pole, 50 Hz
(Source: data from draft FDIS IEC 60034-30-1, 2013)
Reduction of motor losses from IE1 to IE4

- Reduction of motor input power between one efficiency class to the next higher class in percentage versus rated motor output power, shown cumulative for 4-pole motors of all IE classes.
The IEC 60034-2-1 standard defines three different preferred methods with low uncertainty within the given range of application. The specific method to be used depends on the type or rating of the machine under test.

<table>
<thead>
<tr>
<th>Ref</th>
<th>Method</th>
<th>Description</th>
<th>Clause</th>
<th>Application</th>
<th>Required facility</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-1-1A</td>
<td>Direct measurement:</td>
<td>Torque measurement</td>
<td>6.1.2</td>
<td>All single phase machines</td>
<td>Dynamometer for full-load</td>
</tr>
<tr>
<td></td>
<td>Input-output</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-1-1B</td>
<td>Summation of losses:</td>
<td>$P_{LL}$ determined from residual loss</td>
<td>6.1.3</td>
<td>Three phase machines with rated output power up to 2 MW</td>
<td>Dynamometer for 1,25 × full-load, or load machine for 1,25 × full-load with torque meter</td>
</tr>
<tr>
<td></td>
<td>Residual losses</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-1-1C</td>
<td>Summation of losses:</td>
<td>$P_{LL}$ from assigned value</td>
<td>6.1.4</td>
<td>Three phase machines with rated output power greater 2 MW.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Assigned value</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In addition to conventional motor tests involving the test object, load machine and torque measurement standard efficiency testing requires a high quality power source, a winding ohmmeter, a power analyzer and a test automation system.

Automated efficiency testing test bench: Example
Power Analyzer & Current Shunts; Example Hioki

- **Hioki PW6001 Power Analyzer**
  - 2 Units, Operating in Master-Slave Mode (23µs Delay through Fiber)
  - 4 Channels per Unit
  - 18-bit ADC (Voltage & Current)
  - 80dB/100kHz CMRR
  - Voltage: ±0.02 % rdg. ±0.02 % f.s
  - Current: ±0.02 % rdg. ±0.02 % f.s. plus Current Sensor Accuracy

- **Hioki PW9001 Shunt Current Box**
  - ±50 A Peak Current
  - 3.5 MHz Bandwidth
  - ± 0.04% Accuracy (2 MHz/PW6001)
### Current Shunts: Measurement Accuracy

<table>
<thead>
<tr>
<th>Sensor model</th>
<th>PW9100</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Sensor rated current</th>
<th>50 A</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Input</th>
<th>Voltage</th>
<th>Current</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>400 V</td>
<td>15 A</td>
<td>6 kW</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PW6001 ranging</th>
<th>Voltage</th>
<th>Current</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>600 V</td>
<td>40 A</td>
<td>24 kW</td>
</tr>
</tbody>
</table>

**Unit accuracy**

<table>
<thead>
<tr>
<th>DC</th>
<th>PW6001</th>
<th>PW9100</th>
</tr>
</thead>
<tbody>
<tr>
<td>rdg.</td>
<td>0.04%</td>
<td>0.057%</td>
</tr>
<tr>
<td>f.s.</td>
<td>0.04%</td>
<td>0.06%</td>
</tr>
</tbody>
</table>

**Total accuracy**

<table>
<thead>
<tr>
<th>45 Hz &lt; f ≤ 65 Hz (± 0.02 % rdg. ± 0.007 % f.s.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined accuracy when using PW9100</td>
</tr>
<tr>
<td>PW9100</td>
</tr>
<tr>
<td>PW6001</td>
</tr>
</tbody>
</table>

**Accuracy is defined to 1 MHz**

<table>
<thead>
<tr>
<th>DC</th>
<th>PW6001</th>
<th>PW9100</th>
</tr>
</thead>
<tbody>
<tr>
<td>rdg.</td>
<td>0.04%</td>
<td>0.06%</td>
</tr>
<tr>
<td>f.s.</td>
<td>0.04%</td>
<td>0.06%</td>
</tr>
</tbody>
</table>

### Calculation Method

Total "rdg." accuracy = "PW6001 rdg." + "Sensor rdg."

Total "f.s." accuracy = "PW6001 f.s." + ("Sensor rated current" / "PW6001 current range") * "Sensor f.s."

Error = ("Input Power" * "Total rdg. accuracy" + "PW6001 Power Range" * "Total f.s. accuracy") / "Input Power"
Efficiency determination: method 2-1-1B

Before this load test, measure the temperature and the winding resistance of the motor with the motor at ambient temperature.

The machine shall be loaded by suitable means with rated output power and operated until thermal equilibrium is achieved (rate of change 1 K or less per half hour).

Apply the load to the machine at the following six load points: approximately 125 %, 115 %, 100 %, 75 %, 50 % and 25 % of rated load. These tests shall be performed as quickly as possible to minimize temperature changes in the machine during testing.

Test at the following eight values of voltage, including rated voltage, so that:
- the values at approximately 110 %, 100 %, 95 % and 90 % of rated voltage are used for the determination of iron losses;
- the values at approximately 60 %, 50 %, 40 % and 30 % of rated voltage are used for the determination of windage and friction losses;

The residual loss data shall be smoothed by using the linear regression analysis (see Figure 4) based on expressing the losses as a function of the square of the load torque.

The efficiency is determined from:

$$\eta = \frac{P_{1,9} - P_T}{P_{1,9}} = \frac{P_2}{P_2 + P_T}$$
Loss Distribution in an IE3 AC Induction Machine

- Test conditions: IE3, 4-pole, 50Hz, ambient temperature: 24°C
Laboratory accreditation

ISO/IEC 17025 – The standard for laboratory competence. The general requirements for laboratory competence are described in the ISO/IEC 17025 standard. This standard establishes a global baseline for the accreditation of all types of laboratories.

ISO 9001 is defined as the international standard that specifies requirements for a quality management system (QMS). Organizations use the standard to demonstrate the ability to consistently provide products and services that meet customer and regulatory requirements.

In order to continuously perform correct measurements, utilized measuring and test equipment must be monitored and calibrated on a regular basis. The corresponding time period is known as the calibration interval. Users of measuring and test equipment frequently ask how often calibration of this equipment is required.
Conclusions

- IEC 60034-2-1:2014(B) is intended to establish methods of determining efficiencies from tests, and also to specify methods of obtaining specific losses.

- To guarantee a high degree of precision and repeatability a fully automated test systems for efficiency measurements with high performance equipment is required.

- Under ISO/IEC 17025, a laboratory's competence is assured via an on-site assessment process and participation in applicable Proficiency Testing programs. This on-site assessment process assures that the laboratory is capable of producing accurate, traceable and reproducible data.

- The effort to setup, manage and maintain such accredited testing labs is not to be underestimated and often a coordinated effort should be considered.
Thank you for your attention!

Prof. Dr. Andrea Vezzini
Questions: andrea.vezzini@bfh.ch

Bern University of Applied Sciences, Institute for Energy and Mobility Research; Laboratory for Electric Machines and Drive Systems
Global Motor Energy Efficiency Program: Reduced Trade Barriers and Other Benefits

Dan Delaney - Regal Beloit, representing National Electrical Manufacturers Association
Dan Delaney received his BS degree in Mechanical Engineering from Purdue University in West Lafayette, Indiana, USA. He has worked in the consumer, commercial and industrial motor and electronic controls industry for the past 20 years. His background includes electrical and mechanical motor design, new product development, product safety certification and standards development for electric motors and associated controls.

Currently with Regal Beloit he serves as the NEMA 1MG Section Chairman and serves on a multitude of standards working groups including NEMA, IEC, IECEE, IEEE, UL, and CSA and has presented multiple papers and presentations at various motor related industry conferences.
“Global Motor Energy Efficiency”

GMEE

Dan Delaney
Regal Beloit
GMEE Convenor - IECEE PSC WG5/6
Chairman NEMA 1MG Section Committee

SEAD Policy Exchange Forum

The Association of Electrical and Medical Imaging Equipment Manufacturers
The National Electrical Manufacturers Association (NEMA) represents nearly 350 electrical equipment and medical imaging manufacturers, across 55 product groups focused on making safe, reliable, and efficient products and systems.

Our combined industries account for 360,000 American jobs in more than 7,000 facilities covering every state.

Approximately 40 Motor and Drive manufacturers

Approximately 80% of Motor and Drive market
WHO IS IECEE?

- 54 Member Bodies (Countries)
- 472 CBTL’s (Certification Body Test Laboratories)
- >100K CBTC each year (CB Test Certificates)

- 78 NCB’s (National Certification Bodies)
- 2,246 Customer Test Facilities
- 23 Product Categories (based on IEC standards)
WHAT IS GMEE?

GMEE - Global Motor Energy Efficiency (CB Scheme Equivalent)

“Motor EE Test Results Passport = 1 test report accepted around the globe”

- Follows successful CB Scheme
- “Direct to Market” Certificate approach
- Global Test Standards (IEC 60034-1, -2-1, -30-1)
- ISO Test Laboratory Quality Requirements (ISO 17025)
- Defined Certification Requirements (model selection/number of models/number of tests, AEDM, etc.)
- No Mandatory Labelling Requirements (CB Test Certificate Number)
- No Verification Program (No Plant Inspections/Follow Up Services/Factory Surveillance)
- 27 GMEE Certificates issued since program released
Why do we need GMEE?

MEPS

- National Energy Savings are not realized without effective CCE (Certification Compliance and Enforcement)
- User confidence in Energy Efficient Motor marking/labels
- Lack of effective MEPS Enforcement and Verification processes
- National MEPS CCE vary and can slow or block international trade
- National Motor MEPS increasing steadily
- Developing Nations creating new CCE requirements
- Simplify Regulatory CCE complexity
- No Global MEPS Program

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Uncertainty</td>
<td>USA (1/4-500HP)</td>
<td>US DOE 10 CFR Part 431</td>
</tr>
<tr>
<td></td>
<td>Europe:</td>
<td>ErP Directive, Regulation 640/2009</td>
</tr>
<tr>
<td></td>
<td>2015* (&gt;7.5kW); 2017* (&gt;0.75kW)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Canada (1-500HP)</td>
<td>Canadian EEA, CSA C390</td>
</tr>
<tr>
<td></td>
<td>Mexico (1-500HP)</td>
<td>NOM 016-ENER-2010</td>
</tr>
<tr>
<td></td>
<td>South Korea</td>
<td>MOCIE/KEMCO</td>
</tr>
<tr>
<td></td>
<td>Australia/New Zealand</td>
<td>AS/NZS 1359:2004</td>
</tr>
<tr>
<td></td>
<td>China</td>
<td>GB 18613-2010</td>
</tr>
<tr>
<td></td>
<td>Brazil</td>
<td>NBR 17094-1</td>
</tr>
<tr>
<td></td>
<td>Turkey</td>
<td>SMG-2012/2</td>
</tr>
<tr>
<td></td>
<td>Argentina</td>
<td>IRAM 62405</td>
</tr>
<tr>
<td></td>
<td>Saudi Arabia</td>
<td>SASO</td>
</tr>
<tr>
<td></td>
<td>Chile</td>
<td>SEC PE No 7/01/2</td>
</tr>
<tr>
<td></td>
<td>Thailand</td>
<td>Thailand TEI</td>
</tr>
<tr>
<td></td>
<td>Japan</td>
<td>Energy Labeling Program</td>
</tr>
<tr>
<td></td>
<td>Vietnam</td>
<td>MOIT 03/2013/QD-TTg</td>
</tr>
<tr>
<td></td>
<td>India</td>
<td>BEE Schedule 6</td>
</tr>
<tr>
<td></td>
<td>Israel</td>
<td>EEEM 5764-2004 / SI 5289</td>
</tr>
<tr>
<td></td>
<td>Costa Rica</td>
<td>Decree No. 25584 / 24.10.96</td>
</tr>
<tr>
<td></td>
<td>Taiwan</td>
<td>CNS 14400</td>
</tr>
<tr>
<td></td>
<td>Peru</td>
<td>MINEM 1-200HP</td>
</tr>
</tbody>
</table>
IECEE. Taking Conformity Assessment Further

HOW DO I FIND IECEE & GMEE?

www.ieCEE.org

IECEE Global Motor Energy Efficiency

The IECEE Global Motor Energy Efficiency Programme (GMEE) addresses the many trade barriers due to diverse country regulations for motor efficiency, and to attempt to set up a globally harmonized and applicable programme.

IECEE Global Motor Energy Efficiency

What is IECEE

The IECEE, the IEC System for Conformity Assessment Schemes for Electrotechnical Equipment and Components, is a multilateral certification system based on IEC International Standards. Its members use the principle of mutual recognition of test results to obtain certification or approval at national levels around the world.

The IECEE Schemes address the safety, quality, efficiency and overall performance of components, devices and equipment for homes, offices, workshops, facilities among others. In all IECEE covers 23 categories of electrical and electronics equipment and testing services (see List of product categories).

The IECEE Schemes, based on IEC International Standards, are truly global in concept and practice. They help reduce trade barriers caused by different certification criteria in different countries and help industry access new markets. They eliminate the delays and costs of multiple testing, thus allowing companies to market their products faster while reducing overall manufacturing costs.

National differences

In countries where national standards are not yet completely based on IEC International Standards, declared national differences are taken into account. However, to ensure the successful operation of the CB Scheme, it is essential that national regulations are harmonized with the corresponding IEC International Standards.

IECEE truly global System

IECEE membership is open to any country that has a Full or Associate Member National Committee of the IEC.

IECEE qualifies the National Certification Bodies (NCBs) that are responsible for recognizing and issuing CB Test Reports and Certificates. In turn IECEE NCBs employ test laboratories, known as CB Testing Laboratories (CBLs), to perform the tests in compliance with IEC International Standards.

Countries that do not have a NCB also accept CB Test Reports and CB Test Certificates.

This website provides full lists of IECEE Members, NCBs, CBLs and other.
HOW DOES GMEE WORK?

STEP 1
- Applicant (manufacturer) applies
- National Certification Body (NCB)
- CB Test Certificate
- Issues
- Requests testing
- CB Testing Laboratory (CBTL)
- Issues
- CB Test Report

STEP 2
- Applicant (manufacturer) submits
- CB Test Report
- National regulator (e.g., US, AU, EU, etc.)
- Verification
- Market access
- (e.g., end user, original equipment manufacturer, distributor)

*May require national compliance marks
STEP 1: GMEE Motor Evaluation Process (NCB and CBTL)

1. Manufacturer provides NCB with desired Product Certification Scope
2. NCB review product scope and determines minimum Sample Selection
   a. Product Line Certificate
   b. AEDM Validation
3. Manufacturer coordinates Testing at CBTL or Manufacturer’s test facility
4. NCB reviews Test Results for compliance to appropriate efficiency class level
5. NCB completes IEC 60034-2-1 Test Report Form (TRF)
6. NCB issues GMEE Test Certificate (CBTC) for covered product
Step 2: GMEE National Regulatory Process

1. Manufacturer submits GMEE CB Certificate and Test Results to National Regulatory Body (i.e. US, Canada, Mexico, China, Australia, South Korea, Saudi Arabia, Brazil, etc.)

2. National Regulatory body reviews test results for compliance and issues compliance statement

3. Manufacturer complies with any national registration and/or marking requirements as needed
FUTURE STATE: NCB submits GMEE Certificate directly to National Regulator
NEXT STEPS...

Industry Challenges
- Global Market Access is challenging (product availability, compliance costs)
- Harmonize Certification Compliance and Enforcement (CCE) rules around the globe
- Common Test Sampling programs (Product Line or AEDM Evaluation)
- Common label identification of compliant products (GMEE, NEMA Premium)

Future for Energy Efficiency...
- Expand GMEE to Include Power Drive System? System Energy Efficiency Regulations (Pump, Fan and Compressor) increasing demand for higher motor efficiencies

What Industry needs from you!
- National Regulatory Bodies endorse/accept GMEE in their EE regulations
- Additional training available for National Regulatory contacts
- Please see me or Kirk Anderson from NEMA to get involved!

With your help and participation, GMEE program will improve CCE and expand growth of energy efficient motors in the global marketplace!
THANK YOU!

QUESTIONS?
Discussion
Guiding Questions

- What are the major barriers and challenges to regulate the motors energy efficiency?
- How can countries use policy tools and incentive programs to promote the adoption of high-efficiency motors, motor driven units (MDUs) and motor systems?
- Where are the biggest opportunities for potential emissions reductions within motor driven systems? What could help to achieve these opportunities?
- Who are the agents of change (e.g. national governments, international and professional organizations, manufacturers)?
- What are the lessons learned from your country or region’s experience?
Closing Remarks

• Key takeaways
• Possible collaboration opportunities
• Encourage participants to follow up the discussions with additional questions and thoughts
• All materials will be made available online
• Thank you for your participation!
For more information or follow up questions please contact:

Lina Kelpsaite, SPEx Coordinator (CLASP)
Email: lkelpsaite@clasp.ngo
Tel: +1 202 750 5122

The presentations and discussion summary will be posted on the SEAD website, along with a recording of the webinar