Electric Motor Systems: targeting and implementing efficiency improvements

8 October 2015

Maarten van Werkhoven
Contents

1. Introduction
2. Efficient motor systems
3. Standards and policies for motor systems
4. Steps for end users to optimize their motor systems
5. Some successful programs, tools and further information sources
Webinar Electric Motor Systems
targeting and implementing efficiency improvements

Maarten van Werkhoven (mvanwerkhoven@tpaby.nl)

- TPA advisors
- Consultant energy, sustainability and management

- Multiple projects on Energy Efficient production, building and policies.

- Electric Motor Systems:
  - Operating Agent Electric Motor Systems Annex, IEA IA 4E EMSA
  - Projects, programs in the Netherlands:
    - Program Green Deal on efficient motor systems (Dutch)
    - Knowledge Network efficient electric motor systems (Dutch)
EMSA Electric Motor Systems Annex

- 6 countries
- EMSA overview
EMSA for market transformation

Global

- harmonized global standards

National

- successful policies

Company

- energy management & audits

Personal

- tools & information
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Global Electricity Demand

Electric motors 46%

Motors 46%

Light 19%

Electronics 10%

Electrolysis 3%

Heat 19%

Standby 3%

Energy and motor systems

Motors in industry:
= 69% of industrial electricity use

Motor systems in industry: applications

Scenarios of global electricity consumption

Motor systems drive pumps, fans, compressors, transportation systems, processes.

They can be improved in new and existing industrial applications, in infrastructure and building systems.

20% - 30% savings
Ventilation system: motor, transmission, fan
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Why globally harmonized standards?
# Group of motor standards

*line operated AC motors*

<table>
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<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SCOPE</strong></td>
<td>IEC 60034-1</td>
<td>IEC 60034-2-1</td>
<td>IEC 60034-30</td>
<td>IEC/TS 60034-31</td>
<td>IECCEE e3</td>
</tr>
<tr>
<td></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>3 major efficiency classes: IE1 &gt; IE2 &gt; IE3, open to advanced technology (IE4)</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
Standards: Motor efficiency (IE-Code)

Electric motors: 4 pole, 50 Hz

Output power [kW]  log scale (Source: IEC 60034-30-1, 2014)
Interaction of stakeholders

Standards are the basis for minimum energy performance standards (MEPS)
## 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>
</tbody>
</table>

- **Super Premium Efficiency**: IE4
- **Premium Efficiency**: IE3
- **High Efficiency**: IE2
- **Standard Efficiency**: IE1
- **Below Standard**:

### Efficiency Classes

- **Super Premium Efficiency**: IE4
- **Premium Efficiency**: IE3
- **High Efficiency**: IE2
- **Standard Efficiency**: IE1
- **Below Standard**:

### Testing Standards

- IEC 60034-30-1, 2014
- IEC 60034-2-1, 2014

### Performance Standards

- **Mandatory MEPS *****
- **Super Premium Efficiency**: IE4
- **Preferred Method **
- **Summation of losses with load test**: Additional losses $P_{LL}$ determined from residual loss
- **High Efficiency**: IE2
- **Standard Efficiency**: IE1
- **Below Standard**:

### National Policy Requirement

- **Canada (< 150 kW)**
- **Mexico (< 150 kW)**
- **USA (< 150 kW)**
- **South Korea**
- **Switzerland**
- **Japan (Toprunner)**
- **EU 28**** (> 7.5 kW)**
- **China ***** (> 7.5 kW; 2016)**
- **Australia****
- **Brazil**
- **Canada (> 150 kW)**
- **China**
- **Mexico (> 150 kW)**
- **South Korea**
- **New Zealand**
- **Turkey**
- **USA (> 150 kW)**
- **Costa Rica**
- **Israel**
- **Taiwan**

### Special Notes

- *italic* means in effect in 2016
- ***) Output power: 0.12 kW - 1000 kW,
- **)  for 3-phase machines, rated output power < 1000 kW
- ***) Minimum Energy Performance Standard
- ****) European Union: IE3 or IE2 + VFD; 2017 above 0.75 kW
- *****) Australia adoption of IE Standards
- ******) China: 2017 IE3 also < 7.5 kW

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Global motor sales

The World Market for Low Voltage Motors by Efficiency Class - Unit Shipments 2014 to 2019

Source: IHS, 2015
European Union
Motor systems MEPS

Motors
- Revision of existing regulation no 640/2009
- Technical study completed, draft 2015, decision expected in 2016
- MEPS for motors 0.12 kW – 1000 kW, plus new VFD losses

Fans
- Revision of existing regulation no 327/2011
- draft 2015, MEPS with increased efficiency tier effective from 2020

Compressors
- Technical study completed, MEPS draft pending

Water pumps
- Plan for revision of existing regulation no 547/2012, start in 2016
Key Stakeholders

Most effective policies stimulate action

**International Standard Makers**
/ National Standard Makers
- Efficiency testing methods for motors, components and motor systems
- Efficiency classes for motors, components and motor systems
- Energy management
- Energy audits
- Measurement, verification and benchmarking

**Manufacturers**
(and associations)
- Energy label
- Industry testing laboratory program
- Training efficiency technology experts
- Database with energy performance data
- Procurement guidelines

**National Policy Makers**
- MEPS
- Product registration
- Laboratory accreditation
- Compliance
- Awareness raising
- Financial incentives
- Procurement

**Power Utilities**
- Reducing demand
- Subsidy programs
- On-bill financing
- Training efficiency managers

**Industrial Users**
(and associations)
- Identify national/local efficiency programs (subsidy, training, etc.)
- Training program for energy efficiency managers
- Company motor policy, replacing old machines

Source: Policy Guidelines For Electric Motor Systems, Part 2, EMSA October 2014
Successful policy implementation

EMSA publications

Upcoming

- Policy Guidelines for Motor Driven Units (2016/17)

Download: www.motorsystems.org
Programs – policy instruments

1. Mandatory audits
   - regular audits with standard protocol

2. Financial incentives
   - pay for system analysis (not for motor exchange)

3. Efficiency targets
   - negotiated target setting for 5 - 10 years ahead

4. Training programs
   - in-house factory personnel
   - energy efficiency experts for industry
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Steps to optimise motor systems

End user

- System improvement with:
  - Motor
  - Variable Frequency Drive for load control
  - Transmission
  - Application
  - System integration
System optimization

- motor replacement = only small savings

BAT: Best Available Technology

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Load control: VFD instead of throttle pumps and fans

![Graph showing input power vs flow rate with VFD and without throttle/choking, indicating potential savings with VFD.]
Analysis of motor system

- Motor / Energy audit
  1. Motor list – inventory + characteristics
  2. First analysis
  3. Measurements
  4. Business cases: cost-efficient improvements
  5. Implementation

- Energy management, motor management
  1. Management commitment
  2. Involving procurement, design, maintenance, suppliers
Stock analysis

Swiss research 2010-14

- **Age:** Never touch a running system
  - 56% of motors are older than their operating life expectancy; these older motors are in average 99% too old

- **Sizing:** Load factor
  - 2/3 have average load factor < 60%

- **Control**
  - 20% have VFD
Motors: efficiency and age

Electric motors: 4 pole, 50 Hz

- IE4 (95.4) > 2020
- IE3 (94.2) > 2015
- IE2 (93.1) > 2012
- IE1 (91.7) > 2000
- Eff3 (90.0) > 1990
- Eff4 (88.3) > 1980

Efficiency [%]

Output power [kW] log scale (Source: IEC 60034-30-1, 2014)
Never touch a running system

56% of motors are older than their operating life expectancy; these older motors are 99% too old.
Only 20% have a VFD

Variable Frequency Drives

- 5.1 kW
- 21.2 kW

Median average

- 17.5 a
- 15.0 a

n=4142
Load factor

68% have an average LF < 60%

n=104
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Programs on Motor Systems

some examples

- Swiss Easy program
  - Financial incentives on 4 analysis steps – tools!
  - Remove barriers

Motor-Systems-Check

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Measures</th>
<th>Subsidy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>Efficiency potential</td>
<td>100%</td>
</tr>
<tr>
<td>Step 2</td>
<td>Motor list</td>
<td>75%*</td>
</tr>
<tr>
<td>Step 3</td>
<td>On-site test</td>
<td>50%</td>
</tr>
<tr>
<td>Step 4</td>
<td>Implementation</td>
<td>10%</td>
</tr>
</tbody>
</table>

* min. 25 %, max. 75 %.

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Calculations

### Effective consumption of electricity of the electrical drives
- **9.707 [GWh/a]**

### Fraction of effective consumption of electricity
- **69.3 [%]**

### Percentage of motors to be replaced
- **64.0 [%]**

### Numbers of motors with VFD
- **40.0 [%]**

### Improved consumption of electricity of the electrical drives
- **8.238 [GWh/a]**

### Potential of energy efficiency (electric energy)
- **1.469 [GWh/a]**

### Potential of energy efficiency (in currency)
- **0.157 [Mio CHF/a]**

### Potential of energy efficiency (in percentage)
- **15.1 [%]**

### Additional investments for realisation of the potential of energy efficiency
- **0.205 [Mio CHF]**

### Payback-time for realisation of efficiency potential
- **1.3 [a]**

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**SOTEA Efficiency Potential**

**ILI Intelligent List**

**STR Standard Test Report**

**MST Motor Systems Tool**
Package of measures

Life Cycle: 10 – 20 years

Payback: Package 2.4 years
Programs on Motor Systems

some examples

- Netherlands: Green Deal
- Audits
- Awareness
- Incentive on motors, and program management

By motivated members of supply chain, and end users
## Projects - examples

*savings, client demand, follow up*

<table>
<thead>
<tr>
<th>Savings</th>
<th>Maintenance/ replacement</th>
<th>EE</th>
<th>Follow up/ extension</th>
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<tr>
<td>P1: 20%</td>
<td>x</td>
<td></td>
<td>yes, motormanagement</td>
</tr>
<tr>
<td>P2: 40%</td>
<td>x</td>
<td>x</td>
<td>yes, all production lines</td>
</tr>
<tr>
<td>P3: 6%</td>
<td>x</td>
<td></td>
<td>yes, motormanagement</td>
</tr>
<tr>
<td>P4: 30%</td>
<td>x</td>
<td>x</td>
<td>yes, other motor systems</td>
</tr>
</tbody>
</table>
Available tools

- Motor Systems Tool: [www.motorsystems.org](http://www.motorsystems.org)
- Easy tools: [www.topmotors.ch](http://www.topmotors.ch)
- EMSA Policy Guidelines: [www.motorsystems.org](http://www.motorsystems.org)
- Webinars
  
  
  
  26 Nov 15  [Optimization of Cooling Systems: compressors and other power consumers](#)
  
  03 Dec 15  [Pumps & circulators: ecodesign and optimization of pump systems](#)
  
  17 Dec 15  [Fans: ecodesign and optimization of fan systems](#)
**MOTOR SUMMIT 2016**

**Save the date!**

Zurich, 11-12 Oct

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*Invitation only

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Conclusions

1. Electric motors use 46% of global electricity
2. 20% - 30% can be saved
3. Rolling stock is too old
4. Payback typically 3 – 5 years
5. Big savings only with improved systems
6. Load control with Variable Frequency Drives
7. Motors are globally traded
8. Harmonized standards basis for Minimum Energy Performance Standards

There is still much more to be saved by using best available technology in matched systems!
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