Energy Saving with Industrial Motors – Quo Vadis?

FIE Conference
Stockholm- April 17, 2013

Jürgen Fuchsloch, Siemens AG, Nürnberg

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Agenda

1. Standards and Regulations

2. Efficiency quo vadis? IE1, IE2, IE3, IE4, ...

3. Trends and Products
Standards and Regulations
Minimum Efficiency requirements for DOL- and Inverter motors in EU

### DOL motors

- **>= 7.5 kW**
  - Min. Efficiency IE2 acc. EU-directive 7.5 .. 375 kW
  - Min. Efficiency IE3 acc. EU-directive 7.5 .. 375 kW

- **< 7.5 kW**
  - Min. Efficiency IE2 acc. EU-directive 0.75 .. 7.5 kW
  - Min. Efficiency IE3 acc. EU-directive 0.75 .. 7.5 kW

### DOL motors in inverter duty mode (Inverter capable)

- Min. Efficiency IE2 acc. EU-directive ..., 0.75 .. 375, ... kW

### Inverter Motors

- “VSD-Motors”
  - No min. efficiency requirements acc. EU-directive, EISA, ...
  - "?\n
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EU legislation

Based on regulation 640/2009, from January 2015 onwards, as an alternative to an IE3 motor, an IE2 motor with converter can be used.

Generally, the new content of the standard is not automatically part of the EU regulation, but is incorporated in a new legislation process on a case-for-case basis. (Example: extension of the validity for motors according to present regulation 640/2009 will first come into effect between about 2017 and 2020)

In the US/China for example, other processes apply regarding standardization and legislation. International standards are only used as a basis to a limited extent.
Overview of Energy-Efficiency Standards in consequence of the EU Mandates M/470 and M/476

IEC TC2: Rotating electrical machines

- IEC 60034-2
  Standard methods for determining losses and efficiency from tests
  Part -1 Fix speed motors
    published 2007-09
  Part - 2 Special-motors
    published 2010-03-16
  Part - 3 (TS) Motors for VSD
    estimated end of 2013

- IEC 60034-30
  Efficiency classes (IE-classes)
  Part -1 Line supply
    Edition 1
    0,12 up to 1000 kW - up to 8 poles…
    FDIS M.2013
  Part - 2 Converter supply
    Vision that harmonic losses will allow marking one IE class better compared to part-1
    IEC /TS 60034-31
    Overview of some EE considerations for motors, stable until 2016

CLC TC22x: Power Drive Systems

- Ecodesign of power drive systems
  M/476

  Part -1 General approach with SAM
  First CD planned for end of 2012

  Part - 2
  - Efficiency classes IE / IES
  - Test / Reference motor
  - Test / Reference converter
  - Methods for determining converterlosses
  - Methods for calculation losses
    - for converter / reference motor
    - for power drive system
  Planned latest at end 2014

  Part - 3
  - Environmental aspects and product declaration
  - Eco-design Performance
  - Guideline to do EPD
  First CD has been published

Quelle: IDT LD AR, Dr. Zwanziger

Page 6
IEC 60034-30-1 energy efficiency classes – Extension is available as draft!

Main change:

- Motor range extending from 0.12 kW up to 1000 kW (from SH 63 up to trans-standard range)
- Detailed description, to eliminate several exception definitions, e.g. temperature range, motors equipped with brakes…
- Extended to include 8-pole motors
- IE4 class will be included in the standard
- Restriction to just three-phase squirrel-cage induction motors no longer applicable
NEW: Energy efficiency classes –
Motors connected to a converter & systems (motor + converter)

NEW – extension has been announced!

- New technical specification 60034-2-3 when measuring power losses of motors when connected to a converter
- IEC 60034-30-2 energy efficiency classes for motors connected to a converter – a draft is still not available
- New standard “IES” system, for efficiency classes for the complete system (motor + converter), is planned for 2014
Legislation in Europe

Supplement regarding the regulation (EC) 640/2009

No exceptions for:

- Ambient temperature from -30 °C up to 60 °C  
  (previously, only from -20 °C up to 45 °C)
- Installation altitude up to 4000 m above sea level

Exceptions:

- Changes are estimated to come into force  
  end of calendar year 2013

| (c) motors specified to operate exclusively:  |
|----------------------|------|
| (i) at altitudes exceeding 4000 m above sea-level; |
| (ii) where ambient air temperatures exceed 60 °C; |
| (iii) in maximum operating temperature above 400°C; |
| (iv) where ambient air temperatures are less than -30°C for any motor or less than 0°C for a motor with water cooling; |
Low voltage motor standards and efficiencies for important countries

USA, Canada & Mexico (NEMA)
Europe (IEC)
Russia (GOST)
Taiwan (CNS)
China (CCC)
Australia* (AS/NS)
South Africa (SABS)
India (IS)
Brazil (ABNT)
Korea (KEMCO)

Countries and regions where the new IE2 and IE3 efficiency standards apply

- IE2
- IE3 or NEMA Premium

* IE3 from 2014 onwards

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Industry Sector
### Efficiency specific certificates

<table>
<thead>
<tr>
<th>Power Range / Frames</th>
<th>Region</th>
<th>Certificate / Organization</th>
<th>Type of Certificate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 .. 400 hp</td>
<td>Canada</td>
<td>CSA - E</td>
<td>Efficiency</td>
</tr>
<tr>
<td>0.25 - 400 hp</td>
<td>Mexico</td>
<td>Mexican Energy Label (NOM)</td>
<td>Efficiency</td>
</tr>
<tr>
<td>1 .. 400 hp</td>
<td>USA</td>
<td>Advanced Energy (CC032A)</td>
<td>Efficiency</td>
</tr>
<tr>
<td>0.73 .. 186 kW*</td>
<td>Australia</td>
<td>MEPS 2 '(2006)</td>
<td>Efficiency</td>
</tr>
<tr>
<td>0.75 .. 185 kW</td>
<td>Brazil</td>
<td>ABNT / INMETRO</td>
<td>Efficiency</td>
</tr>
<tr>
<td>0.75 .. 150 kW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.75 .. 110 kW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.37 .. 315 kW</td>
<td>Canada</td>
<td>CSA - E</td>
<td>Efficiency</td>
</tr>
<tr>
<td>0.75 .. 375 kW</td>
<td>China</td>
<td>CEL - China Energy Label</td>
<td>Efficiency</td>
</tr>
<tr>
<td>1LE10 in fs 100 .. 160</td>
<td>Korea</td>
<td>KEMCO</td>
<td>Efficiency</td>
</tr>
<tr>
<td>all</td>
<td>Korea</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.37 .. 315 kW</td>
<td>USA</td>
<td>Advanced Energy (CC032A)</td>
<td>Efficiency</td>
</tr>
<tr>
<td>0.75 .. 7.5 kW</td>
<td>Chile</td>
<td>Energy Label Chile</td>
<td>Efficiency</td>
</tr>
<tr>
<td>0.75 .. 7.5 kW</td>
<td>Chile</td>
<td>Energy Label Chile</td>
<td>Efficiency</td>
</tr>
</tbody>
</table>

**China: CCC**

**China: CEL 2012 for IE2**

**Korea: KEL 2012 for IE2**

**Australia: MEPS**
### Region specific conformity certificates

<table>
<thead>
<tr>
<th>Power Range / Frames</th>
<th>Region</th>
<th>Certificate / Organization</th>
<th>Type of Certificate</th>
</tr>
</thead>
<tbody>
<tr>
<td>all</td>
<td>Europe</td>
<td>CE</td>
<td>Conformity</td>
</tr>
<tr>
<td>1 .. 400 hp</td>
<td>USA, Canada</td>
<td>UR inverse / UL - Underwriters Laboratories</td>
<td>Conformity</td>
</tr>
<tr>
<td>0.09 .. 4 kW</td>
<td>Argentina</td>
<td>IRAM</td>
<td>Conformity</td>
</tr>
<tr>
<td>0.37 .. 315 kW</td>
<td>Canada</td>
<td>CSA - Canadian Standards Associations</td>
<td>Conformity</td>
</tr>
<tr>
<td>Up to 2.2 kW (4-pol)</td>
<td>China</td>
<td>CCC - China Compulsory Certification</td>
<td>Conformity</td>
</tr>
<tr>
<td>&gt; 200 kW</td>
<td>Colombia</td>
<td>RETIE</td>
<td>Conformity</td>
</tr>
<tr>
<td>all</td>
<td>Russia</td>
<td>GOST-R</td>
<td>Conformity</td>
</tr>
<tr>
<td>all</td>
<td>Europe</td>
<td>Eco - Design - Standard Prior: RoHS - Restriction of Hazardous Substances / WEEE / Reach - Regulation</td>
<td>Conformity</td>
</tr>
<tr>
<td>all</td>
<td>Russia</td>
<td>GOST-R</td>
<td>Conformity</td>
</tr>
<tr>
<td>0.37 .. 315 kW</td>
<td>USA</td>
<td>UR inverse / UL - Underwriters Laboratories</td>
<td>Conformity</td>
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</tr>
<tr>
<td>0.09 .. 4 kW</td>
<td>Argentina</td>
<td>IRAM</td>
<td>Conformity</td>
</tr>
<tr>
<td>all</td>
<td>Taiwan</td>
<td>CNS</td>
<td>Conformity</td>
</tr>
</tbody>
</table>

**Russia:**

**GOST Certification**

![GOST Certification Image]
Efficiency quo vadis?
IE1, IE2, IE3, IE4 ...
### Efficiency Levels – Past, Present & Future?

<table>
<thead>
<tr>
<th>Efficiency</th>
<th>20 HP, 4 pole</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perpetual motion</td>
<td>100 %</td>
</tr>
<tr>
<td>Super Conducting Motor</td>
<td>98.5 .. 99 %</td>
</tr>
<tr>
<td>PM Motor</td>
<td>93.5 .. 94.5 %</td>
</tr>
<tr>
<td>Potential Copper Rotor</td>
<td>93 .. 93.6 %</td>
</tr>
<tr>
<td>Today Premium Efficiency</td>
<td>93 %</td>
</tr>
<tr>
<td>EPAct</td>
<td>91 %</td>
</tr>
<tr>
<td>1975</td>
<td>&lt; 88 %</td>
</tr>
</tbody>
</table>

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Industry Sector
Future Standards
New Energy Efficiency Class IE4

- IE4 standard is being released – only possible energy efficiency differentiation for ourselves and our customers from 2015 onwards
- At IE4, conventional motor technologies reach their limit – new approach needed, depending on application and customer requirements
Energy efficiency requirements keep moving on
Motor Technologies

Efficiency

New technologies

IE1
IE2
IE3
IE4

PM / Reluctance Motors (SYN)
Induction Motors (ASM)
Four different motor technologies have been evaluated and compared

<table>
<thead>
<tr>
<th>Induction motor (ASM)</th>
<th>PM Line-Start motor (LPSM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Torque production by induced voltage → disadvantage: losses in rotor</td>
<td>▪ Combines induction and synchronous machine</td>
</tr>
<tr>
<td>▪ In order to reach IE4 efficiency level more active material is needed:</td>
<td>▪ Asynchronous start-up directly on grid; automatic synchronization near rated speed → advantage: no rotor losses</td>
</tr>
<tr>
<td>▪ longer lamination stacks</td>
<td>▪ Established Technology → Siemens 1FU8 (since ~1960)</td>
</tr>
<tr>
<td>▪ more copper in stator</td>
<td>▪ Disadvantage: magnets needed</td>
</tr>
<tr>
<td>▪ copper bars in rotor</td>
<td>▪ Suitable for all relevant applications except constant torque drives, no limitations regarding power</td>
</tr>
<tr>
<td>▪ Suitable for all relevant applications, IE4 difficult to achieve below 3 kW</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Synchr. Reluctance motor (RSM)</th>
<th>Synchr. PM motor (PSM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Due to differences in inductances in d- and q-axis rotor aligns with air gap field/stator</td>
<td>▪ Excitation by permanent magnets on rotor → advantage: no rotor losses</td>
</tr>
<tr>
<td>▪ Disadvantage: power density lower than that of PM machines</td>
<td>▪ Disadvantage: magnets needed</td>
</tr>
<tr>
<td>▪ Advantage: no magnets and no copper in rotor</td>
<td>▪ Advantage: highest power density of all four concepts</td>
</tr>
<tr>
<td>▪ Suitable for all relevant applications</td>
<td>▪ Suitable for all relevant applications, no limitations regarding power</td>
</tr>
<tr>
<td>▪ no limitations regarding power</td>
<td></td>
</tr>
</tbody>
</table>
Trends & Products
## SIMOTICS portfolio

The members of the family ....

### Motors

<table>
<thead>
<tr>
<th>General Purpose</th>
<th>Severe Duty</th>
<th>Trans-standard</th>
<th>Flexible Duty</th>
<th>Definite Purpose</th>
<th>Explosion Protected</th>
<th>Servo</th>
<th>Main</th>
<th>Linear</th>
<th>Torque</th>
<th>DC</th>
<th>High-voltage motors</th>
</tr>
</thead>
<tbody>
<tr>
<td>GP</td>
<td>SD</td>
<td>TN</td>
<td>FD</td>
<td>DP</td>
<td>XP</td>
<td>S</td>
<td>M</td>
<td>L</td>
<td>T</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Low-voltage motors** for line and converter operation
- **Motors for motion control applications**
- **DC motors**
- **High-voltage motors**
The challenge

**Challenges for automation suppliers**

- More emphasis on Total Cost of Ownership and Life Cycle Costs
- Limiting the operating costs
- Speeding up the time-to-market
- Energy and raw material prices are increasing
- Energy efficiency is on the political agenda
- Operating costs are of considerable significance, especially for end user sectors
- Energy efficiency has become a competitive factor
- Holistic and integrated automation solutions create a productivity and innovation lead
Reduce environmental stress

- Optimal material-efficiency ratio
- Reduction of energy consumption
- Reduction of CO₂ emission
Minimize lifecycle costs

Total Cost of Ownership (TCO)
Energy consumption typically up to 95% of life cycle costs !!!

Source: stat. Motorlebensdauer DKI-Informationsdruck* 09/99, page 10

*statistical motor lifetime DKI info brochure

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Industry Sector
Faster payback time

Generally payback time for the additional price is less than 18 months. Every additional operating month reduces the overall costs.

e.g. 11 kW, 4-pole, energy-saving motor, 10 ct / kWh energy costs, 1-shift operation, S1-power

<table>
<thead>
<tr>
<th>Operating years</th>
<th>Lifecycle costs in EUR</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>400</td>
</tr>
<tr>
<td>4</td>
<td>500</td>
</tr>
<tr>
<td>6</td>
<td>600</td>
</tr>
<tr>
<td>8</td>
<td>700</td>
</tr>
<tr>
<td>10</td>
<td>800</td>
</tr>
</tbody>
</table>

Cost saving area
Standard Motors – platform for various efficiency classes, applications and motor technologies

Alu-Platform AH 80 .. 225

CI-Platform AH 80 .. 315

cross use of parts

IE2
IE4
IE1
IE3

IE4

IE2
IE4
IE1
IE3

IE4

IE2
IE4
IE1
IE3

IE4

IEC
AH 80 .. 225

IEC
AH 80 .. 225

IEC
AH 80 .. 315

IEC
AH 80 .. 315
SIMOTICS GP, SD and XP Series
and this is what it looks like …

GP Motors
1LE10

SD Motors
1LE15

XP Motors Ex t, Ex nA
1MB10

NEMA SD100 Motors
1LE2

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Configured Motors
Platform for various motor technologies

Induction motors

Synchronous motors

Synchronous generators

Sleeve bearing

Exciter

Induction motor squirrel-cage rotor
2-16 pole

Synchronous motor cylindrical rotor
2-pole

Synchronous motor cylindrical rotor
4-6 pole

Synchronous motor salient pole rotor
4-6 pole
“H – modyn – 2nd Generation”  
and this is what it will look like …

Individual drive solutions for application and industry sector-specific customer requirements

A universal platform for:
- induction motors,
- synchronous motors, (massive salient pole)
- synchronous motors, (massive cylindrical rotor)
- synchronous motors, (laminated cylindrical rotor)
- all versions also available for generator application

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Industry Sector
SIMOTICS HV Series
and this is what it will look like …

April 2013 Hannover Fair:
- New SIMOTICS corporate design
- New name: SIMOTICS HV series H-compact PLUS
- Motor in SH 500 for showroom

SIMOTICS corporate design
Addressing key market trends with best-in-class innovations based on Integrated Drive Systems

<table>
<thead>
<tr>
<th>Customer benefit</th>
<th>Integrated Drive Systems</th>
<th>Innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>Integration of drive products along the Drive System</td>
<td>SIMOGEAR</td>
</tr>
<tr>
<td>Reliability</td>
<td>Integration of the Drive System in the TIA World</td>
<td>TIA Portal – V12</td>
</tr>
<tr>
<td>Productivity</td>
<td>Integration of the Drive System into PLM Engineering Tools</td>
<td>Virtual NC</td>
</tr>
</tbody>
</table>