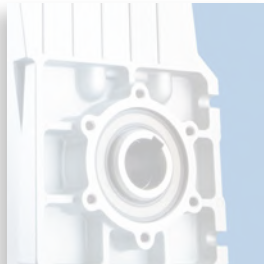
CONTROL ENGINEERING

Optimizing Drive Solutions for Energy Efficiency



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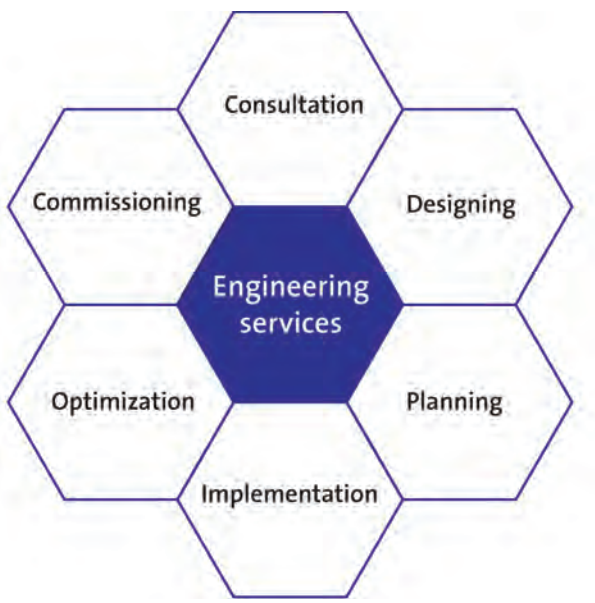

As a global specialist in Motion Centric Automation, Lenze offers you products, drive solutions, complete automation systems, and engineering services and tools from one single source. Lenze supports the entire machine development process – from initial idea to after sale, from control systems to drive shafts. We are a reliable solutions partner with the knowledge and expertise to provide you with the best possible overall solutions.

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In the face of economic uncertainties and increasing environmental concerns, many businesses are trying to make their operations more lean, efficient, and environmentally friendly. Examining your electricity bill is a good place to start. The top consumers of electricity are HVAC systems, water heating, lighting, office equipment, and machinery.

Christian Fritz, *National Instruments*

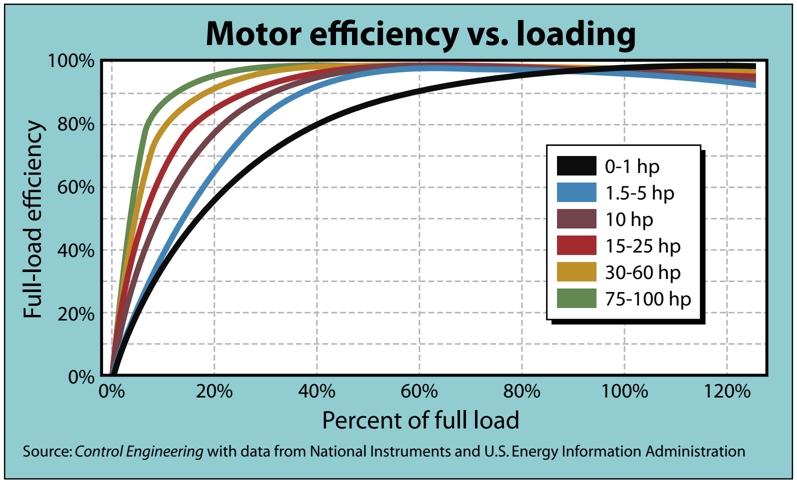
In the face of economic uncertainties and increasing environmental concerns, many businesses are trying to make their operations more lean, efficient, and environmentally friendly. Examining your electricity bill is a good place to start. The top consumers of electricity are HVAC systems, water heating, lighting, office equipment, and machinery. More specifically, the motors within these machines are responsible for approximately two-thirds of the total electrical energy consumption in a typical industrial facility. To improve the efficiency and lower operating costs of motors in your enterprise, consider the following factors.

High efficiency motors

A motor running at 50% efficiency is converting only half of the electrical power into useful mechanical work. The rest is wasted. This makes the extra investment in efficient motors prudent since electricity costs make up 96% of the total life cycle costs of a motor. According to the U.S. Department of Energy (DOE), switching to a motor with a 4-6% higher efficiency rating can pay for itself in two years if the motor runs more than 4,000 hours a year. Unfortunately, simply replacing existing equipment is a luxury. Many facilities host motors that are very large and costly to replace. Hence, users are always looking for ways to squeeze more efficiency out of existing assets. The key to reaping savings could lay in the drive control algorithms and implementation of commercial-off-the-shelf (COTS) hardware. Essentially, when you cannot replace the motor, replace the algorithm and controller to achieve better efficiency. With high computational power silicon devices, such as the Virtex or Spartan FPGAs from Xilinx, along with available commercial off the shelf (COTS) hardware like National Instruments' CompactRIO, one can rapidly prototype and realize precise custom control systems to increase motor efficiency significantly.

Right size motors

A second fundamental component is proper motor sizing. The DOE estimates that 80% of all motors are oversized, causing businesses to pay a high price in wasted energy. As shown in the graph, efficiency drops dramatically when the load is below approximately 40% of the full-rated load. A number of sizing tools are available online to assist you in the process, such as MotorMaster+ for AC induction motors and VisualSizer for DC servo motors. When sizing, a good rule of thumb is to choose a motor with a peak and RMS torque rating approximately 25% higher than the application requires. Similar to advances in FPGA technologies which reduce complexities in design, new virtual prototyping tools are just around the corner to help provide more accurate torque and velocity data by linking motion control programming software, such as NI LabView, with 3D mechanical CAD environments for simulation and rapid design prototyping.



Motors running at leass than full load can lose much of their efficiency, this is particularly true of smaller size motors.

Appropriate motor technology

The type of motor you choose for an application has a big impact on energy efficiency. Induction motors, also known as asynchronous ac motors,

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are one of the oldest and most well established types of motor. With their low cost and ability to operate without sophisticated controls, ac induction motors are the workhorse for most household goods. They are usually operated in constant speed applications but can also be augmented with more sophisticated controls for use in applications requiring variable speed and torque.

For low-power applications, inexpensive stepper motors and brushed dc motors are popular due to the simple control circuitry necessary. However, they provide somewhat lower energy efficiency and therefore higher operating costs. Stepper motors are particularly inefficient, because they draw power even when stopped and they must be significantly oversized due to poor torque output at high speeds.

Brushless dc motors and permanent magnet synchronous ac motors (PMSM) are both commonly referred to as brushless dc (BLDC) motors but they do differ in the way their stator is wound. When rotated, the stator of the BLDC is wound in such a way as to produce a trapezoidally shaped back emf voltage, while the PMSM produces a sinusoidally shaped voltage. Brushless dc motors are more costly but provide better energy efficiency and performance when controlled using advanced algorithms compared to the ac induction motors explained above, and they can scale up to serve very high power and high speed applications.
BLDC motors are a type of synchronous motor. This means the magnetic field generated by the stator and the magnetic field off the rotor rotate at the same frequency. Usually BLDCs are equipped with three phases. Most BLDC motors have three stator windings connected in star fashion. The internal structure is like an induction motor containing pairs of permanent magnets on the rotor rather than windings. Since there are no brushes, commutation must now be provided electronically. To rotate the BLDC motor, the stator windings are energized in a sequence. To calculate which winding to energize at a time it is necessary to know the rotor position typically measured by three Hall Effect sensors embedded into the stator of the motor. Based on the triple combination of these sensor signals, the exact sequence of commutation can be determined by the control electronics. Because brushless motors use permanent magnets in their rotor rather than passive windings, they natively provide higher power for their size and weight compared to induction motors. The key to high efficiency operation, however, lies in the control system.

Control algorithms for motors

The use of microprocessing technologies in motor control has increased in recent years. Their purpose is to control algorithm execution in order to deliver better efficiency. For example, when using brushless motors, a wide range of control system algorithms is available, including trapezoidal, sinusoidal, and field-oriented control.

Trapezoidal control: Also known as six-step control, trapezoidal control is the simplest but lowest performance method. For each of the six commutation steps, the motor drive provides a current path between two windings while leaving the third motor phase disconnected. This method has significant performance limitations in the form of torque ripple which causes vibration, noise, mechanical wear, and greatly reduced servo performance.

Sinusoidal control: Also known as voltage-over-frequency commutation, sinusoidal control addresses many of these issues. A sinusoidal controller drives the three motor windings with currents that vary smoothly. This eliminates the torque ripple issues and offers smooth rotation. The fundamental weakness of sinusoidal commutation is that it attempts to control time-varying motor currents using a basic proportional-integral (PI) control algorithm and doesn't account for interactions between the phases. As a result, performance suffers at high speeds.

Field-oriented control (FOC): Also known as vector control, FOC improves upon sinusoidal control by providing high efficiency at faster motor speeds. It delivers the highest torque-per-watt of power input compared to other control techniques, and allows precise and responsive speed control when the load changes. FOC also guarantees optimized efficiency even during transient operation by perfectly maintaining the stator and rotor fluxes.

Understanding FOC

One way to understand how FOC works is to form an image of the coordinate reference transformation process. If you picture an ac motor operation from the perspective of the stator, you see a sinusoidal input current

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applied to the stator. This time variant signal generates a rotating magnetic flux. The speed of the rotor is a function of the rotating flux vector. From a stationary perspective, the stator currents and the rotating flux vector look like ac quantities.

Now, imagine being inside the motor and running alongside the spinning rotor at the same speed as the rotating flux vector generated by the stator currents. Looking at the motor from this perspective during steady state conditions, the stator currents look like constant values, and the rotating flux vector is stationary.

Ultimately, you want to control the stator currents to obtain the desired rotor currents. Using coordinate reference transformation, the stator currents can be controlled like dc values using simple PI-control loops. Under the hood, the FOC algorithm works by removing time and speed dependencies and enabling direct and independent control of both magnetic flux and torque. This is done by mathematically transforming the electrical state of the motor into a two-coordinate time-invariant rotating frame using mathematical formulas known as Clarke and Park transformations.
An efficient method to control the power electronics is called space vector pulse width modulation (PWM). It simultaneously maximizes usage of motor supply voltage and minimizes harmonic losses. Harmonics can significantly reduce motor efficiency by inducing energy-sucking eddy currents in the iron core of the motor. Best of all, field-oriented control can be utilized for both ac induction and brushless dc machines to improve efficiency and performance, and FOC can be applied to existing motors by upgrading the control system. In fact, vector control techniques such as FOC, can be employed with ac induction motors to enable servo-motor-like performance.

FOC with FPGAs

To implement FOC, powerful computation devices are needed which makes FPGA advancements in lower cost-to-performance a natural fit for motor control. The vector control algorithm must be continuously recomputed, at a rate of 10 to 100 kHz. In parallel to the control algorithm, additional IP (intellectual property) blocks such as the high speed PWM outputs need to execute without affecting control algorithm timing. Capable to perform control algorithms with loop rates up to hundreds of KHz, combined with its inherent parallel execution and hardware reliability can make an FPGA perfect solution for this application. This approach leaves additional room to perform communication and provide data for user interface applications, and the reconfigurability of FPGAs allows users to adjust the control algorithm whenever necessary.

The NI LabView FPGA module delivers graphical development for FPGAs on Reconfigurable I/O (RIO) COTS hardware targets allowing users to create custom applications using built-in functions or existing HDL IP. LabView is well suited for FPGA programming because it clearly represents parallelism and data flow. IPNet (ni.com/ipnet) is a companion site for LabView FPGA to search, download, and exchange

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additional IP algorithms. Field-oriented control algorithms for LabView FPGA can be downloaded free of charge through the NI intellectual property network (IPNet).

To connect the algorithm embedded in the FPGA to real world signals, the compact RIO and single board RIO offer a wide range of I/O connectivity and validated I/O drivers to read the Hall Effect sensors and control the power electronics driving the motor. NI Single-Board RIO is a low-cost OEM board-level embedded platform capable of executing the same code developed for the compact RIO modular platform. This combined solution allows design teams to prototype embedded systems rapidly with modular, flexible compact RIO then quickly deploy to low-cost single-board embedded hardware with 100% code reuse. Other key benefits of such a solution include shortened time to market and increased machine reliability with validated middleware.

One of the biggest challenges in embedded design is the effort required to create, debug, and validate driver-level software stacks to integrate all of the hardware components of the embedded system. Traditionally, this integration process is left to the user, which complicates and lengthens the embedded system design process. The RIO platform middleware drivers go beyond the basic drivers that traditional single-board computer and other embedded system providers offer to deliver increased productivity and performance and short time to market.

Driver software and additional configuration services software are included with every RIO-supported device. The built-in middleware driver tools contain built-in functions for interfacing between analog, digital, motion, and communication I/O and the FPGA, transfer functions for data communication between the FPGA and processor, methods for interfacing the FPGA/processor to memory, functions for interfacing the processor to peripherals (RS232 serial, Ethernet), and multi-threaded drivers for high performance.

Improving motor operating efficiency can produce significant energy and dollar savings, and provide a rapid return on investment. For example, a 5% efficiency increase on just one 500 horsepower motor operated 8,000 hours/year could save over $12,000 and 170 kWh of electricity each year. When evaluating control system upgrades, keep in mind that energy costs are typically orders of magnitude higher than hardware costs over the lifecycle of the motor.

LINKS

For more information, visit:

Download Field Oriented Control IP for LabView FPGA at www.ni.com/ipnet

DOE whitepaper, Buying an Energy Efficient Motor at www1.eere.energy.gov/industry/bestpractices/pdfs/mc-0382.pdf

DOE MotorMaster+ sizing tool for AC induction motors at www1.eere.energy.gov/industry/bestpractices/software.html

Copperhill Media VisualSizer for DC motors www.copperhillmedia.com/VisualSizer/

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The third edition of Motor Summit drew experts from research, government, and the private sector to focus on the latest technological innovations, current state of market penetration, and strategies needed to spur widespread use of efficient motor systems. See motor efficiency deadlines from Europe, China, and USA, with a comparative table of more than a dozen nations.

Frank J. Bartos, P.E., is a *Control Engineering* contributing content specialist

This international forum dedicated to debating and promoting relevant motor system efficiency issues presented a growing program on Oct. 26-28, 2010, in Zurich, Switzerland-following prior successful "summits" in 2007 and 2008 at the same locale. Motor Summit supports various ongoing processes of the Electric Motor Systems Annex of the International Energy Agency's Efficient Electrical End-Use Equipment program (IEA 4E EMSA), namely:

- European Union's Energy-using Products Ecodesign Directive;
- Harmonized IEC (International Electrotechnical Commission) motor testing and energy classification standards; and
- NEMA Premium Motors minimum efficiency performance standard (MEPS), which became U.S. law in Dec. 19, 2010 (January 2011 in Canada).

An increasing number of nations have, or are adopting, minimum efficiency performance standards (MEPS) for industrial motors.

Efficiency levels	Efficiency classes	Testing standard	Performance standard
	IEC 60034-30	IEC 60034-2-1	Mandatory MEPS
	Global 2008	Includes stray load losses 2007	Policy goal
Premium efficiency	IE3	Low uncertainty	USA 2011
			Canada 2011
			Europe* 2015 (27.5kW); 2017
High efficiency	IE3		USA
			Canada
			Mexico
			Australia
			New Zealand
			Korea
			Brazil
			China 2011
			Switzerland 2011
			Europe 2011
Standard efficiency	IE3	Medium uncertainty	China
			Brazil
			Costa Rica
			Israel
			Taiwan
			Switzerland

Source: Motor Summit 2010 and *Control Engineering*.

* IE3 motor or IE2 motor with VFD

Summit segments consisted of "International strategy day" (Oct. 27), "Swiss implementation day" (Oct. 28), and two EMSA workshops: "IEA 4E: Testing Centers," and "New Motor Technology" (on Oct. 26 and Oct. 28, respectively).

Presentation topics ranged widely from efficiency assessment of motor systems-including pumps, fans, and variable-frequency drives (VFDs)—to associated testing methods and to market potential for new technologies, and more. (A systems view of energy efficiency and permanent magnet motor technology are covered in a separate online article.) Other Summit topics included VFD testing methods and efficiency standards developments-including that for "small motors"—as outlined below.

Standards developments, VFDs

As presented in "New IEC Standards for Motor Efficiency Classes and Testing," Dr.-Ing. Martin Doppelbauer, manager, design and development motors, SEW Eurodrive GmbH & Co KG, Germany, explained differences between standards and regulations and provided an overview of European energy-efficiency standards for industrial motors. Focus was on

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IEC 60034, which has several parts dealing with such items as efficiency test methods, a guide for selecting/applying efficient motors and VFDs, and motor efficiency class definitions. IEC 60034-30 covers the latter area and has defined four international efficiency (IE) classes to harmonize general-purpose, line-fed, three-phase, squirrel-cage, ac induction motors, namely: standard efficiency (IE1), high-efficiency (IE2), premium efficiency (IE3), and super-premium efficiency (IE4). IE2 compares to EPAct and IE3 to NEMA Premium performance standards specified in the U.S (see below).

The European Union's regulation EC No. 640/2009, has implemented energy-efficiency requirements in Europe based on IE class definitions, which become mandatory in three time steps:

- IE2 efficiency on June 16, 2011 for motors of 0.75-375 kW power range;
- IE3 efficiency on Jan. 1, 2015 for motors of 7.5-375 kW power range; and
- IE3 efficiency on Jan. 1, 2017 for motors of 0.75-375 kW power range.

EC 640/2009 recognizes that VFDs can often save much more energy than energy-efficient motors alone. Premium-efficiency requirements (starting in `15 and `17) apply to constant-speed, line-fed motors only, explained Doppelbauer. "Motors in variable-speed drive applications are just required to be high-efficient (IE2)," he said. "This should give users a small incentive to switch from constant speed to variable speed wherever [such drives are] useful."

Doppelbauer also mentioned some noteworthy future projects of IEC Technical Committee 2 and its working groups 28 and 31. He is convener of WG 31. These tasks include

- Future efficiency standards developments for ac induction motors (namely IE4);
- Possible introduction of other motor types: single-phase induction, PM synchronous, reluctance synchronous, motors specifically built for VFD operation, etc; and
- Introduction of a new state-of-the-art energy-efficiency class (IE5).

http://motorsummit.ch/data/files/MS_2010/ms_int_10/10_doppelbauer.pdf

Also see Ref 1.

Importance of VFDs to motor system efficiency was explored by Pierre Angers, P. Engineer at the Energy Testing Laboratory of Hydro-Quebec (Canada), in "Variable Frequency Drive Testing Methods." The context was to establish appropriate testing procedures and ability to compare efficiency of VFD systems (drive, motor, and connected system) at different loads and speeds.

http://motorsummit.ch/data/files/MS_2010/ms_int_10/16_angers.pdf

An increasing number of nations worldwide have, or are adopting, minimum efficiency performance standards (MEPS) for industrial motors—see table. Two papers presented progress in developing motor standards in Asia, namely in China and India, respectively. These were "Small Motors and Pumps Standards in China," by Zhang Xin, China National Institute for Standardization; and "New Motor Standards in India," by Milind Raje, director of Energy Solutions, International Copper Association (India).

http://motorsummit.ch/data/files/MS_2010/ms_int_10/11_xin.pdf

http://motorsummit.ch/data/files/MS_2010/ms_int_10/12_milind.pdf

Rob Boteler, director of marketing at Nidec Motor Corp. (and chairman of NEMA Energy Committee), discussed current energy-efficiency measures in the U.S. in his presentation "Small Motors Regulations Update." However, he first reviewed MEPS developments for integral horsepower (hp) motors. Surprisingly, this is an area where the U.S. has taken worldwide leadership. Progress has come in three stages:

- Environmental Policy Act (EPAct 1992) implemented in 1998 for general purpose, T-frame, single-speed, squirrel-cage induction motors in the 1-200 hp (0.75-150 kW) range. This corresponds to IEC's level IE2;
- Energy Policy Act of 2005 (EPAct `05) that established higher NEMA Premium (IE3 level) efficiency ratings as the basis for federal motor purchases; and
- Pending implementation passed by the U.S. Congress on 19 Dec. 2010 as part of the Energy Independence & Security Act (EISA 2007) that extends efficiency coverage for induction motors from 1 to 500 hp (Premium Efficiency, IE3).

Boteler mentioned that EISA 2007 includes motor varieties and designs previously exempted from minimum efficiency requirements. The following are now included: U-frame, NEMA Design C, close-coupled pump motors, footless motors, vertical solid shaft

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normal thrust motors, eight-pole (900 rpm), and polyphase motors with voltage of not more than 600 V (other than 230 or 460 V). However, motors sized between 200 and 500 hp need only meet EPAct 92 efficiency ratings, according to Boteler.

http://motorsummit.ch/data/files/MS_2010/ms_int_10/9_boteler.pdf

Attention of the U.S. Dept. of Energy (DOE) has also been drawn to energy efficiency of small electric motors—generally below 1 hp rating, but extending up to 3 hp for some types. A multi-year process culminated in a so-called DOE Final Rule, "Energy Conservation Program: Energy Conservation Standards for Small Electric Motors," published March 9, 2010 in the Federal Register (10 CFR Part 431).

The ruling adopts energy conservation standards for general-purpose, polyphase (actually, three-phase) motors ¼ through 3 hp (0.18-2.2 kW) with 2-, 4-, and 6-pole designs and 42 through 56 frame sizes. Also covered are single-phase, capacitor-start motors of the same power range and pole count. Applicable IEC motors and corresponding frame sizes are likewise included. Effect date is five years after publication date in March 2015.

DOE's new ruling has drawn disagreement from motor manufacturers. Nidec Motor Corp.'s Boteler (and others) have pointed out that efficiency rule making is more complex for this product sector. Fractional hp motors have different designs and types; more frame size possibilities; more diverse applications; fewer operating hours; and less recognized efficiency testing methods compared to larger induction motors used in industrial and commercial applications.

Moreover, motor manufacturers disagree with the definition of "small motor" in DOE's Final Rule, based on which NEMA has filed a lawsuit against the Rule. The good news is that substantial time remains to resolve any differences before the rule's effective date of March 2015. Organizers and sponsors of Motor Summit 2010 were The Swiss Agency for Efficient Energy Use (S.A.F.E.), in collaboration with the International Energy Agency's 4E EMSA and the national SwissEnergy program. Control Engineering was a participant at Motor Summit 2008.

For full content of the Motor Summit 2010 program, visit http://www.motorsummit.ch

and Ref 1:
http://motorsummit.ch/data/files/MS_2010/ms10_proceedings.pdf

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See the motors and drives area at www.controleng.com/motors

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Energy Efficiency in Motor Driven Systems (EEMODS)—a notable international conference on electric motors, drives, and numerous related systems—drew some 150 attendees from industry, academia, government, research labs, and other service organizations to Alexandria, VA (greater Washington, D.C. area) during Sept. 12-14, 2011, to discuss, debate, and promote advances in energy-efficient technologies. This part 2 of two articles covers developments in efficiency standards and newer motor technologies.

Frank J. Bartos, P.E.

ee mods '11 conference

energy efficiency in motor driven systems

Held for the first time in the Americas, EEMODS `11 consisted of parallel presentation tracks, panel discussions, and several table-top exhibits. As explained in part 1 of the conference coverage (Ref. 1), "systems" aspects of efficient motor-driven equipment is drawing

deservedly increased attention from developers and providers of the underlying technologies. Meanwhile, work continues to further advance the efficiency of motors.

MEPS around the world

Motor minimum efficiency performance standards (MEPS) formed the topic of one of EEMODS' panel discussions. Andrew Delaski, ex-director of ASAP (appliance standard awareness project)—a broad-based coalition of agencies to promote energy efficiency of various appliances—stated, "Savings from standards grow over time from accumulated results and from [an influx of] new equipment."

Because the U.S. Department of Energy is required to periodically amend existing standards, a likely upcoming change will be expanded definition of motors covered, followed by fewer exceptions to the definition. "Much better results are expected from an increased scope of motors covered than trying to further increase efficiency of existing motor classes," Delaski added.

Sarah Hatch, senior project officer, Australian Government Dept. of Climate Change and Energy Efficiency, spoke about the MEPS environment and experience in Australia—a country with strong advocacy for efficient equipment regulation, where MEPS are mandatory and manufacturers and suppliers must register their products. "Ongoing education and compliance are likewise part of Australia's E3 (equipment, energy, efficiency) program," Hatch stated.

Among comments of Paolo Bertoldi, European Commission Directorate, JRC, Institute for Energy, were upcoming regulations from the European Commission that will require reporting of product efficiencies at 50% and 75% load, in addition to full load. "Overall, the objective of MEPS is to phase out the least efficient products," Bertoldi said.

Dr.-Ing. Peter Zwanziger, of Siemens AG and CEMEP (European Committee of Manufacturers of Electrical Machines & Power Electronics), spoke about first experiences of CEMEP with new IE-class low-voltage ac motors as defined in International Standard IEC 60034-30. (See more at Ref. 2 about effective dates of European Union regulations based on IE classes for motors. IE refers to international efficiency.) Market penetration of IE2 motors (1st phase of regulation) has been held down by applications that fall outside of the ruling, among other factors. Zwanziger called the European market transformation "on track but in need of strong market sweeteners" and noted that some customers are interested in even higher (IE4) class motors for their new systems.

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section of NEMA (National Electric Manufacturers Association), EEMODS `11 was the 7th biennial running of the event and held for the first time in the U.S. (or the Americas). Looking ahead, Zwanziger noted that future legislation must not block the influx of permanent magnet (PM) motors, often cited as a prime IE4 candidate, while induction motors remain protected as "an economical but effective technology." See more below, about alternative efficient motors.

How MEPS will likely impact system design was discussed by Phillipe Juhel of CAPIEL, (European low voltage switchgear and controller manufacturers association) France, in "Does the new EU regulation for energy-efficient motors change the way to design a system?" First phase of the recent EU regulations has gone into effect in mid-June 2011 (see Ref. 2).

Among CAPIEL's findings were that reasonably short payback periods apply for IE2 and IE3 motors when running for 800 hours or more per year, as measured in reduction of life-cycle cost (LCC). Moreover, IE3 motors should be considered for use first in high-duty applications, where they can reduce environmental impact and may also reduce LCC.

"It's not always obvious to use variable-speed drives (VSDs) with efficient motors," Juhel said. "It depends on the application and system involved." He gave an example of an airport horizontal belt-conveyor application using a 2.2 kW, 4-pole gear motor. The motor driven direct on line consumed less energy than when under VSD control, for operations up to 300 start/stop cycles per hour. "It was a case of lower power consumption at constant speed but higher consumption during startups," Juhel noted.

Moving beyond MEPS

The presentation, "When enough MEPS is enough: Conflict of resource utilization between system efficiency gains and MEPS," by Neil Elliott of ACEEE (American Council for an Energy-Efficient Economy) was part of another panel discussion. While continued efficiency standards activities remain useful, Elliott suggested moving beyond MEPS to system approaches. Motors, pumps, lights, some appliances, etc. have already been covered. "We're beginning to hit the point of diminishing returns with components as MEPS become more and more incremental," he said.

Use of the private sector's limited resources might gain more results from developing newer technologies. Elliott contrasted a static approach of "perfection" (for example, developing the perfect induction motor) versus a continuous and changing approach of "excellence" that involves systems and energy management—where the big savings exist.

Other areas of potentially large energy savings were pointed out by Bruce Benkhart, director of Applied Proactive Technologies, in his presentation "Whole System Approach to Improving Efficiency in Industrial Facilities." Benkhart listed candidates for energy savings such as direct-drive PM motors, change of gearing type, more VSDs applied to motor control, synthetic lubrication, etc. Use of helical gearing rather than worm gearing, for example, can be up to 20% more efficient. Bringing the majority of motor systems (more than 2/3) with centrifugal or variable-speed loads under VSD control could result in 5-50% energy savings. About 60% of the total motor population fits that type of loading, according to Benkhart.

Motor rewind issue

Overall, motor population efficiency is expected to increase through attrition of older units. However, attrition may take decades due to long product life and motor rewind policies, among other factors, Benkhart explained.

Rewinding of old motors is often a fact of life for machines rated 50 hp (37 kW) or larger. This rule-of-thumb in industry happens because of substantial first cost of the motor and inherently higher original efficiency of larger units.

This hindrance to greater market penetration by new, energy-efficient motors was noted by other EEMODS presenters. Some limitation on rewinding after a certain age of the motor may be a future development. One of the presenters, Conrad U. Brunner—director of A+B International, Switzerland, and operating agent for 4E EMSA, (Electric Motor System Annex)—proposed eliminating motor rewinds after 20 years of service life to accelerate influx of more efficient motors.

Alternative efficient motors

The venerable induction motor continues to serve as the workhorse of electric motors, but other technologies are coming on stage. "Advanced/alternative motor (AAM) technologies market implementation," presented by Rob

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Boteler, consultant for Nidec Motor Corp., provided insight on the approach OEMs take to adopt AAM technologies for their motor-driven systems. "Accelerating the adoption rate of new technology is proving difficult and must include service, supply, and other considerations," Boteler said. AAM technologies also involve risk assessment and a need to assure customers that claims of energy savings are deliverable.

"Energy savings for cost reduction rate only third-place motivation when OEMs consider new technology purchases," Boteler noted. Initial cost and improved system performance came in ahead of energy savings considerations.

Careful evaluation and total understanding of the process application is needed to make the best motor technology decision. This can range from speed, torque, duty cycle, and controls to environmental specs, interfacing, life expectancy, agency approvals, and more. Another possible item to consider: Could a low-efficiency gearbox be eliminated from the system, for example.

Alternative efficient motor technologies include permanent magnet (PM) synchronous motors, which offer the best specific torque per volume; switched reluctance (SR) motors may provide a future impact, Boteler explained.

SR motor technology also received attention in "Electric motors for the modern world—a look at new motor technologies," presented by Satish Rajagopalan of EPRI (Electric Power Research Institute). Renewed interest in SR motors comes from absence of permanent magnets in the design, which makes them an alternative to motors requiring costly (and scarce) rare-earth magnets. Notable usage has been in the medium-power market (<300 kW), such as household appliances and automotive applications, according to Rajagopalan. However, SR motors have some noise, torque ripple, and vibration issues that need to be minimized for wider application success.

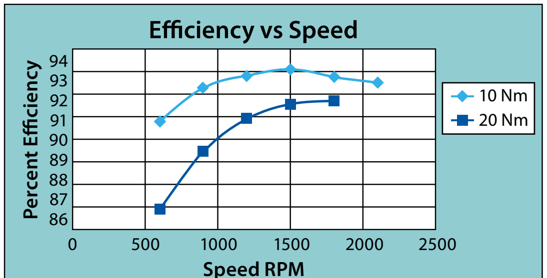
Another IE4-class candidate was the synchronous reluctance motor, which starts like an induction motor, then locks into synchronism at operating speed. "Absence of slip translates to reduced rotor losses, hence higher efficiency," Rajagopalan said.

Ferrite magnets for efficiency

Permanent magnet motors offer higher efficiency than induction machines—and maintain their efficiency over a wide torque/speed range, but rare-earth PMs pose a cost challenge, noted John Petro, founder and CTO of NovaTorque Inc. The company's initial design to develop a new IE4-plus efficiency motor was based on neodymium-iron-boron (Nd-Fe-B) magnets, but "we saw high cost of rare-earth magnets coming," Petro said.

Instead, a PM motor with equivalent benefits was developed using less costly ferrite magnets, as described in Petro's paper, "Exceeding IE4 efficiencies with cost-effective ferrite magnet PM motors." However, the new design required compensation for the 3:1 lower power density of ferrite versus Nd-Fe-B magnets, explained Petro. An axial motor with conical air gap, allowing for flux concentration and a special stator design contributed to obtaining 91.7% efficiency at 20 Nm output at 1,800 rpm—as well as 93% efficiency for a smaller motor capable of 10 Nm output at 1,500 rpm (see diagram). The design is scalable upward (more easily) or downward for motor size, Petro explained. Commercial availability of these motors is pending.

Ferrite PM Motor



Source: NovaTorque, Inc.

Efficiencies for NovaTorque's motors indicated above include that of the drive, since PM motors can't be run directly on line. One tradeoff with this design is a substantially heavier motor due to larger mass of ferrite magnet needed.

Updating, harmonizing standards

"New EU-mandate & IEC 60034-30 energy classes" by Martin Doppelbauer, Prof. at Karlsruhe Institute of Technology, Germany, updated developments concerning the major multi-part International Standard IEC 60034. Latest (2nd) edition of standard's part 30 (IE code classes) has been approved; parts 30-2-1 (motor efficiency measurement and testing) and 30-2-3 (harmonic loss testing due to converter power supplies) are slated for approval in 2012 or 2013. IE4 motor efficiency class is now formally

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included in the 2nd edition of IEC 60034-30 standard. A still higher IE5 class has been proposed but no qualifying commercial motor is available, according to Doppelbauer. However, such a motor is envisioned to be able to lower losses by 20% compared to IE4 class.

Motor size range covered in IEC 60034-30 has been widened to now include the range of 0.12-500 kW, for 50 Hz units. Higher power ratings up to 800 kW will have flat efficiency limits. More motor types are now included: all fixed-speed, wound-rotor synchronous, single-phase designs, and virtually all brake motor types; as well as variable-speed PM synchronous motors, within the speed range of 1,000-5,000 rpm. To avoid loopholes, operating cycle and temperature range definitions, among others, have been tightened in the latest version of IEC 60034-30.

Switched reluctance, dc motors, and electronically commutated motors are not formally part of the standard but can be included if tested for efficiency with a drive. Future standards will cover this issue.

Upcoming standards will also look at line-fed versus converter-fed motors. The latter include the effect harmonic losses due to the drive and will need an efficiency assessment to factor-in use of a sine filter. IEC 60034-2-3 will look at test methods for determining losses and efficiency of converter-fed motors using VSDs. Future standards will address increasingly wider systems. One example is IEC 528xx, which will cover efficiency of VDSs, power drive systems, and complete drive systems, Doppelbauer noted. In "Harmonized standards for motors & systems: global progress report and outlook," Conrad U. Brunner—A+B International and operating agent for 4E EMSA—summarized various accomplishments of energy-efficiency organizations and companies. Brunner cited continued global expansion of MEPS with coverage accounting for approximately 45% of electricity generation and about 70% of electricity usage. Standard operating conditions have also been more specifically defined for motor output, operating losses, life span, and load factor, among others.

Overall, fewer exception to motor standards are now allowed; for example, explosion-proof and gear motors, brakes, and operation at >40 C and higher than 1,000 m elevation. Harmonized testing for motor efficiency has been approved. "The 2012 revision of IEC 60034-2-1 will have one preferred test method for motors up to 1 MW output," Brunner emphasized.

A new RFID tag has been specified to allow tracking of individual IE-class motors. This is in addition to the name plate that shows efficiency class and nominal efficiency in conformance with European Ecodesign requirements.

Brunner summarized what's needed from energy-efficiency providers to spur further gains:

- Help OEMs understand life-cycle cost
- Include variable load efficiencies in MEPS
- Develop system MEPS (for pumps, fans, compressors, etc.)

Since its inception in 1995, EEMODS has been staged in Europe, Asia, and now in North America. The next, 8th edition in 2013 will be held in Rio de Janeiro, Brazil.

See related article:
http://www.controleng.com/industry-news/more-news/single-article/eemods-11-successful-1st-us-staging-of-efficient-motor-systems-conference/bdca41a3b4.html

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Lenze's Drive Solution Designer has optimized sustainability for material handling industry.

SOURCE: Lenze America

Lenze Americas has launched a Drive Solution Designer (DSD) for the material handling industry. A software tool for design engineers, the Lenze DSD analyzes the complete drive train of an application to ensure the correct design and dimensioning of a decentralized system.

"With the long running times in material handling applications, energy use is one of the major cost factors – and one of the first places we look to reduce costs," said Craig Dahlquist, Lenze Product Manager.

The Lenze DSD software performs a comprehensive examination aimed at deriving real energy savings through the use of highly efficient motors and transmissions; achieving precisely matched speed control through the use of frequency inverters; and enabling the utilization of regenerative energy produced during motor braking.

"The intelligent and economical use of the energy in each component of the drive train translates into a reduction in total energy consumption and a swifter return on investment," adds Dahlquist.

The energy requirements of a drive train and the individual components are calculated along with the amount of regenerative energy that can be exchanged via the DC bus or fed via a regenerative module to the supply system. Lenze DSD optimizes the energy use of each component by determining the loss/load ratio of the mechanical processes. Since drive train components work at low efficiency in partial load applications, contributing to high energy loss, the DSD works to accurately specify the precise load-dependent power requirements of the machine, in order to maximize energy savings.

Backed by extensive application libraries and process-specific calculations, the DSD guides users step-by-step through product options and benefits, offering in depth comparisons of multiple drive solutions.

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Lenze Americas' high efficiency, dynamic performance 8400 inverter series boosts motion control and logistics automation control productivity.

SOURCE: Lenze Americas

Lenze Americas launched the Lenze 8400 Inverter Series. The 8400 series features L-Force automation technology for tailored motion control solutions that deliver stable and high dynamic performance in a range of material handling and logistics application, the company said.

"The 8400 product family runs the gamut from basic inverter to 'servo' inverter. From simple continuous motion applications, like driving a conveyor, to controlling complex synchronized pick-and-place applications, there is an 8400 inverter right-sized for the job," said Darrow Hanesian, director of inverter products, Lenze Americas. "Matched with high efficiency Lenze motors, gearboxes and brakes, the 8400 series steers the whole drive package."

Most mechanical processes have variable power requirements that depend on external parameters, such as the production volume. A frequency inverter matches the speed and torque with the process requirements. In addition to L-Force control and software, the 8400 series inverters incorporate intelligent features, including memory modules, online diagnostics and optional integrated safety systems.

The Lenze 8400 BaseLine, StateLine, HighLine and TopLine versions are a scaled series of frequency inverters to match the requirements of a given application. The 8400 motec and protec inverters offer decentralized drive technology. Identical installation, parameterization, and user operation across the 8400 series enable ease of installation and operation of a single production line or full factory automation. The 8400 inverters are designed to optimize automated industrial processes, such as winding, packaging, positioning, extruding, and filling.

"Efficiency is a major cost factor in inverter drive systems, especially in demanding applications with protracted running times, acceleration and lifting operations. The robust 8400 inverters bring maximum productivity together with the highest order picking quality and reliability," added Hanesian.

Lenze Americas describes itself as a global manufacturer of electrical and mechanical drives, motion control and automation technology.

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Intelligent concepts to cut costs and protect the environment

Almost half of the electric energy produced in the world is used by the industry sector. And, electric drives are responsible for approximately two thirds of this power consumption.

When evaluating energy use, the entire drive system—comprising an inverter, motor and gearbox—should always be considered. The total efficiency determines how much electric energy is required for a defined process. While work often focuses on increasing the efficiency of the electric motor, greater energy savings can typically be obtained by optimally adapting the drive to the operating process.

Saving energy is one of the biggest challenges we face today and in the future. Consequently, Lenze is acting responsibly and has implemented effective ways to use drives in order to save energy.

Three ways to improve energy efficiency

There are a number of parameters which determine the energy efficiency of drives. And there are just as many potential starting points with a correspondingly large number of options for increasing energy efficiency. The appropriate measures can be determined by analyzing the mechanical process and its energy requirement.

Improving energy efficiency in drives follows three approaches:

1. Electric energy used intelligently
2. Converting energy with high efficiency
3. Using recovered braking energy

The greatest potential for improving energy efficiency can be found in the intelligent provision of electrical energy (75%). This is followed by the use of drive components with a high level of efficiency (15%). Further potential lies with using braking energy (10%).

Electric energy used intelligently

In order to make effective use of the energy available, the mechanical power output by the electric drive must meet the actual needs of the application. Both the maximum amount of power needed and fluctuations in operations should be taken into account.

An intelligent, needs-oriented provision of energy therefore requires:

• the drive to be designed in accordance with the maximum amount of mechanical power needed, and
• the mechanical power output to be adapted to the prevailing need, which fluctuates greatly in many applications

In order to effectively implement this, it is important to ensure an accurate design, the use of speed-controlled drives, and diagnostics at the inverter.

Accurate Design

The optimum efficiency of drive systems often lies in a narrow band around the rated power. However, many drives are oversized to "be on the safe side". As a result, the drive is operated far below its rated power and efficiency is significantly reduced. As oversizing also means

1. Using electrical energy intelligently: as little as possible	2. Converting energy with a high degree of efficiency	3. Using the recovered braking energy
Concepts with high energy efficiency (should be used)		
▶ Requirements-based dimensioning ▶ Controlled drive (frequency inverter) ▶ Energy-efficient open-loop and closed-loop motion control	▶ Components with a high degree of efficiency (motors, gearboxes)	▶ Energy exchange between the drives ▶ Intermediate storage of the braking energy ▶ Feeding back of the braking energy
Concepts with low energy efficiency (should be avoided)		
▶ Oversizing ▶ Uncontrolled operation	▶ Components with a low degree of efficiency	▶ Use of a brake resistor

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higher procurement costs, the first measure worth taking when improving energy efficiency is to accurately orientate the drives to the maximum mechanical energy required by the application.

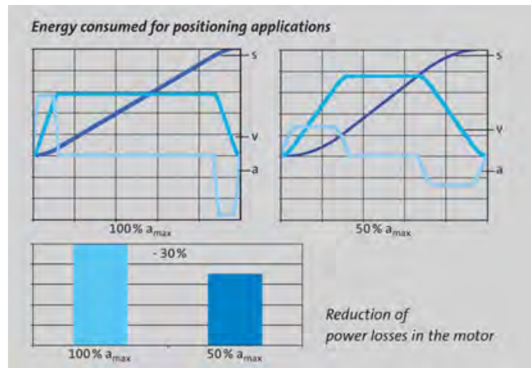
Lenze's Drive Solution Designer and its "Energy Performance Certificate" enable the selection of a drive system, exactly customized to the respective application. This results in lower procurement costs and lower energy consumption.

Use of Speed-Controlled Drives

The amount of energy needed varies in virtually every mechanical process. This is especially the case in cooling and heating systems where the output power of pumps and fans depends on the prevailing ambient temperature. Large fluctuations in the output power needed also may arise in material handling technology if the throughput isn't constant.
To improve efficiency, the power output by the motor must be adapted to these different needs. An inverter is used in order to change the motor speed and therefore the output power, the product of speed and torque. Using an inverter greatly improves energy efficiency in virtually all applications. And, savings of up to 60% are common in applications with pumps and fans.

Efficient Motion Profiles

Dynamic motion sequences can be designed so that energy efficiency is as high as possible. For example, many positioning tasks don't always need the maximum acceleration and braking times. Adjusting to the dynamics actually greatly reduces losses in the motor.
In processes that tend to be static, adjusting the motor's operating point to the actual load can minimize losses. Using a frequency inverter to adjust the motor voltage produces better efficiency, in particular for partial load operations with standard three-phase AC current motors.



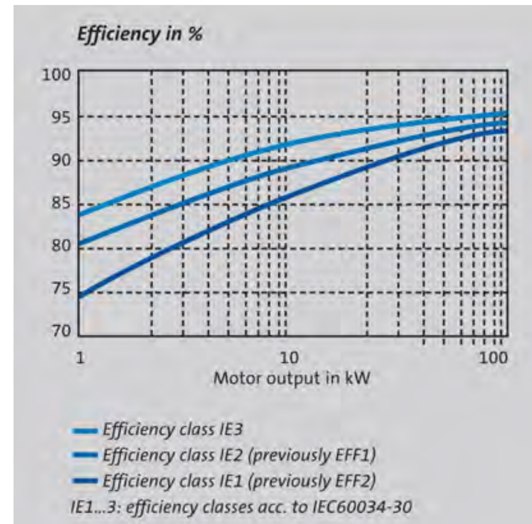
Diagnostics at the Inverter

In controlled drives, inverters record the status of the drive. This can be used for preventive maintenance, and the designer can reduce over-dimensioning in the design.

Converting energy with high efficiency - Standard three-phase AC motors

The most commonly used standard three-phase AC motors are available with different efficiency classes. Since 2011, only motors of efficiency class IE2 or higher may be used in Europe. Currently, most widely used motors of class IE1 are not allowed in new installations.

Motors of efficiency class IE3 are significantly larger and more expensive than those of class IE2, with the same power output, and should therefore only be used in applications where they are permanently operated at rated speed- and high load. Usually the better solution for achieving higher energy efficiency is the use of an inverter that adapts the output power of the drive to the application.



Synchronous rather than asynchronous servo motors

As a general rule, controlled drives with asynchronous motors can also be used with synchronous servo motors. As the magnetization of the motor on a permanently excited synchronous motor is not generated via the infed reactive current, but by permanent magnets, the motor currents are lower. This results in better efficiencies than can be achieved with a corresponding asynchronous motor. And, the amount of energy needed for

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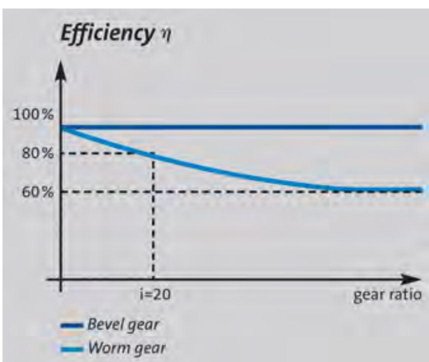
typical positioning applications drops by 30%. Lower motor currents, however, also mean that a smaller power loss occurs in the inverter, and if necessary, a smaller inverter can be selected, which in turn increases the total efficiency of the drive. It is therefore well worth checking all applications with controlled drives to see whether a synchronous servo motor with improved energy efficiency would not offer a better solution.

Energy-efficient gearboxes

Gearboxes adjust the high motor speed to the mechanical process. A ratio of around 20 is most commonly used.

This can be achieved at very high levels of efficiency with two-stage helical gearboxes. Worm and bevel gear toothing is used for right-angle gearboxes. While worm gearboxes generally cause high losses, bevel gearboxes can be used with high degrees of efficiency.

Additional increases in efficiency can be achieved if an inverter or lower power motor can be used thanks to improved efficiency of the gearbox.



	Three-phase AC motor of energy efficiency class IE1 with worm gearbox	Three-phase AC motor of energy efficiency class IE2 with bevel gearbox
Shaft output	0.8 kW	0.8 kW
η gear	72%	95%
η motor	78%	81%
η total	56%	77%
Required motor output	1.5 kW	1.1 kW
Procurement costs	500 €	530 €
Electricity costs per year	490 €	360 €
Total costs in 3 years	1,970 €	1,610 €
Total costs in 3 years	**100%**	**82%**
Pay-back period		less than three months

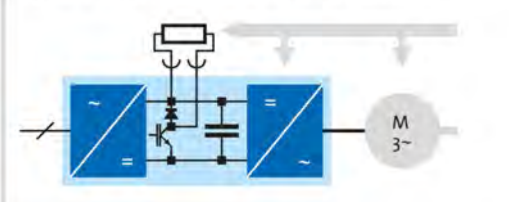
Inverters

Today, inverters have an auxiliary power of approximately 15 W, which is primarily required to supply the control electronics. In addition there are power-dependent losses in the output stages of the inverter, which are determined by the level of motor current. The selected switching frequency and the length of the motor cable also have a significant influence on the total losses. Inverters currently reach a very high efficiency of between 94 and 97%.

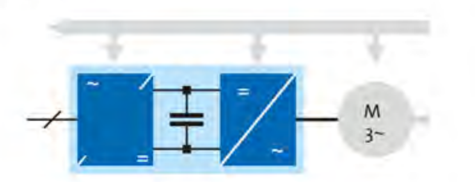
Braking energy put to optimum use – power recovery into the mains

Most inverters cannot supply energy back to the mains as this process incurs additional costs and is not necessary in many cases. If it is worth recovering power to the mains, an extra regenerative module must be connected to the DC bus of one or more inverters. Therefore, it makes economic sense to use a regenerative module if the average regenerative power exceeds 5 kW.

Operation in generator mode with brake resistor



Operation in generator mode with power recovery to the mains



Energy exchange between two drives

In many applications with noteworthy braking power, there are other drives running in motor mode at the same time, such as synchronized

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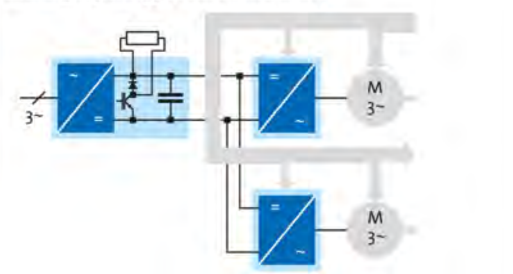
drives and unwinders in continuous production lines. In such cases, the inverter's DC buses should be linked (DC-bus connection) to allow energy to be exchanged directly. A DC-bus connection can also be used to make joint use of a central regenerative unit with several drives and thereby save money.

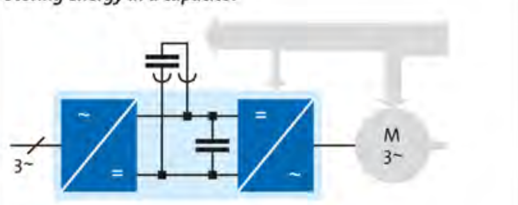
Exchange of energy between two drives



Energy storage in a capacitor

Another way in which braking energy can be used is to store it in a capacitor and then make it available again during the next acceleration or lifting procedure. Compared with a regenerative unit, this option is less expensive, but the storage capacity of the capacitor is limited. Energy storage is currently cost-effective for very fast cycled drives.

Storing energy in a capacitor



Learn more about Lenze's energy efficiency concepts in our "Lenze BlueGreen Solutions" brochure.

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Author: Mariusz Jamroz, Senior OEM Commercial Engineer

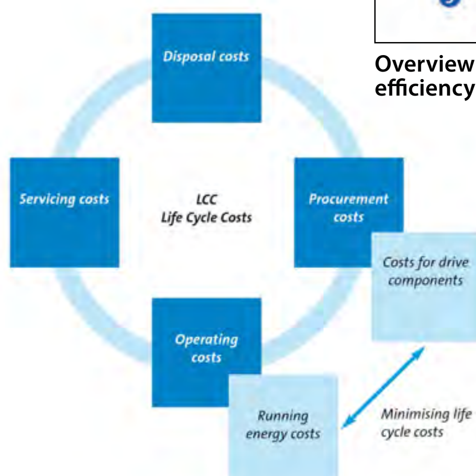
Control Engineering e-Guide

Industry consumes almost half of the world's electric energy use, with electric drives representing a majority of that power consumption. The subject of energy efficiency has garnered the support of every industrialized nation and top management levels of leading industrial enterprises. Machine automation in continuous operations, such as automotive, material handling, packaging, and food and beverage industries, has heightened demand for energy efficient machinery. By using the right design tools and drive components, a reduction in energy use can equate to less pollution, conservation of resources and a reduction in energy costs without sacrificing productivity.

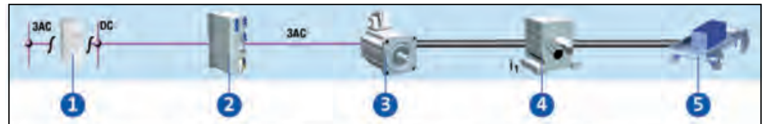
There is virtually no part of the production process, automated transport, and factory logistics that operates without electric drives. Most drives found in industrial applications have a power output between 100 watts and several megawatts. Process engineering plants are dominated by drives with high output power. In contrast, factory automation and logistics centers use a larger number of drives with lower output power. Thousands of drives can be found in a typical automotive manufacturing plant or an automated distribution center. Even an average industrial plant usually has several hundred drives operating in processes and machines.

Calculating Total Drive Energy

The calculation of energy costs in drive systems often equates to no more than a recount of procurement costs. The overall cost effectiveness of the drive system can only be assessed as part of a life cycle costs (LCC) analysis. Although a commonly used tool in business management, LCC analyses are rare for drives. With rising energy costs, that is changing. In the future, machine operators will increasingly include running costs in their purchasing decisions and expect adequate information from the supplier.



Multiple parameters determine drive energy efficiency. In evaluating total energy efficiency for a defined process, the entire drive system, comprising inverter, motor and gearbox, merits consideration.



Legend	Possible optimisation potentials	Effect for complete system
1	**Power supply / power recovery**	
	► in DC-bus connection	++
	► with power recovery to the mains	++
2	**Inverter with**	
	► energy optimised motor control	++
	► moderate switching frequency (e.g. 8 kHz)	0
	► 2-switch modulation (e. g. Inverter Drives 8400)	0
3	**Motor**	
	► use of synchronous motor	++
	► use of IE2 motor or 120Hz motor	++
	► utilisation of speed setting range	+
	► 87Hz operation for standard motors	+
4	**Gearbox with**	
	► high efficiency	++
	► low number of stages	+
	► avoiding very high drive speeds	0
5	**Energetically optimised mechanical components with**	
	► low friction	++
	► low inertias	+
	► optimised motion profiles	+

++ high
+ medium
0 low

Regarding case of application and interplay!

Overview of energy saving potential. Tips for optimizing the energy efficiency of drive systems.

All drive components work with a comparatively poor efficiency in the partial load operational range and thus generate high losses in proportion to the mechanical process. The more precisely the machine requirements and the load-dependent power requirement are defined, the better the drive components can be selected. Optimum efficiency of drive systems often lies in a narrow band around the rated power. Despite this, too often drives are oversized as a safeguard measure. An oversized drive costs more and operates below its rated power, with commensurately lower efficiency. Accurately sizing machine drives to the maxi-

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EEMODS '11—efficient motor systems conference: standards, new technologies

Drive Solution Designer harnesses energy, cost savings

Inverters feature high dynamic performance, efficiency for motion control

Energy saving drive solutions

Adaptive tools and engineering to reduce drive system energy consumption

mum mechanical energy required by the application is a critical first step.

L-Force Drive Solution Designer (DSD)

Powerful engineering and configuration tools can help machine engineers set the right course in the design and development phase. A new process tool from Lenze is helping design engineers select the right drives and motors for optimal machine performance. DSD software not only enables the exact determination of the process variables and evaluation of the components, but also their optimum coordination. DSD sizes components based on user-entered machine torque, time, and motion profiles, and generates data specifying where and when and by which means efficient savings can be achieved. The patented Energy Performance Certificate presents the energy consumption of the main drive train components calculated by differentiated loss models.

Existing software requires recalculations in order to compare scenarios. DSD works within a concise and comprehensible graph format clearly showing usage by each component, with a comparative analysis and payback for multiple design scenarios. DSD not only streamlines the design and sizing process. It goes several steps beyond by converting the drive energy savings into kilowatts used, fuel cost and wasted CO2. DSD provides reliable data by quickly calculating solution variants on the basis of mechanical performance figures. These values are then used to determine the energy costs and CO2 emissions. By comparison of different solutions, the user can identify the optimum combination of components and the best motion sequence for

Energy Performance Certificate

Joe Bloggs Ltd
Name, Surname
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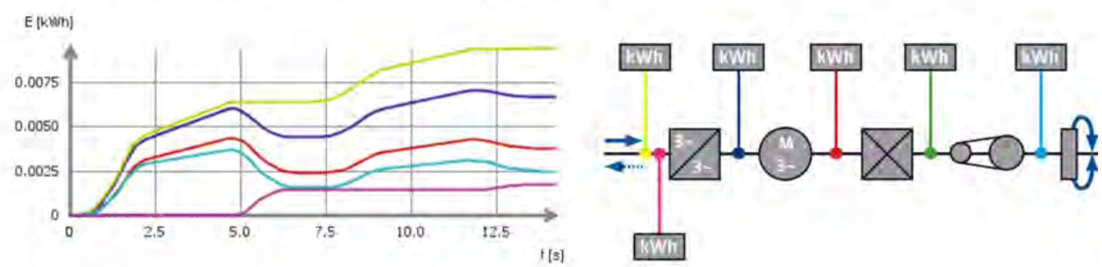
Project: Motion Drive
Drive axis:

Kinematic key data	
Cycle time	14.2 s
Max. velocity	3.50 m/s
Max. acceleration	2.39 m/s²
Max. mass of payload	1350 kg

Linear axis with belt drive		
Belt pulley diameter	d_{Cog}	250 mm
Moment of inertia, deflection pulleys	$J_{aux,1}$	0 kgm²
Driving pulley moment of inertia	J_{Cog}	0 kgm²
Mass of the slide	m_{aux}	150 kg
Angle of tilt	β	0 °
Belt transmission efficiency	η_{Blt}	0.950
Mass of belt	m_{Blt}	0 kg
Specific travelling resistance	F'	0.100 N/kg

Energy per cycle at the input of the drive components



Analysis of energy efficiency

Specified reference variables:			
Period under consideration	5.0 a		
Basic price	0.1000 €/kWh		
Number of cycles	5.1E06		
Average machine operating time	46 %		
Entire system:	**Energy requirement**	**Energy costs**	**CO_2 component**
One cycle	9.5E-03 kWh	9.5E-04 €	5.2E-03 kg
Total period under consideration	48102 kWh	4810 €	26456 kg
Energy savings with power recovery	8752 kWh	875 €	4814 kg
Drive components:	**Energy requirement**	**Energy costs**	**Type**
Inverter	5141 kWh	514 €	E94ASxE0134
Motor	14908 kWh	1491 €	MCA 21X25-RS0B0
Gearbox	6595 kWh	659 €	GST09-2 / Direct mounting
Application:	**Energy requirement**	**Energy costs**	**Type**
Energy requirement for the application	12705 kWh	1271 €	Belt drive, rotating

Note: The energy efficiency of a drive system depends on operational and ambient conditions, and physical energy losses cannot be predicted with sufficient accuracy. In light of this, the results of these program-based calculations are only approximate values which, in all probability, will not correspond to the actual values produced by the local operational and ambient conditions. As such, no liability can be assumed for the accuracy of energy data relating to the dimensioned drive system.

Energy Performance certificate

1. Calculation of the energy requirement per cycle 2. Calculation of the energy costs 3. Calculation of CO2 emissions

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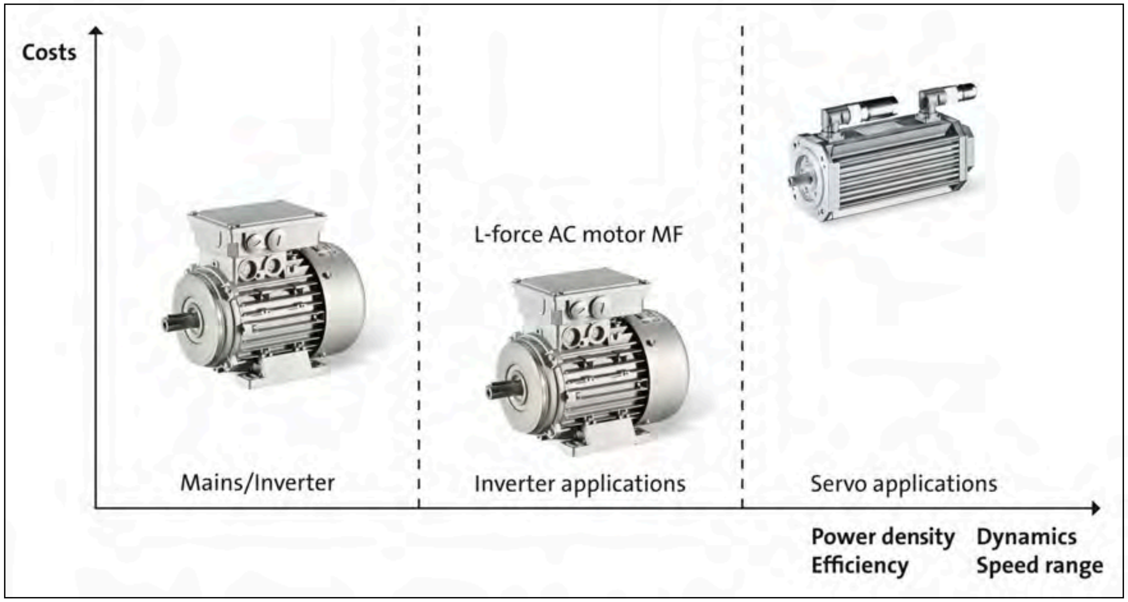
the drive task. Optimized mechanics and reduced inertias and frictions fundamentally reduce the power requirement to be met by the drive.

Efficient High Performance Motors

The most widely used class IE1 motors have been phased out and prohibited in some new installations. DSD is a particularly timely tool as machine markets transition to higher efficiency motors. Lenze developed the compact MF series of motors to help design engineers avoid increases in frame sizes and thus complex design adaptations for the migration to Class IE2 AC motors. New to the market, the MF series is designed for open and closed loop controlled operation with frequency inverters. The L-force MF AC motors are developed for a higher nominal speed than conventional 4-pole motors.

Due to its features, the MF motor aligns perfectly with the machine concept. Bridging the gap between conventional servo motors and high efficiency IE2 Class AC motors, the new L-force MF three-phase AC motors have nominal frequency of 120 Hz with a speed - setting range of 1-24. The MF motor incorporates high ratio gearboxes to achieve higher output speeds of up to 3,500 RPM. With efficiency ranging from 94 to 98 percent, the right-angle and axial gearboxes ensure almost loss-free energy conversion. Low inertia translates into less energy consumption during speed changes. During rated operation, MF three-phase motors surpass the minimum efficiency of Class IE2 motors, but are unaffected by IEC 60034-30. MF can be specified up to two sizes smaller than IE2-motors of equivalent power. Another major plus of the MF motor is its multifunction capability. Applications that may have required multiple conventional motors (of varying frame sizes and power ranges), can now be satisfied with only one MF motor, thereby reducing costly motor inventory.



L-Force MF AC motor offers economical solution and closes the large performance gap between conventional AC motors and servo motors.

Motors from the IE3 efficiency class are significantly larger and more expensive than those of the IE2 class with the same power output and should, therefore, only be used in applications where they are permanently operated at rated speeds and high loads. Often the better solution for achieving higher energy efficiency is the use of an inverter that adapts the output power of the drive to the application.

VFCeco Inverter Advantages

To improve efficiency, the power output by the motor must be adapted to different needs. Energy efficiency not only depends on right-sizing and selection, but on the adaptation of efficient products to the individual application case. Using an inverter greatly improves energy efficiency in virtually all applications. Adjusting the motor's operating point to the actual load in processes that tend to be constant can greatly diminish losses. Dynamic motion sequences can be designed such that energy efficiency is as

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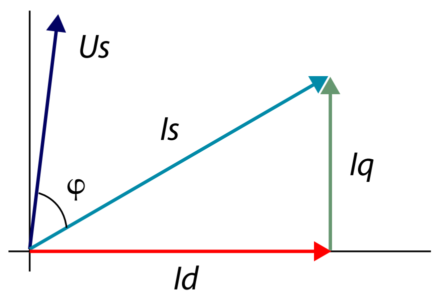
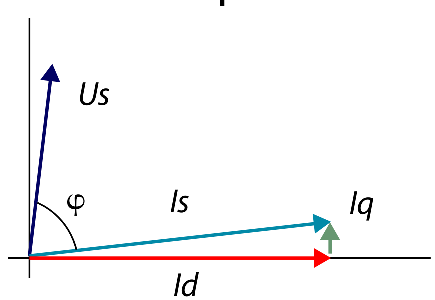
high as possible. For example, a lot of positioning applications don't always need the maximum acceleration and braking times. Adjusting to the dynamics actually needed greatly reduces losses in the motor.

Using a frequency inverter to automatically adjust motor voltage produces better efficiency in partial load operations with standard three-phase AC motors. Normally, in partial load

Motor under full load

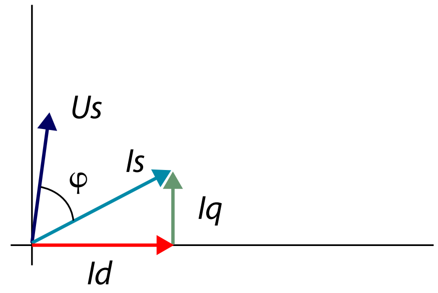


Motor under partial load



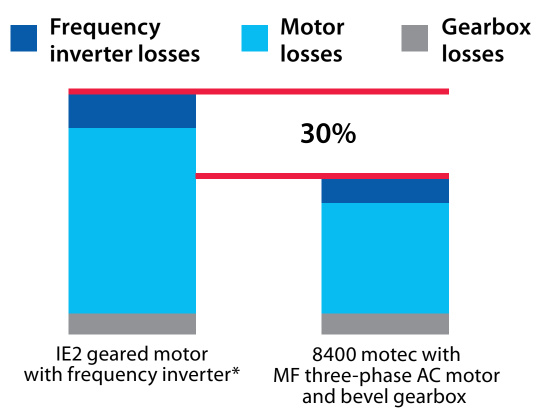
Const. flux (~Id):
excessive voltage/current
excessive energy losses

Motor under partial load (VFC)



Flux reduction:
red. voltage / current
minimized losses

operation, three-phase AC motors are still supplied with a greater magnetizing current than actually required by the operating conditions. Additional energy savings can be yielded in combination with high-efficient gearboxes and inverter drives with energy saving VFCeco (Voltage Frequency Control economic).



Partial load (30% M_N)
***without magnetism adjustment**

Built-in to the Lenze 8400 inverter drives, this energy saving feature makes it possible to reduce energy consumption by up to 30%. Designed for centralized and decentralized frequency inverters, VFCeco senses load and torque, then adapts to partial loads by automatically reducing the magnetizing current of the motor to the actual requirement. VFCeco can be temporarily disabled for manual control or full load operation.

In the case of load changes (n-settling time <1sec, for VFC < 0.5sec), VFCeco mode delivers better dynamic performance than other products on the market. In applications with long, extreme partial load phases, a voltage reduction enables the reduction of the average required power. That makes VFCeco particularly practical in applications with great partial load operation, low requirements with regard to the dynamic performance, and infrequent load changes, as commonly found in material handling roller conveyors, conveying belts, pumps and fans.

It is well worth checking all applications with controlled drives to see whether a synchronous motor with improved energy efficiency would not offer a better solution. Controlled drives with asynchronous motors can always be implemented using synchronous motors. The motor currents in such drive systems are lower as a permanently excited synchronous motor is magnetized—not by the supplied reactive current, but by permanent magnets. This results in better efficiencies than can be achieved with a corresponding asynchronous motor. But lower motor currents also mean less power loss

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in the inverter. Depending on the application it may be possible for a smaller inverter to be selected, thereby reducing total drive efficiency.

Maximum energy efficiency, low acquisition costs, and short payback periods are just some of the challenges machine engineers face in today's global marketplace. The basis of an intelligent and economical use of energy is the knowledge of the steady state or variable requirements of certain processes. Given the high proportion of total energy represented, improving the efficiency of electric drives is the best targeted approach to reduce overall energy consumption. All the described possibilities for increasing energy efficiency can be calculated and compared by using the DSD engineering tool, yielding a design template for an energy-efficient complete machine. The benefit resulting from this quickly becomes evident: less power leads to smaller and, therefore, more economical components and reduced energy consumption.

Learn more about Lenze's products, solutions and systems capabilities in the Lenze "Our Products, Your Advantage" corporate brochure.