Low-Efficiency Motors and Gears Still Prevalent

Michelle Figgs

Electric motor-driven systems are the single largest end-user of electricity, accounting for over 40% of global consumption according to the International Energy Agency. As the component that actually converts electrical energy to mechanical energy, the motor is a major focus of energy efficiency concerns, as illustrated by the fact that minimum energy performance standards (MEPS) apply almost exclusively to motors. However, industrial electric motor-driven systems include a variety of components, all of which affect a system's efficiency because the total energy loss by a system is a product of the energy lost by each component in the system, as presented in Figure 1.

Figure 1 shows four common components of an electric motor-driven system: a variable frequency drive (VFD), motor, gear drive and load. Even when assuming a very high-efficiency level of 99% for each component, the mechanical energy output from the system is only as high as 96.1% of the electrical energy that was input into the system. System 1 shows a more realistic system that uses a pump as an example of the load. With an IE1 motor running at an 85% efficiency, a worm gearbox at an 80% efficiency, and more accurate, realistic efficiencies assumed for the other components, the total system efficiency is only 56.1%.

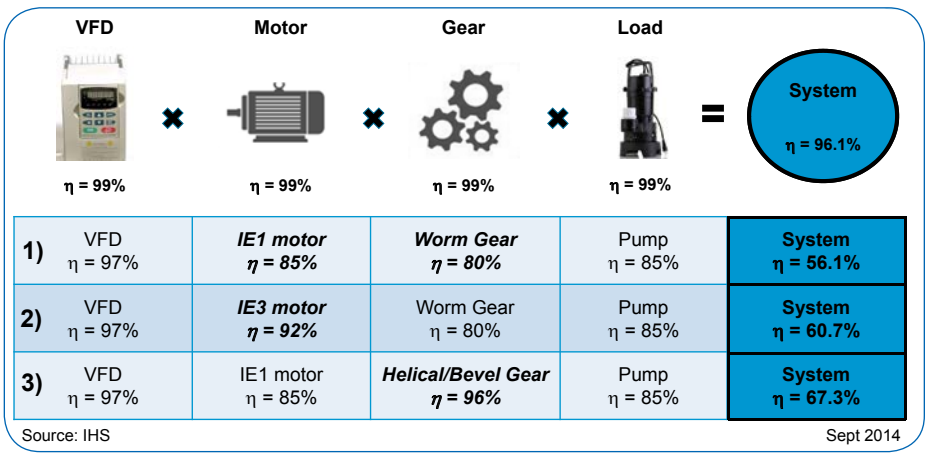
This article focuses on the motor and gear components of a system, discussing the prevalence of low-efficiency products and explaining the barriers that are currently impeding the adoption of higher-efficiency components.

Statistics on the Market for Electric Motors

Most energy-efficiency legislation has focused on the market for integral horsepower motors with a voltage rating less than or equal to 690V, and this article will specifically center on this motor type, which is called a low-voltage (LV) motor in this report. Please note that these figures exclude motors with integrated gearing. Figure 2 shows the various motor classifications, associated efficiencies, and unit shipment distribution for LV motors in 2013. Of course, the exact efficiency of a motor depends on a number of factors, including the power of the motor and where the motor is operated with regards to its torque/speed curve, but the efficiency ratings shown in Figure 2 are commonly associated with each efficiency level.

The cheapest and least-efficient option, an IE1 motor, remained the type most sold in 2013, accounting for nearly 63% of unit shipments. This is surprising given the fact that the initial purchase price of a motor accounts for only 2% of the total cost of ownership, while nearly all of the total cost, 96%, is attributed to the electricity required to operate the motor over its lifetime. In Figure 1, system 2 shows that an efficiency gain of approximately 4.6% can be achieved in an electric motor-driven system by replacing an IE1 motor with an IE3 motor, which can result in significant energy and cost savings over the 15- to 20-year lifetime of a motor. Still, IE2 motors accounted for only 20% of unit shipments, IE3 motors accounted for less than 15% of unit shipments and IE4 motors constituted a negligible portion of the market (0.4%). The remaining 1.8% of the market included motors that did not fall into the aforementioned categories, typically because these motors are not regulated.

An analysis of the regional variation of motor types shows that, to date, the adoption of more energy-efficient motors has been driven primarily by legislation commonly referred to as minimum energy performance standards (MEPS). For instance, the American



1)	VFD η = 97%	***IE1 motor η = 85%***	***Worm Gear η = 80%***	Pump η = 85%	**System η = 56.1%**
2)	VFD η = 97%	***IE3 motor η = 92%***	Worm Gear η = 80%	Pump η = 85%	**System η = 60.7%**
3)	VFD η = 97%	IE1 motor η = 85%	***Helical/Bevel Gear η = 96%***	Pump η = 85%	**System η = 67.3%**

Source: IHS Sept 2014

Figure 1 System efficiency is a product of component efficiencies.

IHS Category:	IE1 - Standard	IE2 - High	IE3 - Premium	IE4 - Super Premium*
European Union	IE1	IE2	IE3	IE4
North America	Below EPAct	EPAct	NEMA Premium	Super Premium
China	Y2, Y3	GB3	GB2	GB1
Russian Federation & CIS	EFF3**			
Approximate Efficiency Rating	85%	89%	92%	94%
% of Unit Shipments from "*Low-Voltage Motors - 2014*"*				
World -2013 (estimated)	63%	20%	15%	0.4%
World -2018 (forecast)	44%	32%	23%	1%

*IEC 60034-30-1:2014 titled Rotating electrical machines – *Part 30-1: Efficiency classes of line operated AC motors*
**GOST standard equivalent efficiency
***published July 2014 by IHS

Source: IHS **Sept 2014**

Figure 2 LV motor classifications, efficiencies, and market statistics.

market accounted for 97% of global IE3 shipments in 2013 because the United States began requiring IE3 motors in late 2010 and Canada in early 2012. On the other hand, Asia has the lowest rate of adoption, with numerous countries yet to enact any MEPS; as such, the Asian market was responsible for 72% of global IE1 shipments in 2013. The European Union transitioned to IE2 motors in mid-2011 and led this category in 2013.

As China transitions to IE2 motors following the enactment of MEPS in late 2012, and Europe plans to begin its transition to IE3 motors in 2015, shipments of IE1 motors are projected to decline. IHS currently forecasts that by 2018, the shipment share of IE2 motors will increase to 32%, and the market share of IE3 motors to 23%. However, IHS predicts that IE1 motors will still represent over 40% of unit shipments in 2018 for a number of reasons, which will be discussed in more detail later in this article. Countries in developing regions that have not implemented MEPS are also predicted to contribute to the IE1 motor market. Furthermore, historical data show that even in countries where MEPS are enacted and thereby require a certain efficiency level, the transition to that level is not instantaneous, but instead occurs gradually, generally over three to four years. Demand for lower-efficiency motors still remains in the market, particularly as there are loopholes that manufacturers and consumers often use to circumvent the pertinent legislation, and there is a transition period for motor suppliers as well, which have to phase out their inventory of lower-efficiency motors and transition their production lines to higher-efficiency motors.

Statistics on the Market for Geared Products

A significant number of electric motor-driven systems incorporate a gearbox, a component that can vary significantly in terms of efficiency. Choosing a type of gearbox is not as simple as choosing a motor based on its efficiency rating because different types offer different technical advantages, but worm gearboxes are generally the cheapest and most inefficient type of geared solution. According to the latest IHS study on the market for industrial gearboxes and geared motors, worm-geared products accounted for over 35% of unit shipments in 2013 (excluding precision applications). For applications with power ratings below 4 kW and gear ratios below 10:1, a worm-geared product is a sensible choice, even from a perspective of energy-efficiency savings because a worm gear can achieve efficiencies over 90% at this ratio. This is especially true for intermittent-duty applications, where the payback time of a more efficient bevel geared product can be too long to justify the additional up-front cost to many customers. Worm-geared products are also more compact than bevel geared products and are better suited from a technical standpoint for applications that require high-shock loads.

However, as the gear ratio increases, the efficiency of the worm gear is drastically reduced, dropping below 85%

at 30:1, and worm-geared products continue to be chosen for applications in which an analysis of the total cost of ownership shows clear financial gains, often in a short period of time, if a more efficient gear were chosen. While suppliers report that there is a clear trend away from worm-geared products towards more efficient options, the movement has been slower than expected given the potential energy and cost savings over the lifetime of the product. In Figure 1, System 3 shows that replacing a worm gearbox running at an efficiency rating of 80% with a helical/bevel gearbox running at an efficiency rating of 96% results in an efficiency gain of approximately 11.2% for the system. Note that this is significantly more than the efficiency gain achieved by upgrading an IE1 motor to an IE3 motor, illustrating the importance of evaluating the efficiency of the system as a whole and optimizing the least-efficient components rather than focusing solely on the motor.

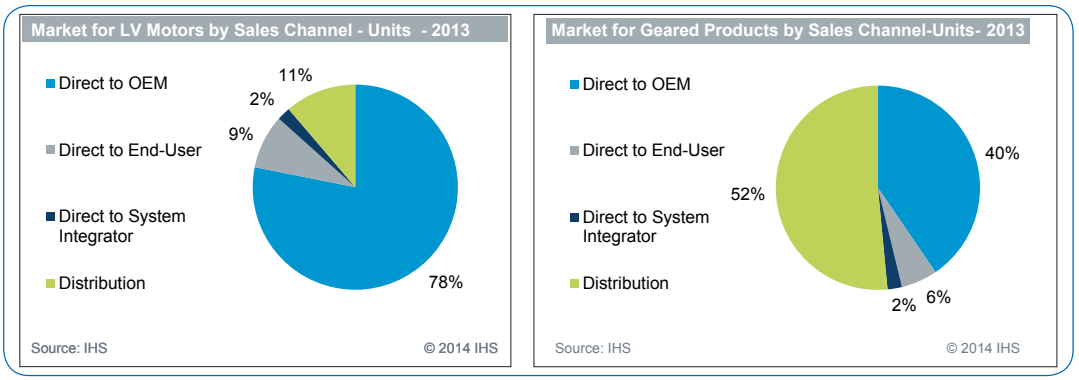


Figure 3 Sales to OEMs account for large proportion of the markets for LV motors and geared products.

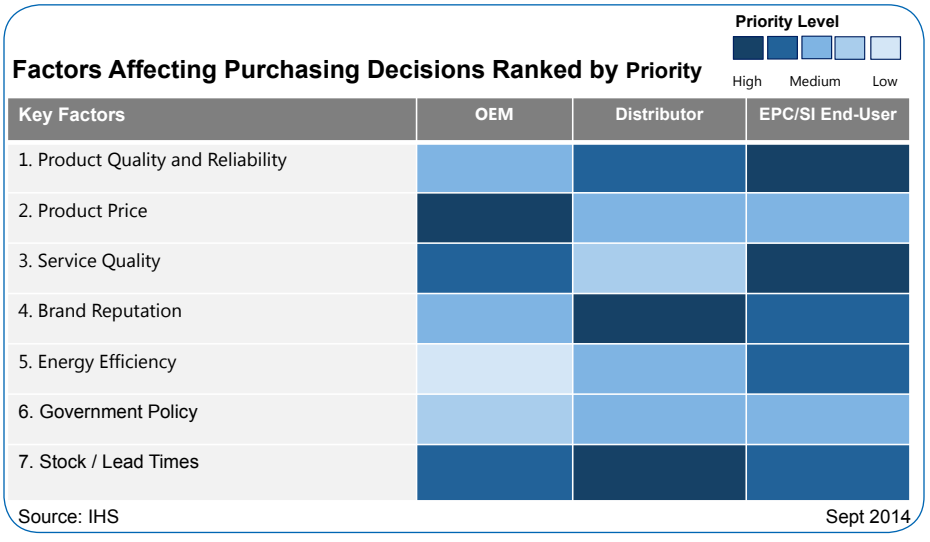


Figure 4 Survey performed by IHS that ranks energy efficiency in terms of priority in purchasing decisions.

Variable Frequency Drives (VFDs)

Since a VFD inherently loses energy because of heat dissipation and inefficiencies in the energy conversion process, simply adding a VFD to a system without making any other changes actually lowers a system's efficiency. However, significant energy savings can be achieved for variable speed applications, where the VFD is used to reduce the speed of the motor by reducing the amount of electricity input into the system. IHS estimates that the attachment rate of low-voltage VFDs was around 20% in 2012, while the percentage of applications that could benefit is far higher.

Barriers to the Adoption of More Energy-Efficient Products

The International Energy Agency estimates that end-users spend over $565 billion annually on electricity to power electric motor-driven systems, but research by IHS clearly shows that the prevalence of low-efficiency motors and gearboxes remains surprisingly high given the amount of energy and cost savings that could be achieved with more efficient products. If just 25% of the users of electric motor-driven systems around the world upgraded to improve their systems' efficiency by 5%, it would result in over $7 billion in savings in terms of electricity costs.

One of the primary barriers to the adoption of more energy-efficiency products is the amount of automation products sold to machine builders (OEMs), which prioritize price over energy efficiency when making purchasing decisions. This is illustrated in Figure 4, which shows that sales directly to OEMs accounted for 78% of unit shipments of low-voltage motors and 40% of unit shipments of geared products in 2013. Since an OEM is not responsible for the electricity costs associated with running such equipment, an OEM has little incentive to purchase more expensive motors or gearboxes (that save money over time because of their higher efficiency) because this would require an OEM to raise the price of its machines, thus lowering its cost competiveness. As Chinese machine builders increasingly look to export machines to the European and American markets to offset the slowdown in demand within China, price competiveness has become an even more important factor for OEMs located in the West.

While an end-user is more likely to purchase higher-efficiency products than an OEM, significant barriers also exist in this sales channel. In particular, there is often a disconnect between the procurement department that makes purchasing decisions and the accounting department responsible for paying electricity bills. Purchasing agents are typically rewarded for minimizing the cost of buying equipment and without project specifications requiring certain energy-efficiency levels; such agents

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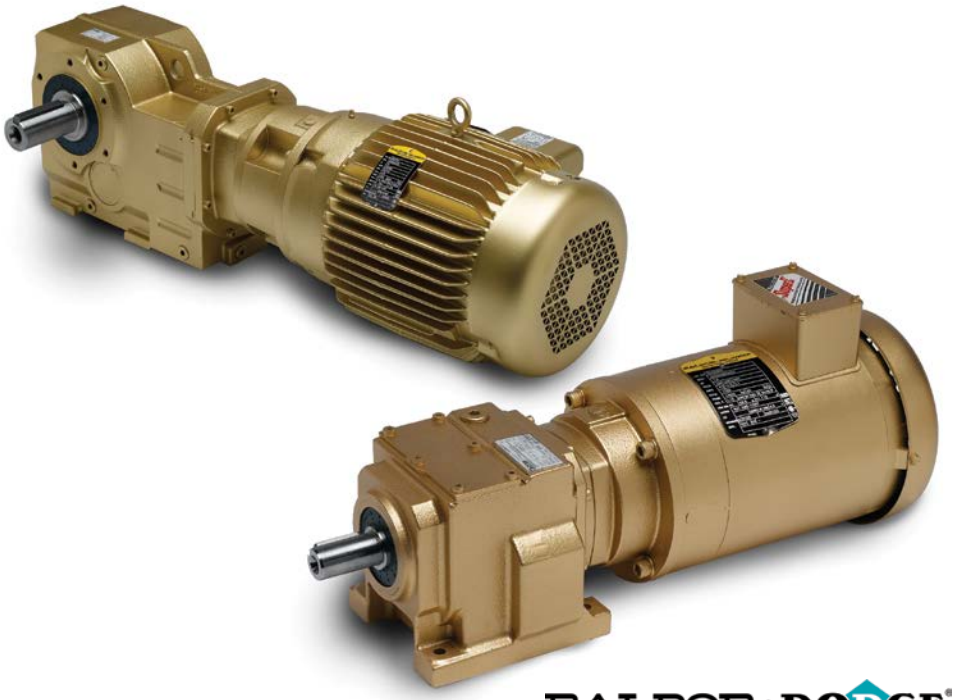

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are also hesitant to a purchase a more expensive product.

The lack of emphasis on energy efficiency is illustrated in Figure 5, which shows the results of a survey recently performed by IHS. When asked to rank the importance of various factors considered for purchasing decisions, OEMs valued product price most highly, distributors valued brand reputation and lead times, and end-users valued product quality and reliability. Energy efficiency appeared at the bottom of the list for OEMs, and was ranked less than or equal to four other key factors by the end-users who stand to benefit the most from the adoption of such products.

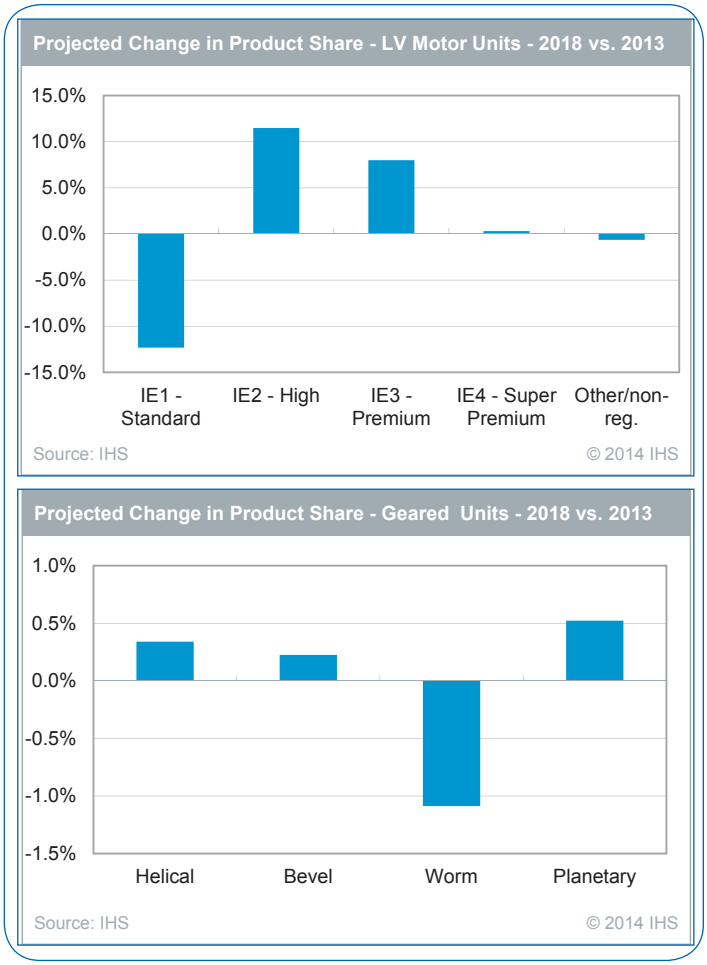

Figure 5 Shift towards energy-efficient products in markets for LV motors and geared products

Conclusion

While disheartening, these statistics show there is still a significant opportunity to achieve energy savings through the adoption of more energy-efficient products. Since products with higher efficiency also typically have a higher profit margin, suppliers of low-voltage motors and geared products continue to play an important role by marketing the benefits of their more energy-efficient products. The current emphasis on the total cost of ownership will continue to drive end-users to more energy-efficient products, both in their own purchasing decisions for automation components and in their requirements for the machines they purchase from OEMs.

While low efficiency products will continue to be sold into the marketplace, the expected shift towards more energy efficient products is illustrated in Figure 5, showing IHS forecasts for changes in product mix for low-voltage motors and geared products. MEPS will continue to drive the low-voltage motors market towards higher-efficiency motors, while the shift towards higher-efficiency geared products is also predicted to increase, albeit at a much slower pace. **PTE**

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