Motor efficiency

Focus on optimizing lifetime performance on motors

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High efficiency motors can deliver significant savings in energy consumption. In addition to efficiency, however, when optimizing a motor's performance over its entire lifecycle other important characteristics must also be considered. These include the product's overall suitability for the application, correct dimensioning, and bearing and winding reliability. ABB manufactures quality motors that are not only highly efficient but also provide superior reliability and availability.

Energy efficient products

High efficiency motors can provide significant benefits, including helping to cut energy costs and limiting carbon emissions. In the EU, the introduction of the European efficiency classification scheme has focused attention on energy efficiency. The scheme divides motors into efficiency levels EFF1 to EFF3, where EFF1 is the highest. The scheme has been very successful in reducing the numbers of low efficiency motors in the market, and the EFF1 classification has come to be seen by some not only as a mark of efficiency but also as a general badge of quality. At present the scheme is being further developed to harmonize the efficiency testing methods so that motors from different manufacturers can be compared more easily.

M3BP motor

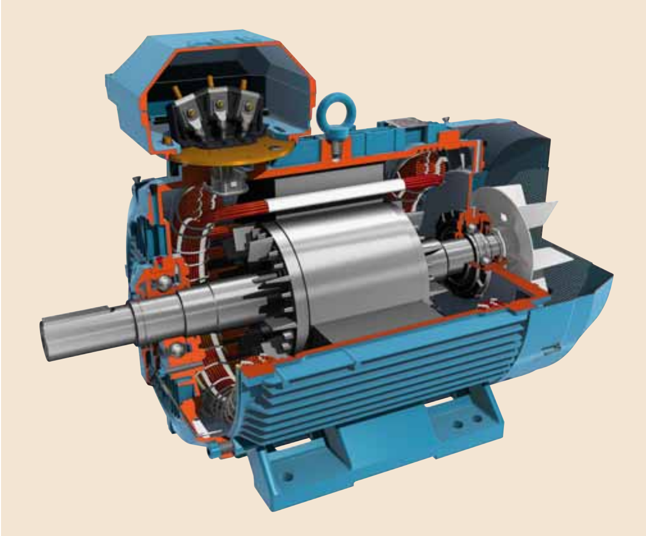

ABB is a long-standing advocate of the need for efficiency in motors and from the outset its policy has been to offer high efficiency motors as standard, ie available from stock with no price premium. As a result, when the EU scheme was introduced, all ABB motors achieved classification in the two highest efficiency classes, with the EFF1 motors coming from ABB's standard product range.

Designing and manufacturing reliable motors with good starting and running performance involves a delicate balance between a number of factors which include not only efficiency and cost, but also bearing, slot and fan design, temperature rise, vibration, and noise. Only the correct balance will result in high quality motors which are efficient and reliable and will provide a long service life, while also being of optimum weight. Rather than focusing on efficiency alone, ABB prefers to take a lifecycle approach and seeks to maximize the benefits and minimize the costs associated with its products over their entire lifetime. In addition to efficiency, the lifecycle approach also emphasizes the importance of reliability and availability.

Energy is generally the biggest lifecycle cost, and soaring energy prices have put energy costs and efficiency firmly in the spotlight. In many parts of the world, authorities are introducing schemes to encourage industrial users to specify high efficiency motors. This situation has led some manufacturers to boost the efficiency level of their products without looking at other areas of performance.

Designing for efficiency

In ABB's view, the key to making efficient motors while minimizing overall lifecycle costs is to ensure that every stage of design and manufacture is based on high quality.

The efficiency of a motor is a measure of how well it converts electrical energy into useful work. Energy which is lost is emitted in the form of heat. These losses have to be reduced in order to increase efficiency.

Factbox 1 Distribution of losses in an ABB M3BP motor

no-load losses	iron losses in core	18%
	windage & friction losses	10%
load losses	stator copper losses	34%
	rotor losses	24%
	stray load losses	14%

Motor losses can be divided into five main categories. Two of these categories – iron losses in the core, and windage and friction losses – are classified as no-load losses because they remain constant regardless of the load. Load losses, which vary with the load, are stator copper losses, rotor losses, and stray load losses Factbox 1. All motor losses can be influenced by design and construction considerations, ie by the quality of the design and manufacturing processes.

Iron losses in the core are due to the energy required to overcome opposition to changing magnetic fields in the core material. Designers can decrease these losses by using better quality steel and by lengthening the core to reduce the magnetic flux density.

Reliability is also an important factor for OEMs that build motors into their own products. If a motor breaks down it will be the OEM's equipment which is perceived as unreliable.

Windage and friction losses are caused by air resistance and bearing friction. In high quality motors these are reduced by improved bearing and seal selection, air flow and fan design. The fan must be large enough to provide adequate cooling, but not too large as this reduces efficiency and increases noise. In ABB motors the blade size and pitch are varied between models for optimum results.

Of the losses which vary with the load, stator copper losses (also referred to as I^2R losses) are caused by heating due to the current flow through the resistance of the stator winding. Techniques for reducing these losses include optimizing the stator slot design. The stator laminations should be of low loss steel, and as uniform and thin as possible to maximize the strength of the magnetic fields. They should be carefully aligned to ensure the channels are straight. Naturally, the thinner the laminations the more expensive they are to produce, and accurate alignment requires more specialized production techniques.

Rotor losses are caused by rotor currents and iron losses. In high efficiency motors these losses are reduced by increasing the size of the conductive bars and end rings to produce a lower resistance. Stray load losses are the result of leakage fluxes induced by load currents. They can be decreased by improving the slot geometry.

Lower temperatures mean better reliability

Motors that operate only occasionally or in non-critical applications do not necessarily have to be ultra-reliable. Of course a breakdown is always a nuisance, but the consequences may not be too serious. In some industries and processes, however, reliability is paramount. In continuously running processes such as cooling applications in the oil and gas industry, or paper machine drives, unplanned downtime has to be avoided at all cost. A stoppage of just a few minutes can cost as much as a new motor.

Reliability is also an important factor for OEMs that build motors into their own products. If a motor breaks down it will be the OEM's equipment which is perceived as unreliable and it will be the OEM's reputation for reliability that will suffer.

ABB's approach to reliability is the same as its approach to efficiency: high quality forms the basis for reliability, especially the quality of the materials used. On average materials account for 55 percent of the cost of a motor. As more than half the total cost goes on materials, it is clear that manufacturers who try to cut costs too aggressively will skimp on materials and the reliability of their products will be affected.

The two most common causes of motor failure are bearings and windings, and these components therefore play a pivotal role in determining overall reliability. In the case of both bearings and windings, the operating temperature within the motor has the greatest impact on the component lifetime. A high quality, efficient motor running at full load can have a normal temperature rise of 60–80 °C but this figure can be up to 100 °C for lower quality motors. The temperature rise can be higher only in motors which have been designed for higher temperature rise and thus have an appropriate insulation system that can withstand higher temperatures.

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For maximum reliability, it is important to ensure that high quality bearings are used Factbox 2. The designers have to select the right type of bearing for the application and load, and then draw up a greasing regime appropriate for the application and operating conditions. As grease is degraded by high temperatures, it is important that the temperature rise is not excessive. A reduction of 10–15 °C in the operating temperature should, in theory, double the working life of the bearing grease.

Excessive internal temperatures also affect the lifetime of windings. In this case, it is the insulation on the copper wire that is degraded by high temperatures. A 10 °C rise in operating temperature can halve the life of the winding. For this reason most motors are manufactured with Class F (155 °C) insulation but designed to operate no hotter than Class B (130 °C). Temperature rise is one aspect of motor performance that is the focus of on-going research Factbox 3.

Another factor in winding reliability is the withstand voltage, which measures the integrity of the winding. Windings usually have a withstand voltage of around 1200 V, but motors can be supplied with a withstand voltage around 1400 V or above if the winding must withstand higher voltage spikes, as produced by some variable speed drives 1.

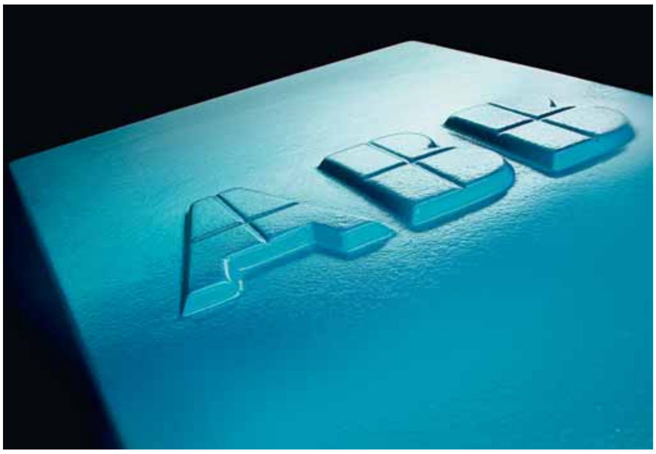
It should also be kept in mind that reliability can also take on a slightly different emphasis in different environments. In motor applications in the oil and gas industry, for example, safety is a primary concern for the process owner. Motors are often operated in very harsh conditions, having to withstand extremes of heat or cold,

Factbox 2 Bearing checklist

For optimum motor reliability the bearings should
- be supplied by a reliable manufacturer
- be dimensioned appropriately for the load and speed
- have an internal clearance suitable for the operating temperature
- use grease suitable for the operating temperature
- be re-greasable if there is a suitable maintenance infrastructure in place (otherwise sealed-for-life bearings are generally preferable)

1 Characteristics of a good winding

Characteristics of a good winding include:
- compact winding with a good slot fill ratio
- small overhang
- high quality copper wire
- high quality winding systems
- high quality slot insulation, impregnation systems and phase insulation systems



for instance, or dusty or moist environments. ABB has built up a great deal of experience in supplying motors both for conventional process industry environments and for extreme conditions. This experience is utilized in the development and manufacture of high quality motors which not only meet official requirements and safety specifications but also perform efficiently and reliably for their whole lifetime.

High quality motors perform better

Electric motors, the "workhorses" of modern industry, can play an important role in efforts to cut energy consumption and carbon emissions. It is estimated that motors use 65 percent of the electricity consumed by industry, and that generating the electricity to drive these motors produces 37 million tonnes of CO_2 annually. Given the magnitude of these figures, even a small increase in each motor's efficiency has a positive impact on a global scale.

Users also have strong financial incentives to purchase efficient motors. Even though high efficiency models command a price premium of 5 to 7 percent (larger sizes) or 15 to 20 percent (smaller sizes), this investment is quickly recovered through reduced energy consumption. The energy used by a motor over its lifetime can cost as much as 100 times the motor's purchase price.

Efficiency represents only one area of performance, however, and energy costs are only one element of overall lifecycle costs. Reliability – and the maintenance costs and downtime that result from poor reliability – can be even more significant in some applications. ABB's experience and expertise give the company a thorough understanding of the complicated relationships that exist, within optimum starting and running performance, between efficiency, weight, temperature rise, noise and vibration. By building high quality products and seeking to minimize their overall lifecycle costs, ABB ensures that its motors will deliver excellent all-round performance.

Factbox 3 Three ways to further improve energy efficiency

Avoid rewinding

Rewinding usually causes a reduction in the efficiency of a motor. Rewinding a motor over 30 kW can reduce rated efficiency by 1 percent, while the figure for smaller motors can be 2 percent. The efficiency reduction on high quality motors is less significant than that of lower quality products.

Avoid oversizing

For a variety of reasons, companies often procure oversized motors. Field tests in process industries indicate that on average motors operate at only 50 to 60 percent of their rated load. Among other disadvantages, running a motor at less than its rated load is inefficient (part-load efficiency). Replacing significantly underloaded motors with smaller, energy efficient motors generally improves system efficiency.

Use VSDs for speed control

There is no point using a high-efficiency motor if the overall drive system is inefficient.[*)] In many pump and fan applications, for example, throttling is still used to regulate flow. Running motors at full speed when only lower speeds are required is extremely wasteful. Variable speed drives (VSDs) provide optimal speed and control accuracy, delivering major energy savings. A recent study performed at the University of Lappeenranta in Finland showed that using drives in parallel pumping installations can produce energy savings up to approx. 70 percent. In addition to its motor business, ABB is also a leading supplier of VSDs.

[*)] See also "Saving energy through drive efficiency" on page 73 of this edition of ABB Review.

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