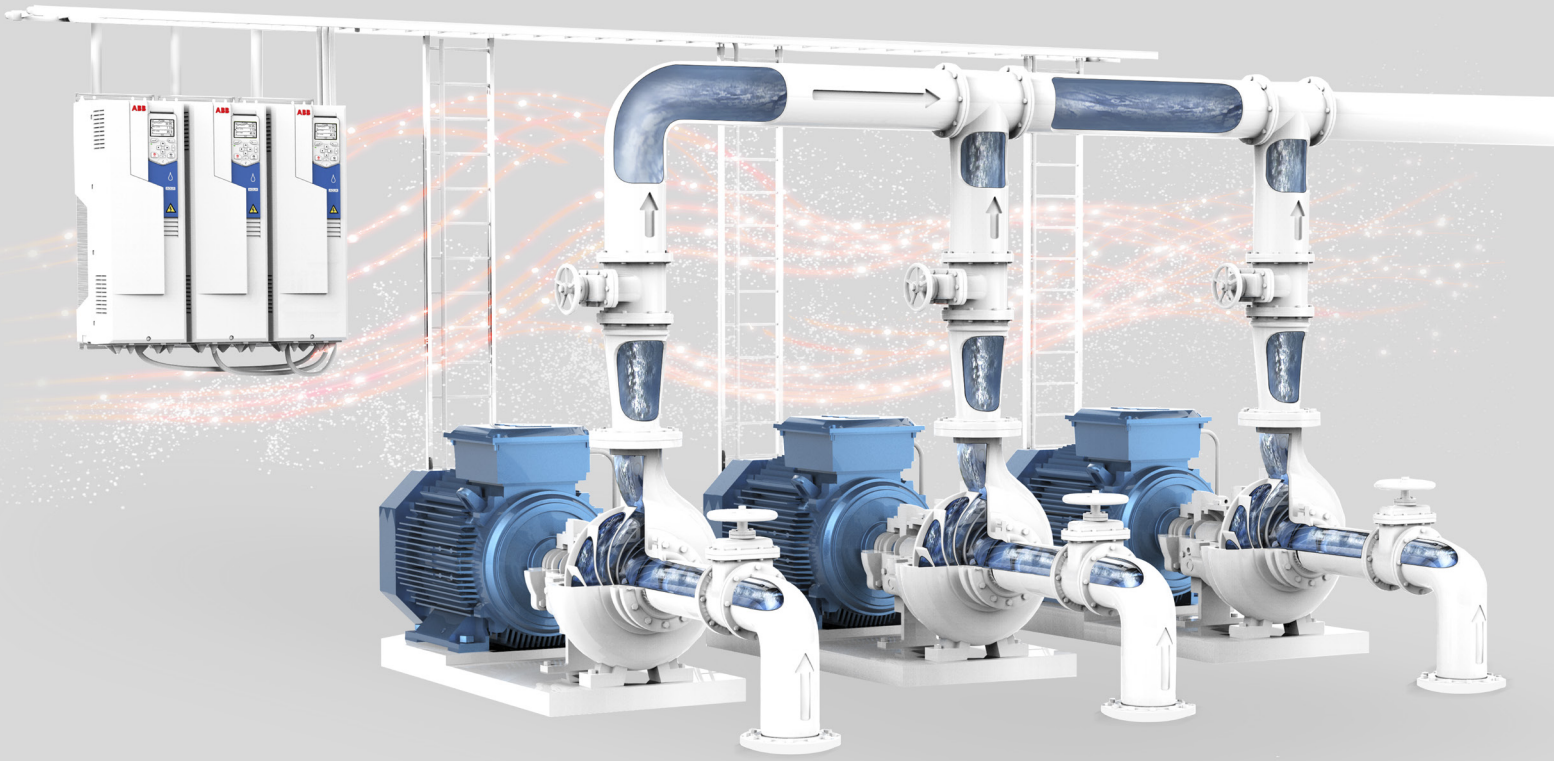
WHITE PAPER

Reaching IE5 efficiency with magnet-free motors



Rapid progress in motor technology

Today, 45% of all electricity is converted into motion by motors in buildings and industrial applications. Clearly, as the world becomes increasingly reliant on electric motors, we need to improve our energy efficiency.

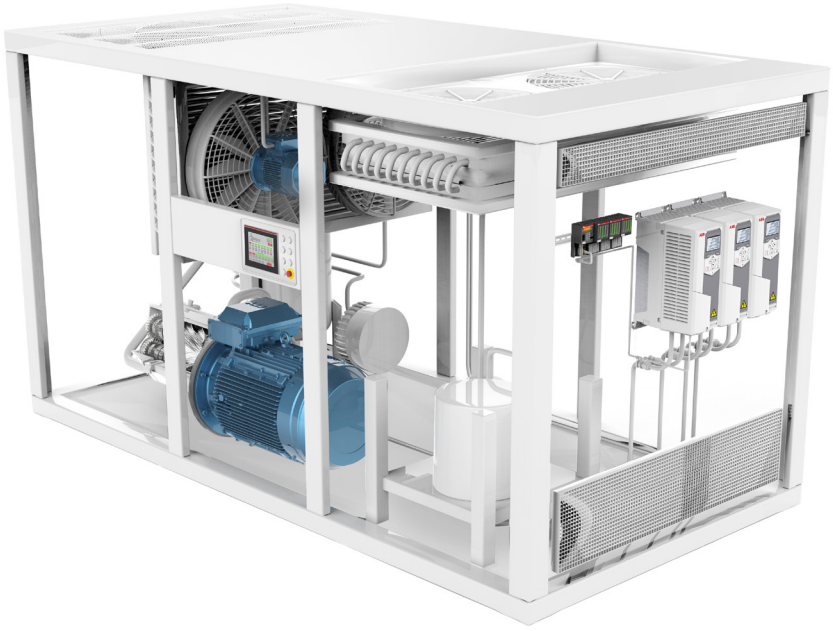
With electric motors, it's always worth looking at the system as a whole and choosing the correct size of motor for the work at hand. An oversized motor will consume excess energy while only delivering a fraction of the available power, and an underpowered motor will waste energy by running too hot. In some cases, simply selecting a more appropriate size of motor can save companies energy and costs.

—

With International Efficiency standards the higher the number is, the higher the motor efficiency.

Once the optimum size of motor has been correctly specified, then it's time to think about the motor efficiency class. While there are a variety of motor technologies on the market, the reality is that the installed base mainly uses older, very low efficiency motors. However, for the past decade, progress in electric motor technology has been exceptionally rapid, with new, energy efficient technologies emerging.

One very significant development is the synchronous reluctance motor (SynRM), which works together with a variable speed drive (VSD). Synchronous reluctance motors can be used as drop-in replacements for standard IE3 induction motors and reduce energy losses in the motor by up to 40 percent.[1]



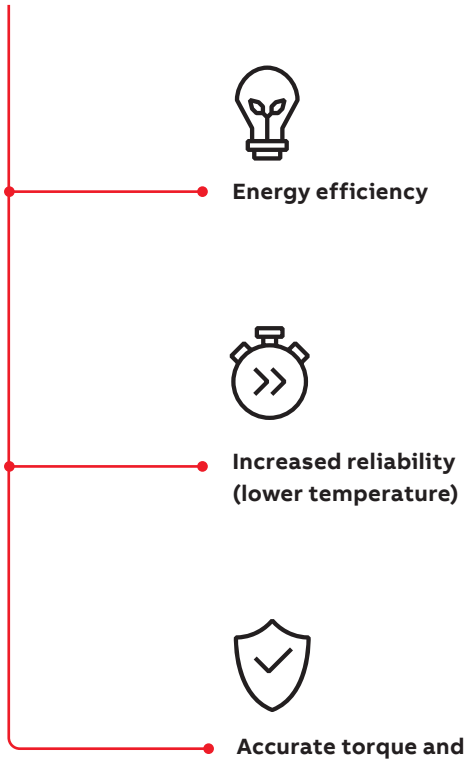
—

SynRM/VSD packages are an excellent solution for motor retrofits. Because the main outer dimensions and the output power remain the same, there's no need for mechanical modifications. For example, an IE5 SynRM is the same size as an IE2 induction motor.

Reaching IE5 efficiency **with SynRM Motors**

ABB IE5 synchronous reluctance (SynRM) motors deliver ultra-premium energy efficiency. This is a new level of efficiency defined by the International Electrotechnical Commission (IEC), and SynRM motors are the new first choice to meet the growing global demand for improved energy efficiency.

The benefits of SynRM motors



Synchronous reluctance technology combines the performance of permanent magnet motors with the simplicity and service-friendliness of induction motors because they do not include rare earth materials in permanent magnets. The rotor in a synchronous reluctance motor has no magnets or windings and suffers virtually no power losses. And because there are no magnetic forces in the rotor, maintenance is as straightforward as with induction motors.

Customers can increase their energy efficiency, improve sustainability and enhance reliability by upgrading to ABB IE5 ultra-premium SynRM motors, which offer up to 50% lower energy losses compared to IE2 motors, as well as significantly lower energy consumption and CO_2 emissions than the commonly used IE2 induction motors.[1]

SynRM technology offers up to 30°C lower winding temperatures and up to 15°C lower bearing temperatures, which increases the reliability, prolongs the motor lifetime, and reduces the need for maintenance. Lower bearing temperatures are an important factor in reducing life-cycle costs because bearing failures cause about 70% of unplanned motor outages.[2]

ABB's highly efficient SynRM motor was launched in 2011 with an IE4 efficiency class, firstly available for pumps and fans, and now for all applications. And then, in 2019, ABB introduced the IE5 SynRM ultra-premium efficiency motor.

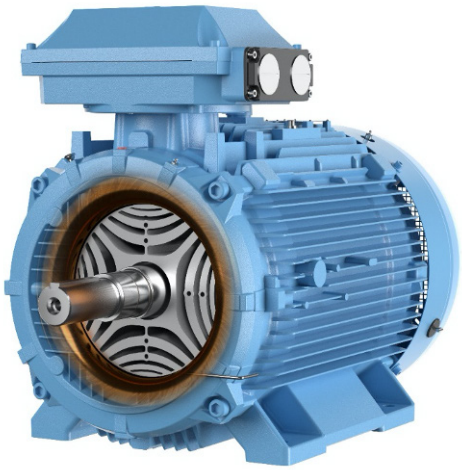
With a standard motor range, the SynRM package is a perfect solution for motor retrofits. The IE5 SynRM is the same size as an IE2 induction motor, eliminating the need for mechanical modifications and making it an easy replacement for traditional induction motors. In addition, these days, the number of VSD applications is increasing, which is driving the commercialization and acceptance of SynRM technology forward.

—

In practice, IE5 motors have 20% less losses compared to an IE4 motor, regardless of the technology or IEC standard used.

Save energy and save money: **IE5 SynRM motors**

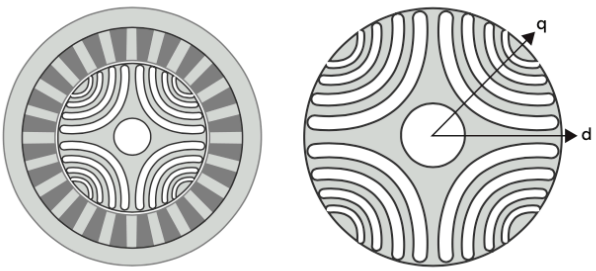
The structure of a synchronous reluctance motor
From the outside a SynRM motor looks very similar to a traditional induction motor. Even the stator inside is traditional. The innovation is in the rotor. The rotor is made from laminated iron layers which form a light but solid construction that allows magnetism to flow through it. The shape is precisely designed to guide magnetic reluctance within the rotor. As a result, the rotor will align itself to the magnetic flux produced by the stator coils, essentially "locking" into position. This enables it to move at exactly the same speed as the magnetic flux, i.e. synchronously, hence the name synchronous reluctance motor. The rotor does not contain magnets or rare earth-based components, and manufacturing it requires less material than a traditional motor.



The function of SynRM
As with other electric motors, a SynRM motor produces rotational motion which can be used to power machines. The rotation of the magnetic flux produced by the stator – and thus the speed of the rotor – is controlled by a VSD. The drive monitors the rotor position, to ensure it stays synchronized.

The benefits of SynRM
SynRM motors have significantly lower energy losses than comparable induction motors. For example, SynRM motors have no losses in the rotor. This results in a lower running temperature which, together with the simple rotor structure without windings, reduces service needs and the risk of failure compared to traditional motors. And if a problem occurs, the connected monitoring systems can indicate the need for potential repairs.

Better still, the noise level of SynRM motors is clearly lower than that of a traditional induction motors resulting in a more comfortable working environment.[3]



—
The torque produced by a synchronous reluctance motor is proportional to the difference between the inductances on the d- and q-axes: the greater this difference, the greater the torque production. Synchronous reluctance motors are therefore designed with magnetically conductive material, iron, in the d-axis and magnetically insulating material, air, in the q-axis.

Getting the most from motors **with Variable Speed Drives**

Variable speed drives (VSD) can help motors run much more efficiently. In fact, by adding a variable speed drive to a standard mid-sized motor application, you can typically reduce power consumption by 25%. And, while they are required to operate synchronous reluctance motor, they are very well suited for use with other types of motor, such as induction motors, as well.

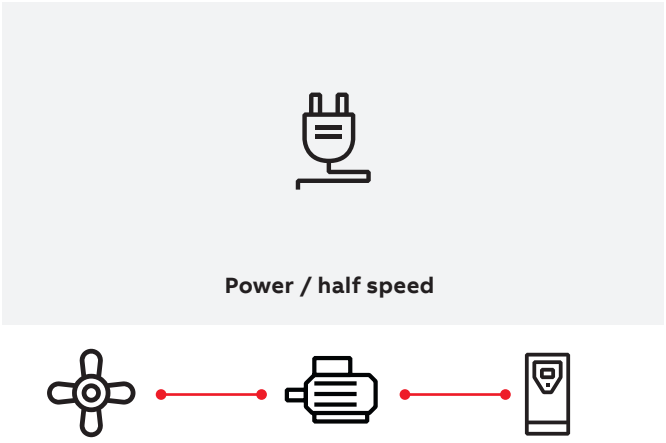
The right amount of energy for the application
A variable-speed drive controls and optimizes the operation of a motor, varying the frequency and voltage of the electricity fed to the motor to adjust the torque and speed. Because VSDs control the speed of the motor directly, no valves, gears, throttles or brakes are needed to control the speed of the application the motor is powering. This means that the motor does not need to run at full speed all the time, and it means that no energy is wasted through mechanical speed control. This is why motors controlled by VSDs can save a lot of energy compared to motors without drives.

At the moment, about 23% of motors are equipped with variable speed drives, so there is still a huge amount of opportunity to improve the energy efficiency of motors around the world.[4]

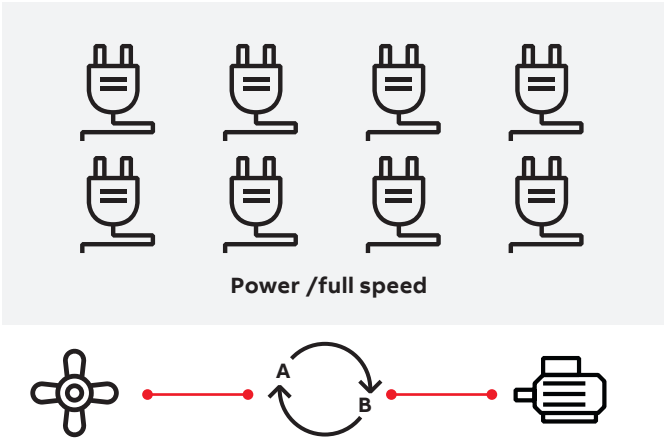
Process stability reduces waste and wasted energy
VSDs also enable excellent process stability. In many production processes this can lead higher quality and fewer rejects, which also means less wasted energy. For example, VSDs can reliably provide a 0.5 rpm tolerance at 1500 rpm. If we apply this over the whole speed range to an extrusion molding machine it results in higher product quality, reduced waste and fewer rejected products. Because waste and rejects are generally fed back to the extruder and re-heated, more precise control of the extruder also reduces energy use.

The most common area of usage for industrial motors is in pumps, fans and compressors. By adding a variable speed drive, you can typically reduce power consumption by 25%

Speed control



Mechanical control



—
Variable speed drives save energy with every rotation. According to affinity laws, pumps and fans running at half speed consume 1/8th of the power.[4]

Meeting **new energy efficiency standards**

As motor technology has advanced, so have the energy efficiency standards that regulate them. There are two IE (International Efficiency) standards that determine the efficiency class of electric motors.

- IEC 60034-30-1 determines the efficiency of typical standard low voltage induction motors with a sinusoidal (DOL) supply.
- The new technical specification IEC TS 60034-30-2 (2016) defines the efficiency classes for VSD motors (i.e. motors which cannot be operated directly on line (DOL)).

According to these standards, electric motor efficiency is currently rated from IE1 to IE5. The higher the number, the higher the efficiency. Some new motors meet the IE4 class standard, which specifies energy losses about 15% lower than those delivered by IE3 motors. And the very latest IE5 motors decrease the losses even further, up to 20% compared to IE4 motors.

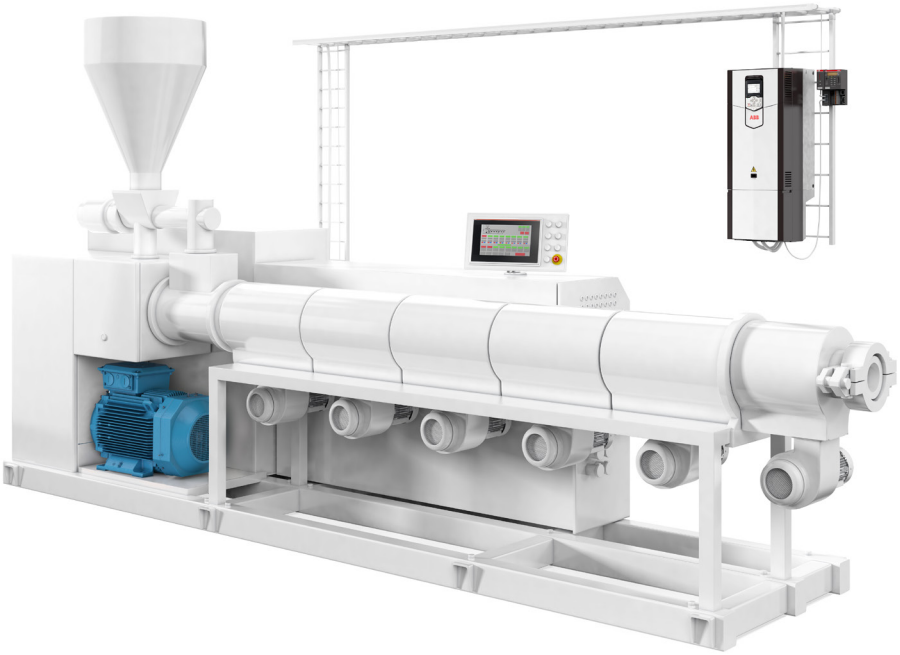
—

With a moderate investment to update your electric motor technology, the return of investment (ROI) can be achieved within as little as one year.

IEC TS 60034-30-2 highlights

- The IE class limit values in the new IEC TS 6003430-2 specification are reduced by adding the additional harmonic losses caused by the drive: 15% additional losses for motors up to 90 kW and 25% additional losses for motors above 90 kW
- Limit values are also available for the IE5 level
- Limit values are to be achieved at 90% speed, 100% torque

This allows direct comparison of the IE class levels of traditional induction motors in variable speed usage with advanced technology motors designed only for VSD (like SynRM motors). It does not matter if the IE classification is done using a DOL supply according to IEC 60034-30-1 or using a VSD supply according to IEC TS 60034-30-2. The given IE class still illustrates the efficiency performance of both solutions in VSD operation very well. This means that IE classes can be compared even if they belong to a different standard, so it possible to compare traditional induction motors to new synchronous reluctance motors. The same IE class gives the same efficiency performance.

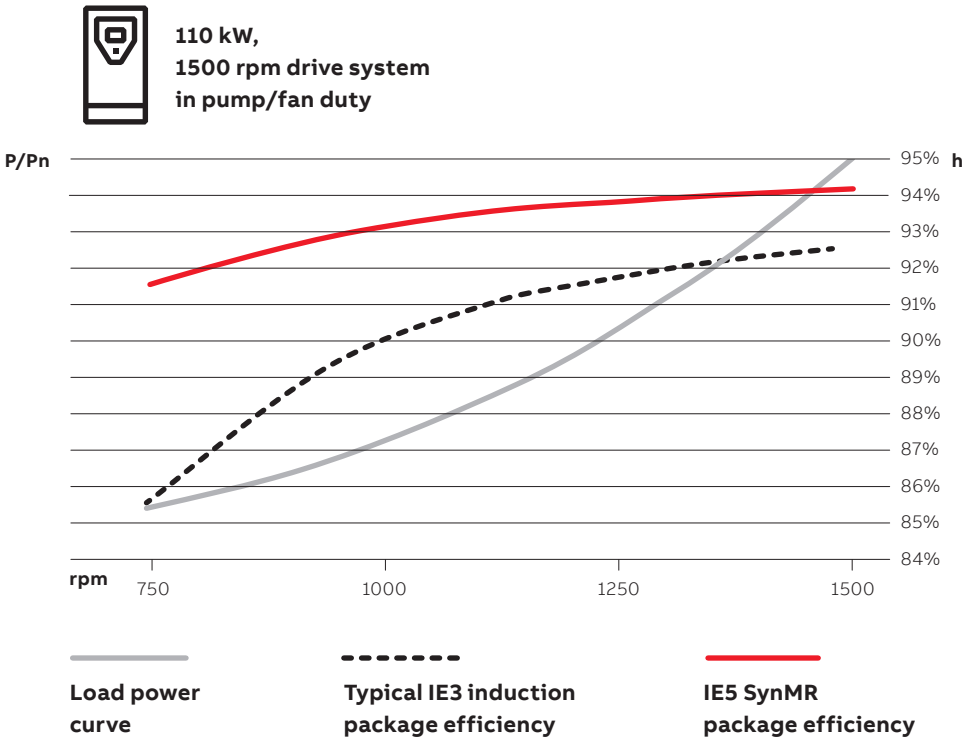


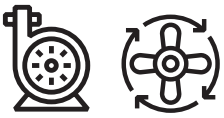
IE5 efficiency delivers **real energy savings**

Partial load efficiency
Where IE5 SynRM motor and VSD packages really shine, is when they are used at partial load. According to the new Regulation EU 2019/1781 (Ecodesign directive) manufacturers need to give the losses in specified load points for the motor (1.7. 2022). This enables motor to motor comparison in partial load conditions with VSD duty. Traditionally comparison has not been possible due to lack of loss information for induction motors in VSD duty.

As you can see in the graph below, there is about a 2% of benefit at full load, while at partial load the benefit can be as much as 6-7%.

IE5 SynRM versus IE3 induction motors in VSD duty
ABB laboratory measurements already show that SynRM IE5 motors have an advantage over IE3 motors, also in the partial load conditions, and the advantage becomes even greater when compared to the nominal point. The figure below shows the typical efficiency performance of SynRM IE5 versus an IE3 induction motor in pump/fan duty according to ABB laboratory measurements.[5]





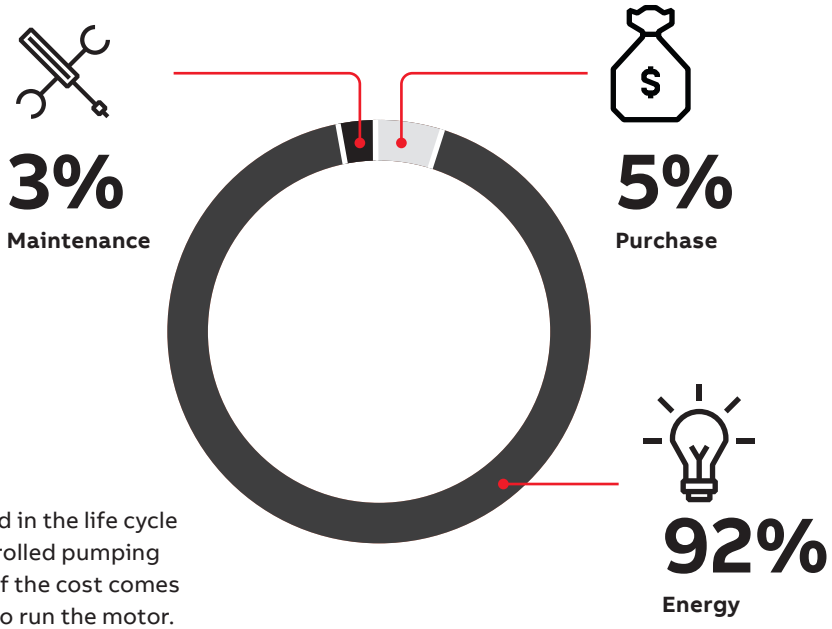
—

Example: For a 110 kW 1500 rpm drive system in pump/fan duty, with an IE3 induction motor the package efficiency is 92.2%, while for an IE5 SynRM induction motor the package efficiency is 94.2%.

Campbell's Australia cuts costs with SynRM

An ABB SynRM and VSD package resulted in a considerable drop in energy costs at Campbell's Australia. Over a 12-month period, the numbers clearly showed a 14% reduction in energy costs. A total of almost AUD 15,000 was saved annually in energy costs, also leading to an annual reduction of approximately 131 tonnes of CO_2 carbon emissions.

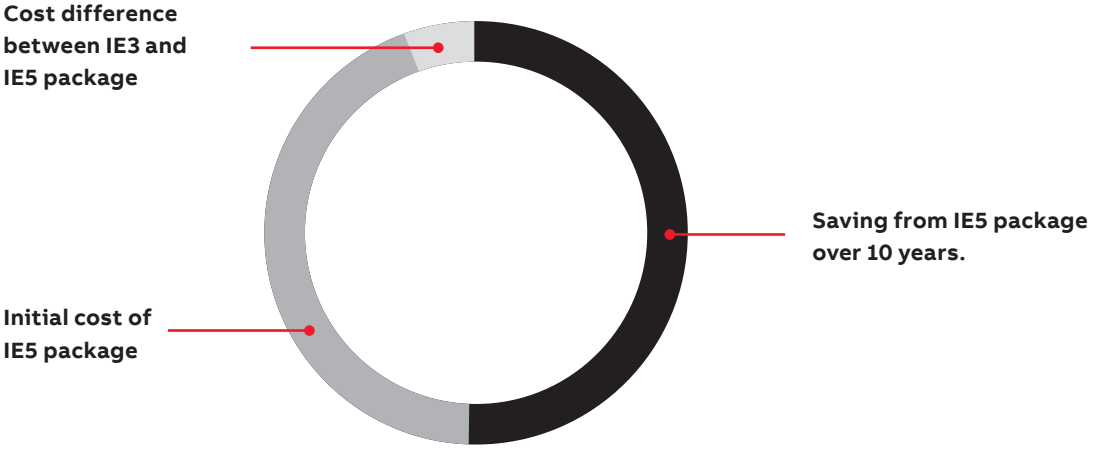
Lower energy use results in lower total cost of ownership
Reducing energy consumption with SynRM and VSD packages means that the cost of running the process and the total cost of ownership will be reduced too. And, although companies can be reluctant to change motors or add drives to their processes due to the up front investment costs, the cost of a motor is only a fraction of the cost of the energy used to run it.



—
The main costs involved in the life cycle of a mechanically controlled pumping system. The majority of the cost comes from the energy used to run the motor.

Life time energy savings pay back
For a 110 kW motor running at 1500 rpm, the difference in initial cost price between an IE5 SynRM motor and an IE3 motor is negligible compared to the annual savings in energy costs. An IE5 motor package will save energy and costs compared to the IE3 package as soon as it is operational, paying back the cost difference after about 13 months. In addition, the IE5 SynRM package will continue to generate annual savings for the rest of its working life, which may be from 10 to 15 years. Within about 10 years the savings generated through reduced energy use will have paid back the initial cost of the whole IE5 package.

Cost vs savings from an IE5 motor package



Conclusion

As discussed, the motor technology needed to radically improve energy efficiency is already available, tested, and proven. SynRM motor and drive packages offer a dramatic improvement in energy efficiency, which if implemented globally, will help reduce energy use and fight against the climate change.

For companies, the decision should be easy. If you can afford to pay a little more for an up-to-date motor, you may see a return on your investment within as little as a year, and further returns throughout the life-cycle of the motor.

For governments and municipal decision makers, it's important to know that more energy efficient options are already available for everything from infrastructure to utilities and public transport. What's needed now is the will to make it happen and your support in making energy efficient solutions the easiest, most preferred option.

(1) As specified by technical specification IEC TS 60034-30-2 (2016).

(2) Reference needed

(3) Reference needed

(4) Source: EEinfog_3AUA0000182864_RevC.pdf

(5) Measured and calculated according to Ecodesign Regulation (EU) 2019/1781.

(6) Source: Copy of Ie5 IE3 calulation tool sample 110kw.xlsx

ABB Motion
P.O. Box 1
FI-00232
Helsinki, Finland

8VZZ005132T0001