
WHITE PAPER

Reaching IE5 efficiency with magnet-free motors



Rapid progress in motor technology

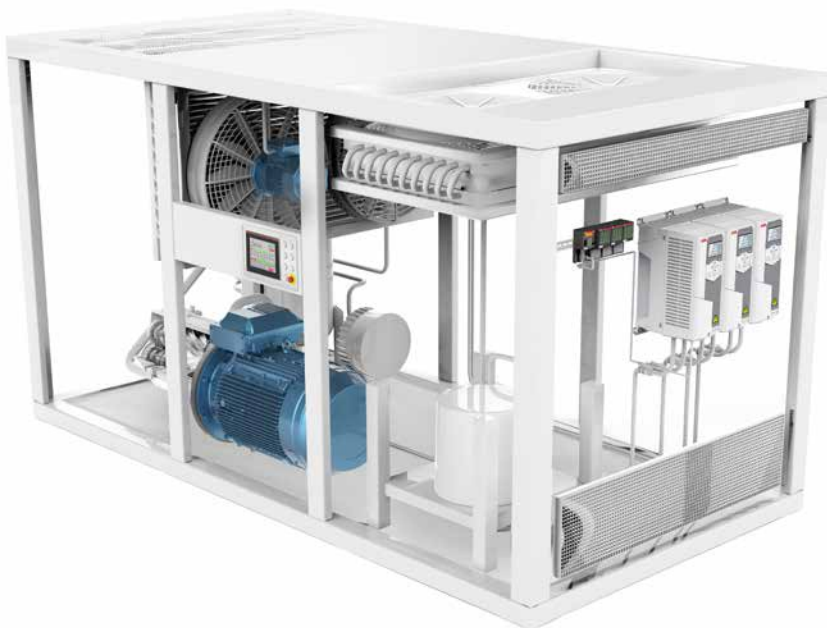
Electric motors consume over 45% of the world's electricity. By 2040 the number of motors will double. It has been estimated that, if all the more than 300 million industrial electric motor-driven systems currently in operation were replaced with optimized, high-efficiency equipment, global electricity consumption could be reduced by up to 10 percent.¹

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.

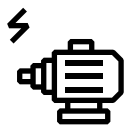
One very significant development is the synchronous reluctance motor (SynRM), which works together with a variable speed drive (VSD). Synchronous reluctance motors can be used as drop-in replacements for standard IE3 induction motors and reduce energy losses in the motor by up to 40 percent.²



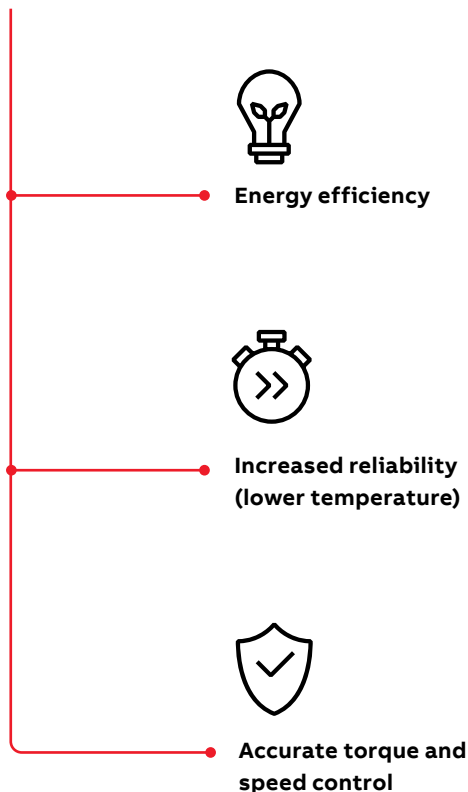
SynRM and VSD packages are an excellent solution for motor retrofits. Because the main outer dimensions and the output power remain the same, there's no need for mechanical modifications. For example, an IE5 SynRM is the same size as an IE2 induction motor.

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 40% lower energy losses compared to IE3 motors, as well as significantly lower energy consumption and CO₂ emissions than the commonly used IE3 induction motors.³ Lowering energy consumption naturally also decreases total cost of ownership over the motors' lifecycle.

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.⁴ Lower energy usage and maintenance needs also result in lower total cost of ownership, increasing not only energy- but also cost efficiency.

Lower bearing temperatures are an important factor in reducing life-cycle costs because bearing failures cause about 70% of unplanned motor outages.⁵

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 and drive 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.

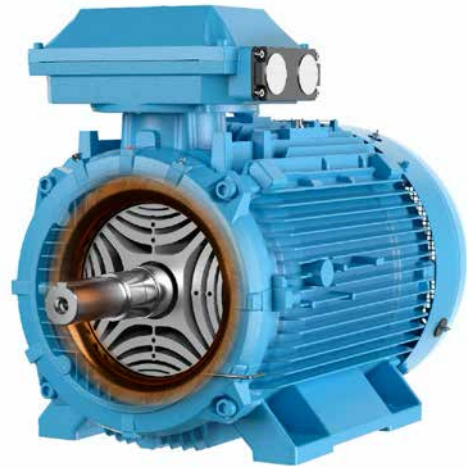
Save energy and save money: IE5 SynRM motors

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.

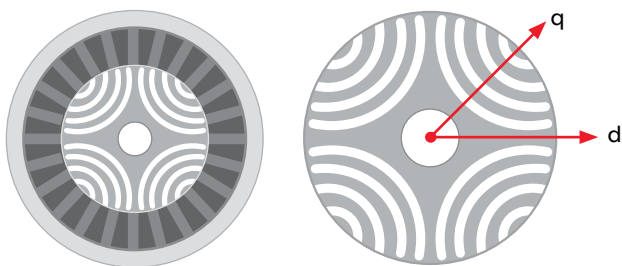


The benefits of SynRM

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.⁶

SynRM motors also have a low environmental footprint because they are manufactured without using rare earth materials, this means no mining is needed and it also creates less waste. Moreover, they have a low carbon footprint over their complete life cycle, from production until recycling, with the best low emission performance in their class.



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.

SynRM Increased Safety motors for safety and efficiency in explosive atmospheres

Keeping motors running safely in hazardous areas

As we have seen, SynRM motors offer many benefits including clear energy savings, reduced total cost of ownership, and a low environmental footprint. Previously, these benefits were only available in non-explosive atmosphere environments. But potentially explosive atmospheres can occur in a wide range of industries, including chemicals, food and beverage, oil and gas, pulp and paper, and pharmaceuticals. Now, ABB is the first manufacturer in the world to provide the same advantages in explosive atmospheres with IE5 SynRM Increased Safety motors.

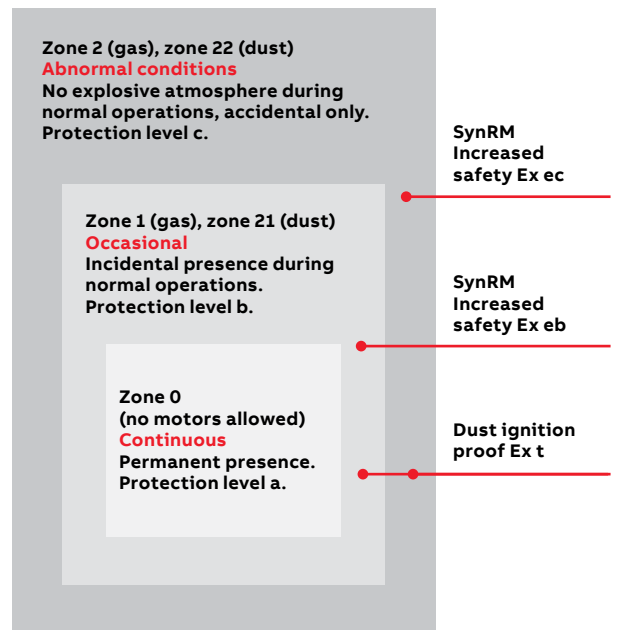
In explosive atmospheres, ensuring the safety of electrical apparatus is paramount. Airborne gas, dust or vapours are potentially highly volatile. To guarantee safe working environments in the presence of such hazards, equipment must conform to international standards. SynRM Increased Safety motors are certified to ATEX and IECEx requirements and certified for use with drives.

The new SynRM Increased Safety motors provide all the benefits of SynRM motors such as ultra-premium efficiency, higher reliability and reduced maintenance.

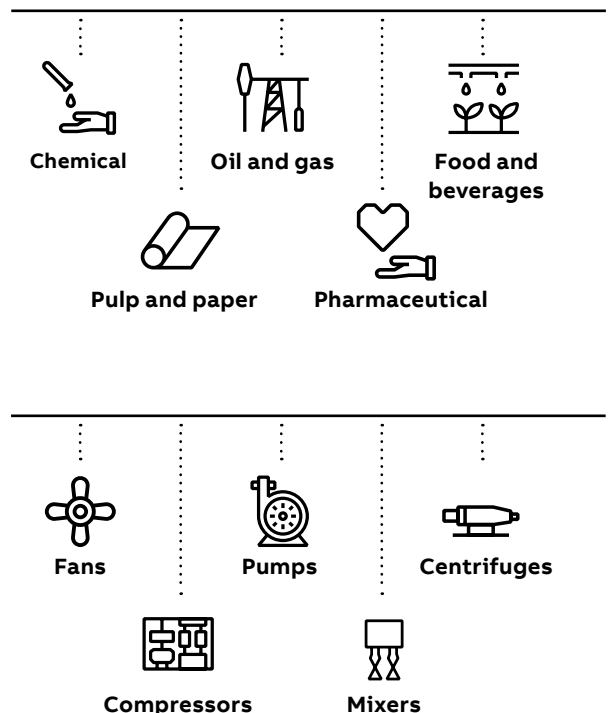
Additionally, the motors can help customers specify a more cost-effective installation. For example, in Zone 1, the cooler running design could allow the use of an increased safety motor where a flameproof motor with a special enclosure would be the traditional choice. While in Zone 2, the improved loadability of SynRM motors, that enables more power to be delivered from the same size as an induction motor, is important. This could enable a smaller, and therefore lower-cost, motor to fulfill the same duty.

The new SynRM variant is manufactured in two versions – Increased Safety and Dust ignition proof. Increased Safety motors are designed to eliminate hot surfaces and sparking during normal operation, ensuring a safer environment. Dust ignition proof motors feature special seals that prevent dust from entering the enclosure, enhancing their reliability in dusty conditions. They are also compatible with ABB Ability™ Digital Powertrain, allowing remote monitoring of electrical motor driven processes.

ATEX/IECEx hazardous zones classification system and ABB SynRM Increased safety motors.



SynRM Increased Safety motors industries and applications



Quieter control and efficiency with **IE5 SynRM Liquid-cooled motors**

For many applications, liquid-cooled motors provide quieter, more efficient operation. ABB is proud to offer the world's first complete range of IE5 SynRM Liquid-cooled motors from 75 kW to 710 kW. The addition of liquid cooling results in high power density without an increase in size, meaning that they are equally efficient at saving energy and cutting emissions in new projects as they are in drop-in replacements for less efficient motors.

Many liquid-cooled induction motors, even when optimized for drive operation, only reach IE1 efficiency. IE5 SynRM Liquid-cooled motors therefore represent significant financial, energy and emissions savings.

Liquid cooling is very effective. The SynRM's cool rotor with cooling ribs on the bearing assembly extends the lifetime of the bearings, enhancing overall reliability by reducing the chance of bearing failures – the cause of around 70% of unplanned motor outages. Higher reliability results in fewer unplanned stoppages, extended service intervals, lower maintenance needs and longer lifetimes.

With tight seals to keep out moisture, dirt and dust, and a smooth outer surface to prevent dust build-up, SynRM liquid-cooled motors are perfect for tough applications like marine propulsion systems and thrusters. Maximum output

in restricted space is ensured through the motor's compact size. High power density means OEMs building rubber and plastics machinery can upgrade to IE5 efficiency with the same or even smaller frame sizes, avoiding the need for expensive redesign work and enabling more compact machines.

One of the liquid-cooled motors' main benefits is the fact that they do not need fans or ventilation for cooling purposes, and therefore do not disturb the surrounding air. This is a big benefit in processes that are impacted by airflow, such as rubber and plastics production, and food and beverage applications like chocolate conche machines. Further, liquid-cooled SynRM motors improve the working environment in industrial plants and are the ideal choice where noise sensitivity is paramount. Their torque characteristics – with a wide speed range for constant torque applications and 100% torque down to zero speed – make these motors very suitable for driving extruders.

IE5 SynRM Liquid-cooled motors enable flexible and accurate control and monitoring of processes for improved overall performance and efficiency, and are compatible with ABB VSDs and ABB Ability™ digital services, including Energy Optimization, Life Cycle Assessment and Remote Monitoring.



Towards IE6 hyper-efficiency

While IE5 SynRM motors are regarded as state-of-the-art in terms of energy efficiency, continuous technological advances are constantly pushing the boundaries of the classification system.

Proven magnet-free SynRM technology is now reaching the theoretical level of IE6 hyper-efficiency - an anticipated efficiency level defined as achieving a 20 percent reduction in energy losses against comparable IE5 motors.

Future-proofing efficiency and costs through SynRM

Early adopters of IE6 hyper-efficiency motors benefit through reduced energy costs and increased productivity while moving ahead of current sustainability targets.

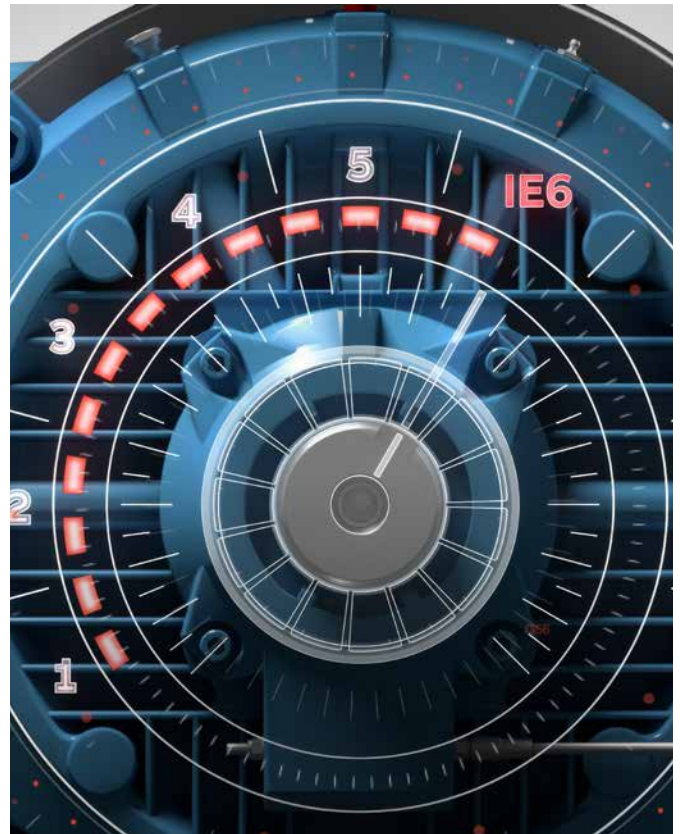
As seen, motor-driven systems in industrial facilities are major users of electricity and therefore maximizing their efficiency offers huge potential to cut emissions and help meet climate change targets. Because the IE6 SynRM is the same size as the equivalent IE3 induction motor it is an easy and straightforward replacement for legacy motors. That makes it possible for customers to upgrade to modern, high efficiency products to future-proof their operations in a world of fluctuating energy costs.

ABB's wide range of SynRM motors has set the benchmark for magnet-free design, with efficiency progressing to the IE5 versions launched in 2019 as discussed in this white paper. Each higher IE efficiency class has had 20 percent lower energy losses than the previous one, now including the IE6 SynRM.

As with previous SynRM incarnations, the performance of permanent magnet motors is combined with the simplicity and service-friendliness of induction motors to achieve high energy efficiency that ensures a short payback time. Like IE5 SynRM, the rotor in IE6 has neither magnets nor windings and suffers virtually no power losses, requires no rare earth metals and offers a high level of usability due to the wide availability of suitable Variable Speed Drives to provide the required control capabilities.

Energy efficiency for optimized TCO

Naturally, IE6 motor technology presents even greater cost and energy savings than IE5. Considering the total cost of ownership (TCO), over a long lifetime the cost of the motor is far outweighed by the cost of the electricity to power it.



As a practical example of what is possible, it is useful to consider the case of a 55 kW motor application operating under a regime where it runs for 6,500 hours a year at 75% power. We assume the energy cost to be €0.2/kWh. In this scenario, upgrading from an IE3 motor and VSD package to an IE6 SynRM package will yield annual cost savings of €1,772 and CO₂ savings of 2,685 kg. Over a service life of 25 years this will deliver a total saving of €44,295 while eliminating 66,000 kg of CO₂.

ABB IE5 and IE6 SynRM motors are part of the ABB EcoSolutions™ product portfolio that provides enhanced transparency about each product's circularity value and environmental impact. Products within the portfolio comply with a set of key performance indicators defined in ABB's circularity framework and carry an external, third-party verified environmental product declaration (ISO 14025 Type III).

Getting the most out of motors with Variable Speed Drives

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

The right amount of energy for the application

A VSD 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.

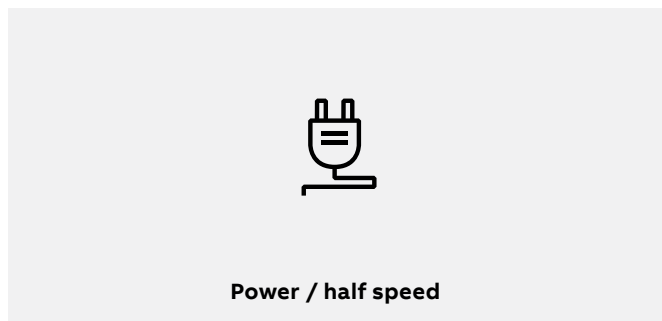
At the moment, about 23% of motors in the world are equipped with VSDs, so there is still a huge amount of opportunity to improve the energy efficiency of motors around the world.⁷

Process stability reduces waste and wasted energy

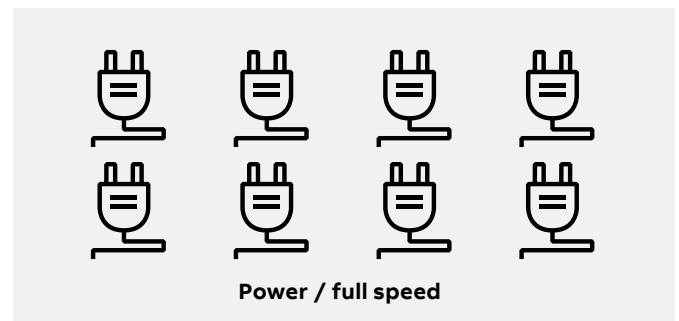
VSDs also enable excellent process stability. In many production processes this can lead to higher quality and fewer rejects, which also means less wasted energy. For example, VSDs can reliably provide a 0.5 rpm tolerance at 1500 rpm. If we apply this over the whole speed range to an extrusion molding machine it results in higher product quality, reduced waste and fewer rejected products. Because waste and rejected products 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. Adding a variable speed drive can typically reduce power consumption by 25%.

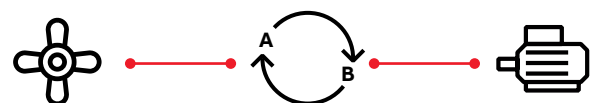
Speed control



Mechanical control



Fan + motor + VSD



Fan + mechanical control + motor

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.⁵

IE5 efficiency delivers real energy savings

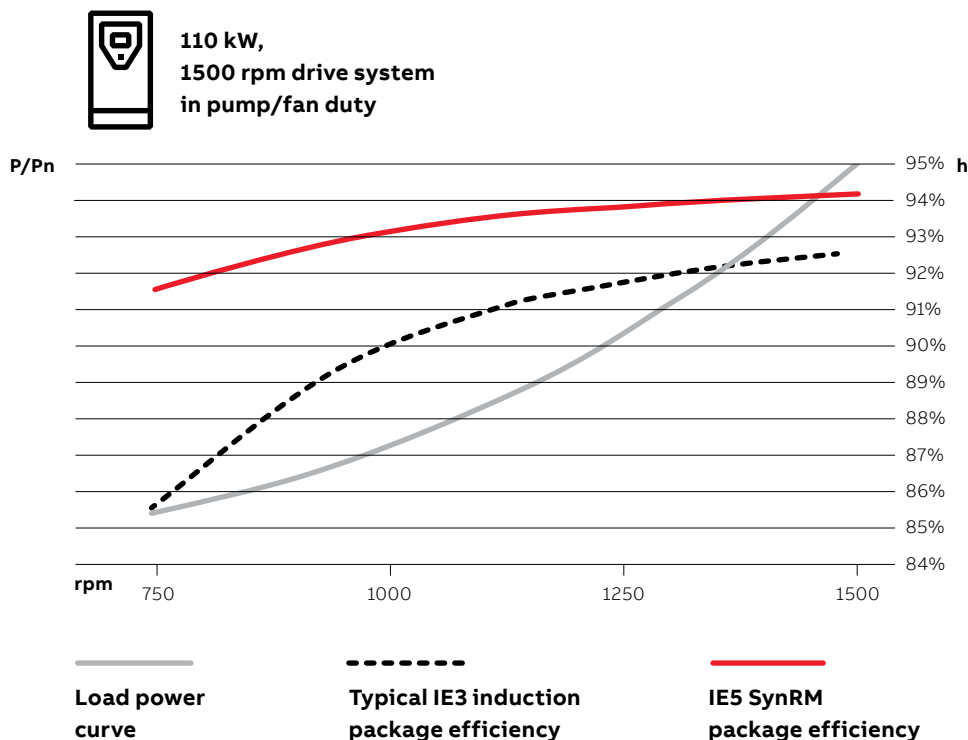
Partial load efficiency

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.

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

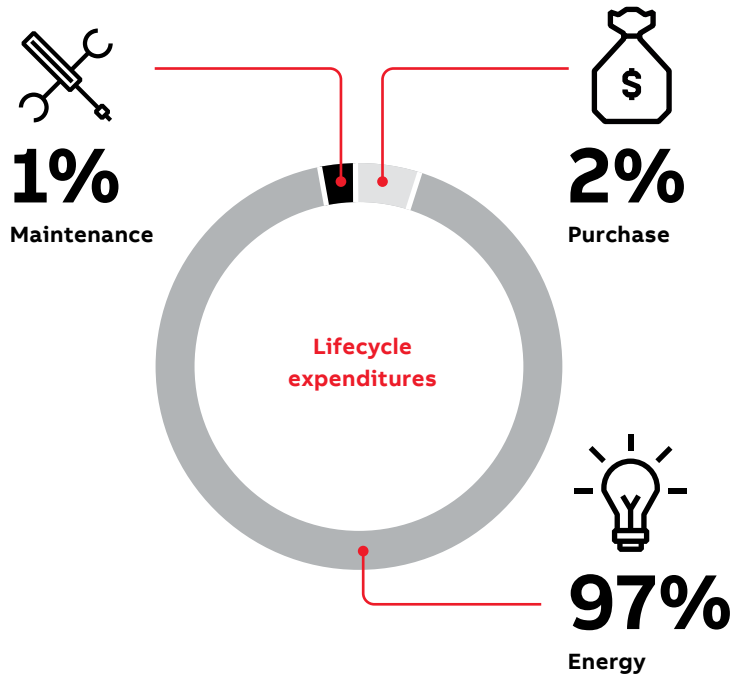
ABB laboratory measurements already show that SynRM IE5 motors have an advantage over IE3 motors, also in the partial load conditions, and the advantage becomes even greater when compared to the nominal point. The figure below shows the typical efficiency performance of SynRM IE5 versus an IE3 induction motor in pump/fan duty according to ABB laboratory measurements.⁸



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.⁹

The main cost in a mechanically controlled pumping system's life cycle is the energy consumed by the motor to power the pump.

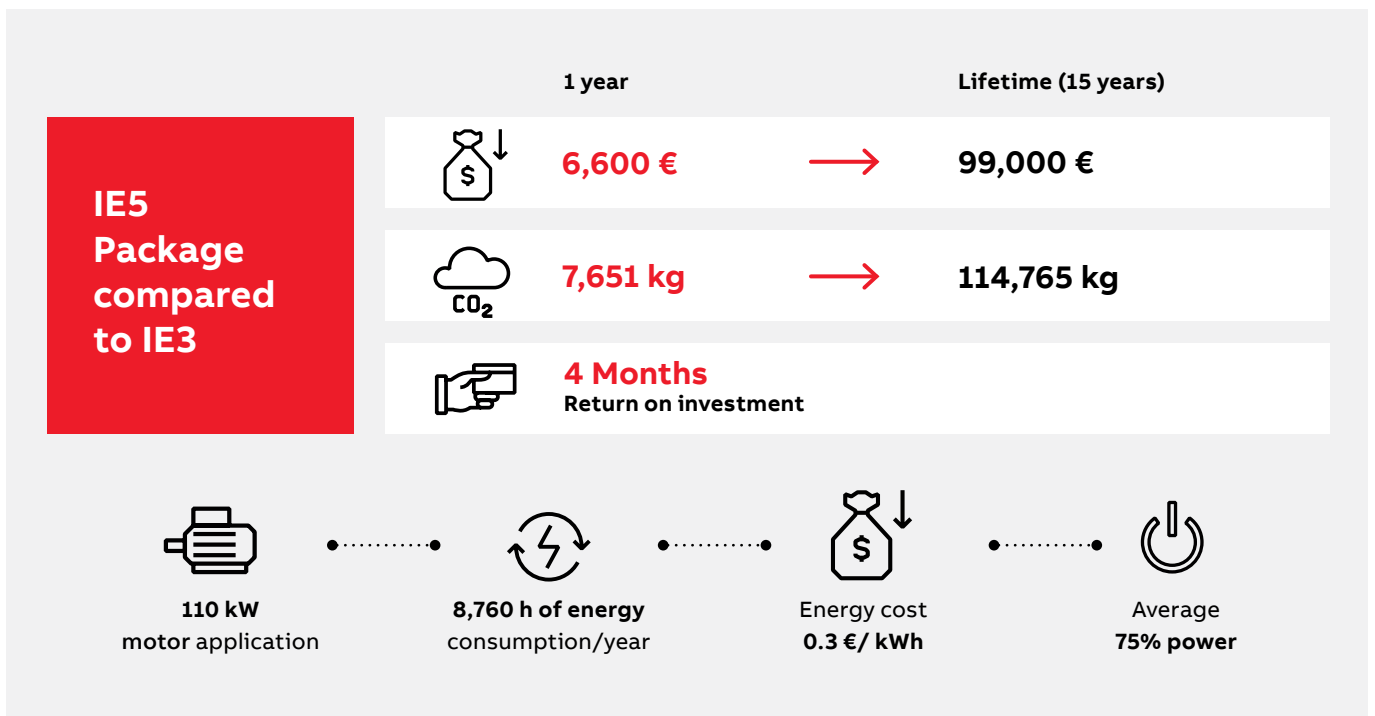


Life time energy savings pay back

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 in a few months in some cases. 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.

IE5 SynRM motor & drive package savings



SynRM customer success stories

CUSTOMER CASE



Campbell's Australia cuts costs with SynRM

ABB's IE5 SynRM and VSD package resulted in a considerable drop in energy costs at Campbell's Australia. Over a 12-month period, a 14% reduction in energy costs was demonstrated. A total of almost AUD 15,000 was saved annually in energy costs, with an annual reduction of approximately 131 tonnes of CO₂ emissions. The refrigeration plant in question runs 24/7, so SynRM technology was able to deliver significant energy and cost savings.

CUSTOMER CASE



Meeting energy efficiency and sustainability goals

In 2020 and 2021 the Bocholt, Germany sewage treatment plant invested in ABB's IE5 SynRM motors and ultra-low harmonic drives to help treat up to 108,000 cubic metres of water every day. The motor and drive packages are the perfect energy- and cost-efficient solution to loads which can vary considerably through many control processes. Instead of regulating partial loads with on-off operation, the facility can now fine-tune their efficiency based on the principle of only using as much energy as is needed.

CUSTOMER CASE



Rich, thick, and energy efficient

Fulfilling our sweet teeth is an energy-intensive task throughout the manufacturing process. In Italy, SACMI Packaging & Chocolate focus their operations on guaranteeing the optimal energy consumption for their machine and full line customers. Bearing this in mind, the company has installed ABB's SynRM IE5 motors to reach a 3-4% electric current saving in their conching machines, which frequently run at different loads and speeds. In combination with a VSD, the SynRM motor has been able to reach twice the nominal speed, pairing energy and production efficiency.

Conclusion

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 adopted globally, will help reduce energy use and fight against climate change.



For companies, the decision should be easy. Return on investment time can be as little as a year, while in the longer term SynRM motors provide multiple benefits including significantly lower maintenance and energy needs. For governments and municipal decision makers, it's important to know that more energy efficient options are available.

With SynRM motors, ABB has created a new energy efficiency standard beyond that required by any current legislation or certification. We and our customers around the world have shown that this technology can make a real, tangible, positive difference to the productivity and efficiency of motor and drive driven processes.

(1) Waide, P. and C.U. Brunner, "Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems," International Energy Agency working paper, Paris, 2011

(2) According to IEC 60034-30-1 and IEC TS 60034-30-2.

(3) According to IEC 60034-30-1 and IEC TS 60034-30-2.

(4) According to tests and measurements by ABB.

(5) Source: Austin.H. Bonnett and Chunck. Yung, "Increased Efficiency versus Increased Reliability," IEEE Ind. Appl. Magazine, Jan/Feb 2008.

(6) Based on customer experience.

(7) Omdia, "Low Voltage Motors Intelligence Service," 2020.

(8) According to ABB measurements and calculations.

(9) According to www.energy.gov/sites/prod/files/2014/04/f15/amo_motors_sourcebook_web.pdf



ABB Motion

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