WHITE PAPER

Designing for optimum energy management:
Selecting the right variable speed motor for HVAC applications

By Mark Gmitro,
Global Product Manager, ABB
July 2021

White paper
Designing for optimum energy management

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Making the right choice pays dividends

There are many benefits of energy efficiency improvements in HVAC installations, including lower energy bills, reduced greenhouse gasses, improved air quality, improved system efficiency and output.

With an abundance of motor technologies available, it pays to choose the right one.

Motor efficiency standards are in place, yet there is still demand to achieve greater efficiencies in order to support industry and sustainability goals.

EC (electronically commutated) motor solutions have helped by introducing higher efficiency and variable speed control to the market, but as regulations tighten on total system efficiency, more may be required to meet new and emerging regulation requirements.

This paper will focus on a newer technology, ferrite assisted synchronous reluctance (FASR), and compare the design performance to other technologies on the market.

Section 1
Background: Electric motors used in HVAC installations

According to the U.S. Department of Energy (DOE), more than half of all electrical energy consumed in the United States is used by electric motors, and the International Energy Agency (IEA) estimates that electric motor-driven systems account for more than 40 percent of global electricity consumption[1]. That number is expected to double by 2040. In the U.S., industrial pumps, fans and compressed air systems account for over 80% of electricity use in industrial motor systems.[2][4]

Improving the efficiency of electric motors can save energy, reduce operating costs and improve productivity; therefore, energy efficiency should be a key consideration when purchasing a motor. Motor systems consume large amounts of electricity and can provide an opportunity for significant energy savings. The annual energy cost of running a motor is usually many times greater than its initial purchase price; however, the purchase of a new motor is often driven by the price, not potential electricity consumption. Even a small improvement in efficiency will result in energy and cost savings. Investing a little more money upfront for a more efficient motor is paid back in energy savings; often in as few as one to three years. And, by following industry best practices, electric motor efficiency can be further improved by 20 to 30 percent, resulting in significant savings and reduced environmental impact, especially in motors that can remain in operation for 20 years or longer.

Many countries and regions around the world have established minimum efficiency performance standards (MEPS) for motors used in industrial, commercial and residential applications. Almost nine-out-of-ten industrial electric motors sold globally are covered by mandatory efficiency standards, albeit at various levels of stringency[3]. The ability to establish and enforce MEPS, however, depends on a standardized testing and classification system for motor efficiency.

Government mandates on motors exist for many reasons. Motors can stay in use for 20 years or longer, so the wasted energy used by an inefficient motor accrues over the lifetime of a product, leading to unnecessary strain on power grids and avoidable CO2 emissions. The technological advancement and adoption of high-efficiency motors and variable speed drives are key factors in achieving significant energy efficiency improvements in industry and infrastructure. Simply by focusing on the selection of an optimal motor, manufacturers can design their equipment to improve overall system efficiencies, leading to reduced environmental impact and cost savings that are passed on to customers.

In addition, new legislation is moving to requiring a fan energy index (FEI) of 1.0 or higher. Starting with the right motor and a broad efficiency island provides greater flexibility for fan design by manufacturers to meet or exceed the FEI standard.

Section 2
Motor efficiency regulations: NEMA vs. IEC

The National Electrical Manufacturers Association (NEMA) has set standards for motors used in North America since 1926. NEMA regularly updates and publishes MG 1, a book that assists users in the proper selection and application of motors and generators. It contains practical information concerning performance, efficiency, safety, testing, construction, and the manufacture of alternating current (AC) and direct current (DC) motors and generators.

While there are many similarities between NEMA and IEC, there are a few fundamental differences in the two motor standards. The NEMA philosophy emphasizes more robust designs for broader applicability. Ease of selection and breadth of application are two of the fundamental mainstays within its design philosophy. IEC, on the other hand, is focused on application and performance. Selecting IEC devices requires a higher level of knowledge about the application, including motor load, duty cycle and full load current (FLC) when selecting an IEC motor.

NEMA designs components with a safety factor and may have as much as a 25 percent service factor while IEC is focused on space and cost savings.

IEC and NEMA efficiency ratings

- Each band of efficiency equates to 10 percent less motor losses.
- Each class of efficiency = 2 bands of efficiency

NEMA	IEC*
Standard efficiency	IE1
High efficiency	IE2
Premium efficiency	IE3
No standard	IE4
No standard	IE5

*Each class of efficiency = 20% less motor losses

What about NEMA?

NEMA has no defined standard available yet for IE4 or IE5, although some manufacturers are marketing a motor/variable speed drive pair as “ultra-premium efficient.” The same concept applies when IE5-equivalent efficiency levels are achieved through variable speed drives at full and partial loads.

An integrated motor/drive system using FASR technology is another solution that will provide an IE5 level of efficiency and simplify the setup while eliminating expensive wiring and installation time.

IEC standards

To standardize motor efficiency classifications, the International Electrotechnical Commission (IEC) introduced the standard IEC 60034-30: 2008, which was updated in 2014. IEC 60034-30-1 defines International Efficiency (IE) efficiency classes based on frequency, number of poles and motor power without regard to motor technologies or supply voltage, making different motor technologies fully comparable with respect to their energy efficiency potential and leveling the playing field between established and new, innovative, motor technologies to enable fair competition and market development.

Motors that fall under IEC 60034-30-1
The IEC standard 60034-30-1: 2014 applies to motors that meet the following criteria:

- Single speed induction or permanent magnet type motors (single- and three-phase) operated on a sinusoidal mains supply
- Frequencies of 50 or 60 Hz
- 2, 4, 6 or 8 poles
- Rated output from 0.12 kW to 1000 kW
- Rated voltage from 50 V to 1000 V
- Capable of continuous operation at rated power without exceeding the specified insulation class (S1, continuous, duty)
- Ambient operating temperature between -20° C and +60° C
- Operating altitude up to 4,000 m above sea level

IEC efficiency classifications
For these motors, the IEC 60034-30-1 standard defines four IE classes for single speed electric motors:

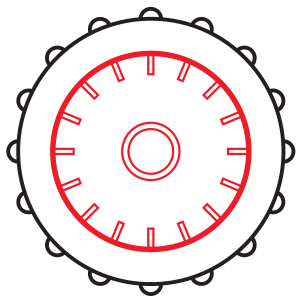
- IE1 Standard Efficiency: NEMA Standard Efficiency
- IE2 High Efficiency: NEMA Energy Efficiency
- IE3 Premium Efficiency: NEMA Premium Efficiency
- IE4 Super Premium Efficiency*: The minimum legal standard in Europe from July 2023 for motors rated 75–200kW

The next version of the IEC standard will introduce the IE5 class, known in NEMA terms as Ultra Premium Efficiency. The Ultra Premium Efficiency class has not been specified in NEMA standards yet, but some manufacturers have already developed motors that will be compliant.

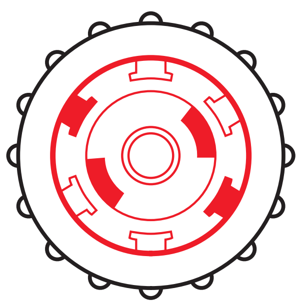
- IE5 Ultra Premium Efficiency*: The best practice standard, commercialized since 2017

* Currently, there are no equivalent NEMA standards for IE4 & IE5.

Section 3
IE3 to IE5 motor technology overview

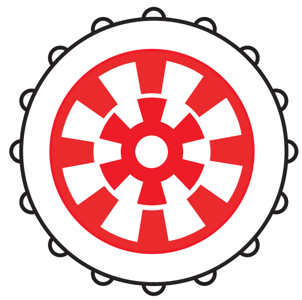


IE3 motors are typically standard induction motors (IM) and have been the standard in HVAC applications for many years. They are easy to control with a standard variable speed drive and have the advantage of being able to run in multi-motor setups where one large drive controls a bank of motors.



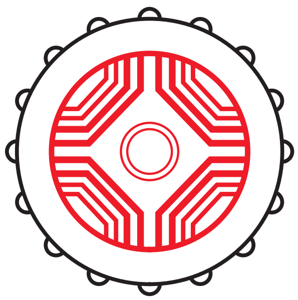
IE4 to IE5 electronically commutated motor (ECM) is one of the first technologies to achieve high efficiencies for motor and fan assemblies. These are normally less than 2 horsepower ECM fan motors that are a brushless DC, with a permanent magnet (PM) rotor and an imbedded drive inside the motor. They are normally packaged with the fan.

ECM motors, though low cost, simple and easy to use, have a number of identified shortfalls including a limited over-speed ability, limited power and speed range, and efficiency drop off at partial load/speed. They also require replacement of the entire assembly (motor/drive/fan) for service.

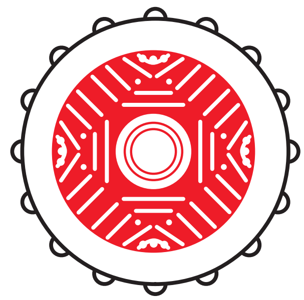


IE4 to IE5 switched reluctance motors are DC motors in which power is delivered to the windings in the stator rather than the rotor. They are very simple mechanical designs, run by reluctance torque, and tend to be compact and reliable. The electrical control is not a standard drive, as a switching system must be used to deliver power to the different windings. This system produces high torque ripple and poor speed torque performance.

Switched reluctance motors deliver high efficiency but not the highest, and they maintain their performance at lower speed and load points. The main drawbacks are high noise (+90 dBA) and very low power factor (35-45 percent), which results in high current draw. As a result, switched reluctance motors require an oversized drive and more complex wiring.



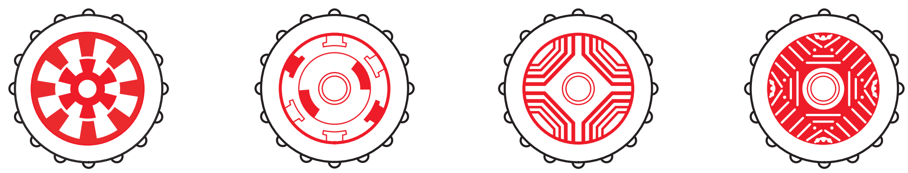
IE5 synchronous reluctance motors (SynRM) have also been used and are based on a standard induction motor but with a no-loss rotor design. Because no magnetizing current passes through the SynRM rotor, it is more efficient than an asynchronous AC induction motor, increasing efficiency to IE5. These motors operate at synchronous speed just like electrically commutated (ECM) motors; only the rotor is different. This simplifies spare part provision and maintenance. It also means that replacing an existing IM with a SynRM is easy.



IE5+ ferrite assisted synchronous reluctance (FASR) motors. Like the traditional EC motor, FASR motors use permanent magnets and require a drive to control properly. Both are synchronous and tend to be more efficient than their induction counterparts. By using a synchronous reluctance rotor designed with embedded ferrite magnets, IE5 efficiency can be achieved across a wide speed/ load range.

These systems maintain higher efficiency at partial loads, and the near unity power factor allows for smaller drives, reducing the footprint of an integrated system. Additionally, using an integrated motor/drive solution saves control panel space and reduces wiring costs by placing the drive on top of or on the opposite drive end of the motor.

Section 4
Comparison of SynRM, Switched Reluctance, ECM & FASR



	Switched reluctance	ECM	SynRM	FASR
Efficiency	IE4 to IE5	IE4 to IE5	IE5	IE5+
Market recognition	Not well known	Well recognized	IEC market	Newest technology
Speed	Synchronous	Synchronous	Synchronous	Synchronous
Above base speed range	Yes, 3600 RPM limit	No, limited to base speed	Yes, highest speeds	Yes, 4000 RPM limit
Rotor design	Magnet-free no-loss rotor	Rare earth magnets, expensive, hard source	Magnet-free no-loss rotor	Low cost, ferrite magnets
Temperature	Low	Low	Average	Lowest (20% less than SynRM)
Power density	Good	Compact, lightweight pancake motor	Average	Highest for NEMA
Integrated units (IMD)	No, separate motor, drive	Yes, built-in control module	No, separate motor, drive	Yes, packaged motor, drive
Complexity	Average simple motor, separate drive	Easy to use and maintain	Average separate motor & drive	Easy to use and maintain
Eff. part load/ speed	Good	Low due to inefficient drive converter	Average efficiency partial loads	Very good
Power factor	Lowest power factor (35 to 45%)	Good power factor (~90%)	Low power factor (~70%)	Highest power factor (92 to 98%)
Harmonics	High fundamental frequency and high torque ripple	Average 35% THDi with choke, high voltage distortion	Lowest 5% THDi available or 35% w/ input choke	Average 35% THDi using input choke
Current draw	Very high currents (higher than SynRM)	DC drive not applicable	High current larger drive needed	Lower current draw / smaller drive needed
Component availability	Stock motor, non-standard drive with limited availability	Must replace entire unit with fan, restricts OEM fan	Stock components easy to service and replace motor or drive	Stock components easy to service and replace motor or drive
Noise levels	Very high noise upward +90 dBA	Lowest noise	Average noise levels, equal to induction	Low noise, less than induction < 70dBA
Mounting standard	NEMA frames available	Packaged fan, motor & drive one supplier	IEC frame dimensions	Drop in NEMA replacement
Drive required	Requires special drive & six lead connection	Requires DC drive	Requires drive	Requires drive

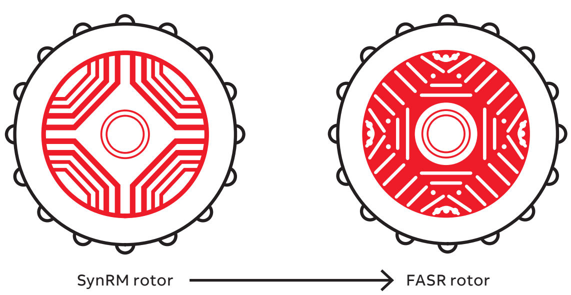
Section 5
FASR: Designed for optimized efficiency

FASR motors operate on the same principle as induction motors for rotation and utilize a standard induction motor stator winding. The base mechanical rotor is a SynRM design. These motors have flux barriers (air gaps in the rotor) that direct the flow of current in the rotor and eliminate losses normally associated with solid induction rotors.

No-loss rotor = Higher efficiency (losses only occur in the stator)

However, power factor is low - in the 70 percent range - with SynRM motors, which contributes to a larger current draw and potential oversized power converter (drive).

FASR motors add ferrite magnets to the rotor, which add to torque generation and field strength. No current is required for ferrite magnets, which results in zero losses and added field strength. This further improves overall efficiency.



Less work stator = lower losses overall = higher efficiency

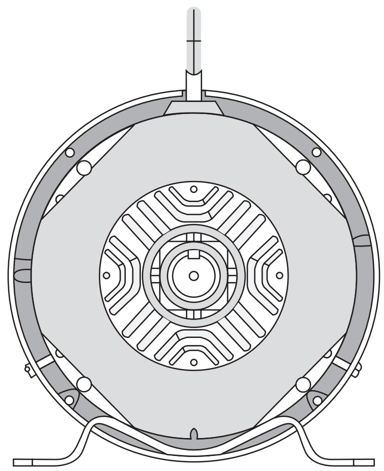
The stator just supplies “torque on demand” beyond ferrite field strength and allows optimization of current and partial loads.

Finally, the ferrite magnets improve the power factor up to a range of 92 to 98 percent.

This results in less current draw than induction motors, a smaller packed option and the ability to use a smaller stand-alone drive.

Section 5
FASR: Designed for optimized efficiency

Highly efficient, sustainable technology
FASR motor technology utilizes available and sustainable materials that can be manufactured into a IE5 efficiency motor design.



This motor design allows for the maximum utilization of the active materials: electrical steel, copper and permanent magnets, achieving an extremely efficient and high-performing machine. The end product is suitable for constant and variable torque applications. The performance is also excellent in the constant power range. The machine is characterized by a "flat" efficiency map, which means that efficiency stays high at any speed and also at partial load.

Sustainable magnet design
FASR motors do not use rare earth magnets, unlike most traditional PM designs which use neodymium-iron-boron (NdFeB) magnets. NdFeB magnets are utilized in PM motors, electric vehicles and solar and wind applications. 80 percent of these magnets come from one global region, and as such, coupled with high demand and availability, NdFeB commodity prices are volatile. By using standard ferrite magnets, FASR motors provide a more cost-effective, lower-risk solution.

Additional environmental concerns are present with the mining of elements used to make rare-earth magnets. Mining activities can lead to the generation of large quantities of heavy metal-laden wastes, which are released in an uncontrolled manner. These materials can cause widespread contamination of the ecosystem and detrimental effects on human health.

Overall, FASR technology results in a product that employs available, price-stable and environmentally-friendly ceramic magnetic material – ferrites. As a result, FASR is an optimal motor design in terms of cost, performance and sustainability.

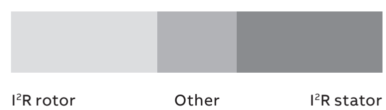
These motors share the same building blocks as standard induction motors, meaning they can be manufactured alongside other motors in the same production facilities. This guarantees high production capacity, product configurability and versatility. Installation and retrofitting costs are kept at a minimum since many motors employing this technology are designed around standard NEMA dimensions and mounting for ease of retrofitting.

Section 6
Motor technology loss comparison

The FASR motor design eliminates losses in the rotor, reduces losses in the stator and boosts power factor to near unity, resulting in an extremely efficient and high-performing machine.

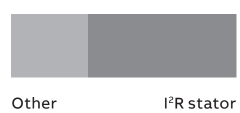
Induction motor
- Slip losses in rotor (I2R)
- Heats bearings and motor
- Lower efficiency adds to heat generated

Higher rotor and stator losses



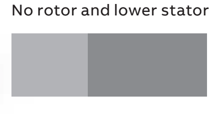
SynRM motor
- Air gaps rotor direct magnet field lines of flux
- Eliminates circulating currents rotor
- Synchronous, no-slip losses
- High efficiency and low motor temperature

Eliminates rotor losses



FASR motor
- Same SynRM rotor benefits with the addition of ferrite material in rotor
- Increases field strength (more lines of flux) less work required stator
- Less overall losses, lower current draw and lower motor temperatures

No rotor and lower stator losses



Section 7
Temperature rise and current draw

Historically, EC motors had the advantage over induction motors: they inheritantly run cooler and draw lower current than either induction or SynRM designs.

The FASR design addresses this with a motor that draws lower current than induction motors (more in line with EC). Higher efficiency results in fewer losses and cooler operation. The high power factor contributes to the lower current draw of the FASR motor design. In many cases, a smaller power converter may be used as a result.

Table 1: 3 Hp 1800 RPM FASR & induction to 3.45 Hp 2200 RPM EC motor
Lab tested data, system efficiency (includes drive losses)

	EC	FASR	Induction
Amps	3.94	3.72	4.27
PF	90%	95%	66%
System Eff.	88.1%	88.9%	86.4%
Frame (°C)	36.64	38.27	46.64

Table 2: FASR motor data vs. induction motor designs

FASR motor data @ 1800 RPM 60 Hz						**IE3 induction motor current**
Motor input voltage	**Hp**	**Motor frame**	**Efficiency**	**Motor PF 1st HRM**	**Motor input current**	
230V/460V	1	140	89.30%	96.60%	2.3/1.2	3/1.5
	2	140	90.70%	96.00%	4.5/2.3	5.6/2.8
	3	140	91.40%	94.90%	7.0/3.5	N/A
		180	92.80%	96.60%	7.3/3.7	8.2/4.1
	5	140	93.00%	97.30%	10.4/5.2	N/A
		180	93.70%	97.30%	10.5/5.3	13/6.5
	7.5	180	94.00%	94.30%	17.5/8.8	N/A
		210	94.00%	92.30%	17.4/8.7	19/9.5
	10	210	94.80%	93.70%	22.0/11.0	25/12.5
	15	210	95.60%	97.20%	34.8/17.4	36.2/18.1
460	20	210	95.90%	90.50%	21.6	24

Compared to an induction motor, the lower current draw and high power factor result in a lower temperature of the motor by nearly 20 percent on average.

Section 8
Increasing efficiency with motor/drive packages

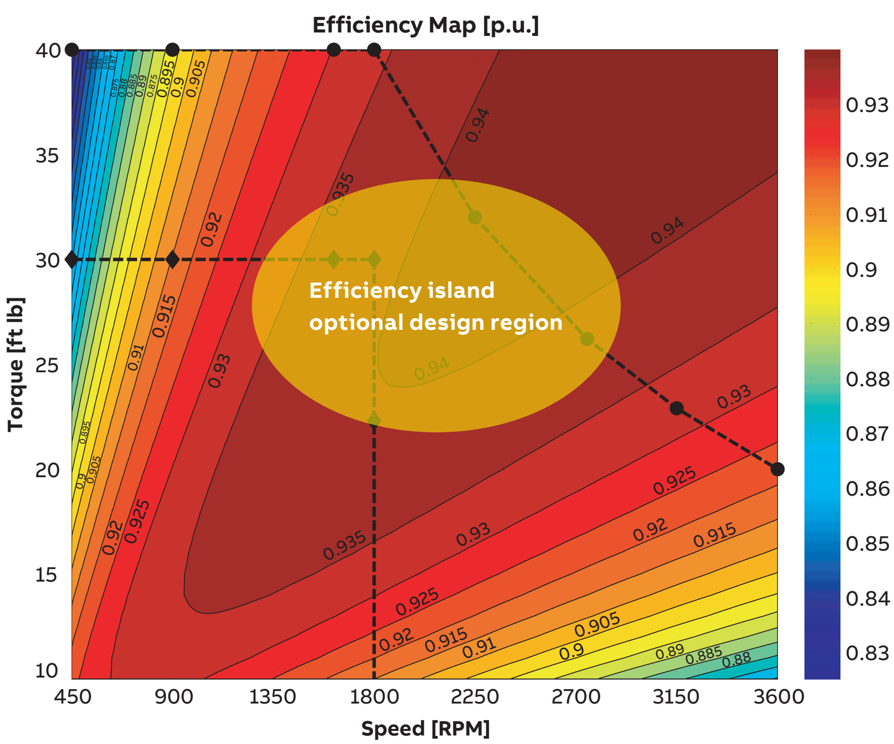
Every technical solution to system configurations has its own benefits and drawbacks. In order to reach optimum system efficiency, the efficiencies of the individual components must be optimized in a manner that does not cause greater losses to other components within the system.

Selecting the optimal combination of individual components ensures the highest system efficiency is achieved. The total system, or package efficiency, inclusive of all components, is what matters most. For an air handling unit (AHU) this is generally referenced as the wire-to-air efficiency, and it is the power taken from the electrical supply compared to the airflow and pressure the AHU generates. This total efficiency is a factor of the drive, motor, coupling, fan, coil and other components' efficiencies.

ηsystem = ηdrive • ηmotor • ηcoupling • ηfan • ηcoil
η = efficiency

Efficiency island: Operation above base speed
When selecting the system design, it is critical to have a motor design that provides the widest – flattest – efficiency island to provide flexibility when designing the fan system. In this example, a 7.5 Hp motor is shown with a fan curve above the 1,800 RPM base speed. The ability to run above base speed is a limitation with EC motors (top speed limited by line voltage) that the FASR motor overcomes.

Using a lower base speed and running up to the fan speed is ideal for fans that typically run full speed and load most of the time.



Efficiency island optional design region:
In this region, the fan can take advantage of the widest maximum efficiency band of any product available.

Having the information and freedom to choose the total combination of equipment to offer the best performance is critical for manufacturers designing air handling applications. The best total efficiency is built from the use of the best components in combinations that have been verified as shown in Figure 1.

Figure 1
IE efficiency bands: IE5 FASR motor values

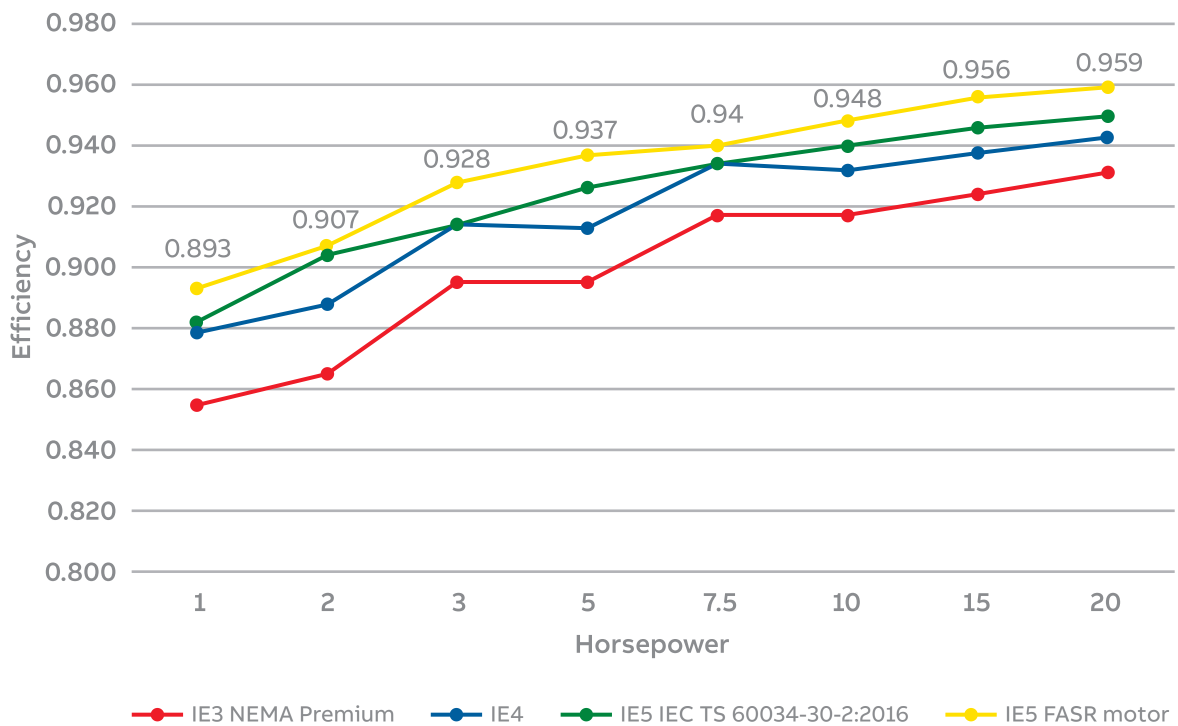
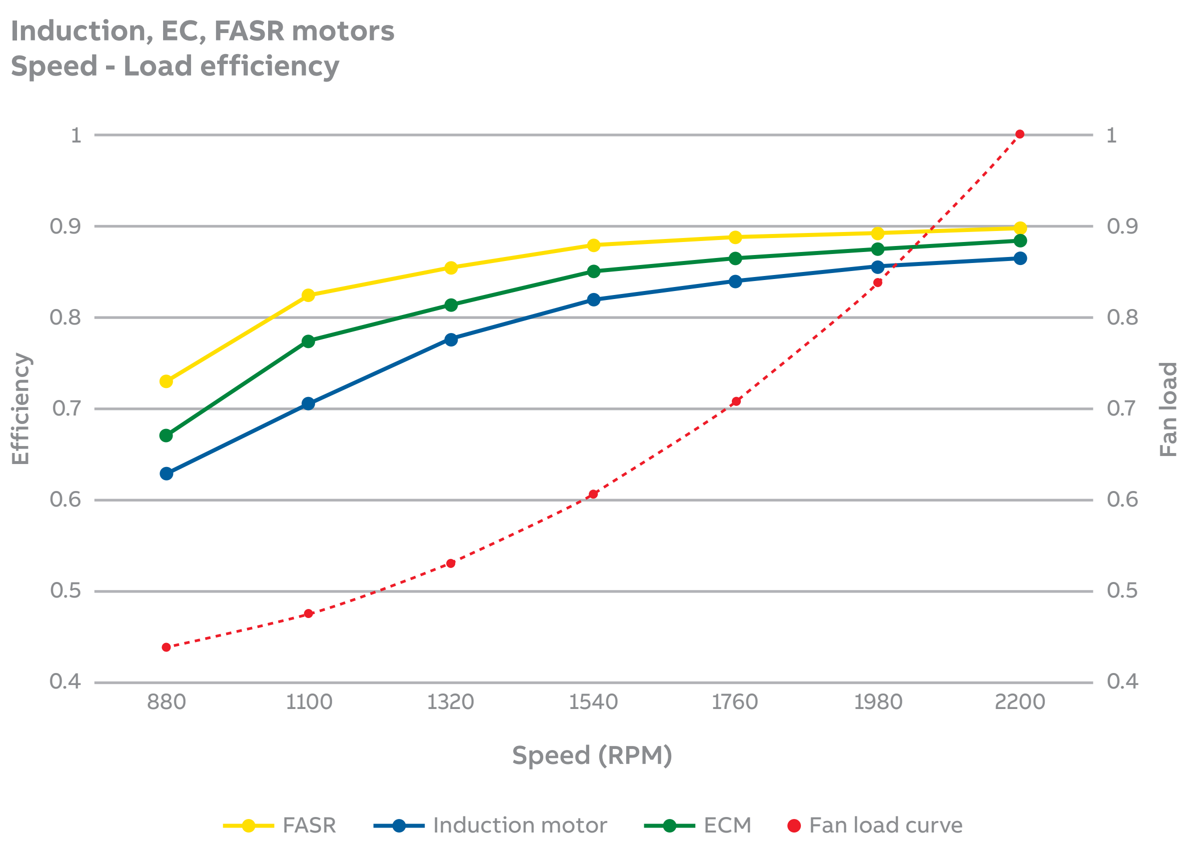


Figure 2
Partial load efficiency

FASR motors' wider speed torque range with higher efficiency allows more flexibility to match a fan impeller and reach a nominal fan duty point. Results at partial load points show efficiency gains of as much as 16 percent over induction motors and eight percent versus EC designs.

Lab test 3 Hp, 1,800 RPM base speed, 2,200 RPM top speed, variable torque load profile, including losses in power converter.



Section 9
Is it worth upgrading?

FASR motors are highly efficient at full and partial loads.

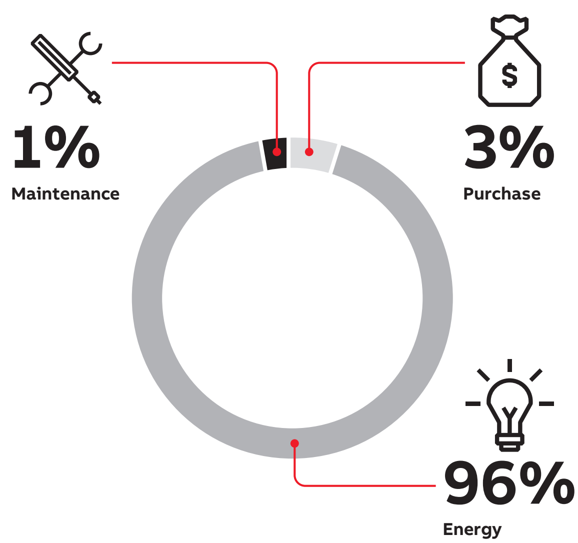
- As much as 16 percent efficiency gain at partial load and speed compared to IE3.
- As much as 40 percent energy savings when combining drives to control motors.

The purchase price of a motor is generally less than three percent of its lifetime cost compared to 96 percent of the lifetime cost spent on electricity to run the equipment over its lifetime. For low voltage motors, the payback time is typically two to three years in the case of a replacement. When considering a new investment, the typical payback time for a higher efficiency class is less than one year.

Estimating the savings from a motor upgrade
Conducting an energy audit is the best method to accurately calculate the cost savings from an equipment upgrade, but a simple calculation can provide an estimate.

$$\text{Motor upgrade savings} = 1 - \frac{\text{Existing motor efficiency}}{\text{New motor efficiency}}$$

For example, replacing a motor with 85 percent efficiency with a unit that has 91 percent efficiency will result in a savings value of 0.066 or 6.6 percent. If the existing motor consumes 300,000 kWh per year, the new one will save 19,800 kWh. With a residential electricity price of approximately 13 cents/kWh and all other factors remaining constant, this is equivalent to $2,574 in annual savings.



Control equals savings
HVAC installations that include fans and pump systems are the target of energy efficiency efforts because they tend to operate on partial loads and are often underloaded (30 percent of fans and 39 percent of pump systems measured were underloaded [5]). If a motor runs consistently at less than 40 percent capacity, considerable energy savings can be achieved by reducing the size of the motor. Similarly, increasing the motor efficiency and using a drive to control the motor will save as much as 40 percent of the total operating cost.

When these systems are underloaded, it is likely that the system as a whole is operating suboptimally. Underloaded motors can reap significant energy savings through power and speed control, and systems can achieve similar energy savings by operating on downsized motors.

Appendix A

Actual customer test results

Induction motor (IE3)	FASR motor (IE5+)	Difference
Average unit consumption per day (seven-day test duration): **57.69 kWH**	Average unit consumption per day (seven-day test duration): **45.1 kWH**	**12.59 kWH**
Estimated monthly energy cost per unit: **$198.38**	Estimated monthly energy cost per unit: **$155.04**	**$43.30** per month per unit
Energy reduction: **20%** Annual savings: **$520 per unit** Estimated return on investment: **18-24 months**		

Motor feature comparison table

	Induction motor	Synchronous reluctance motor	Switched reluctance motor	Ferrite assisted synchronous reluctance motor	Permanent magnet motor	Electronically commutated motors (ECMs, EC motors)
Typical power range	Wide power range	5.5 - 315 kW	1 to 15 Hp	1 to 20 Hp (0.55 - 18.5 kW)	Wide power range	Lower power range 0.5 to 10 Hp
Efficiency range	Up to IE3, some IE4 available	Up to IE4, some IE5 (larger motor)	IE4 to IE5	IE5+ and above	Up to IE5	Typically, between IE3-IE5
Speed range above FWP	Up to 2 x nominal speed	1.4 x nominal speed or more	3600 RPM top speed	Up to 1.5 - 2 x nomi-nal speed	Up to 1.2 x nominal speed	Limited to base speed range
DOL/VSD	DOL and VSD	VSD, special control SW needed	Requires special drive control	VSD, special control SW needed	VSD, special control SW needed	Built-in VSD for speed control is required
Frame size versus IE2 induction	IE3 and IE4 larger frames typically	Same or smaller, larger for IE5	Same as typical NEMA frames	Same or smaller	Same or smaller	Shorter with wider diameter for application

Appendix A

Motor feature comparison table

	Induction motor	Synchronous reluctance motor	Switched reluctance motor	Ferrite assisted synchronous reluctance motor	Permanent magnet motor	Electronically commutated motors (ECMs, EC motors)
Applications	All industrial applications such as pumps, fans, compressors, conveyors, extruders, winches, cranes	Most industrial applications including pumps, fans, compressors, conveyors, extruders	Most industrial applications including pumps, fans, compressors, conveyors, extruders	Ideal for applications with highest efficiency demands	Most industrial applications where high efficiency is important	Pumps, fans
Advantage	• Well-known, robust and proven technology • Simple and easy to maintain	• High efficiency • Simple & reliable • Good power density • Cool motor, lower temperature bearing/windings • Longer bearing lifetime • No rotor-cage • Magnet-free • Can be controlled without encoders • Cost-efficient	• High efficiency • Simple & reliable • Good power density • Cool motor • Lower bearing temperature and longer life • Magnet-free	• Highest efficiency • High power factor • Low current draw • Ferrites are more cost-efficient than rare-earth magnets • High power density • Cool motor, lower temperature bearing/windings • Longer bearing lifetime • Cost effective	• Significant energy saving potential • Permanent magnets reduce rotor losses and increase motor efficiency • Compact motor • Low noise levels • Low bearing temperature	• One package with everything integrated • Quick to install with only power and reference or Modbus connection required • EMC compliant installation
Disadvantage	• Difficult to reach highest efficiency levels • Higher bearing & winding temperature compared to others	• Lower power factor • Higher current demand • May required larger drive size	• Very low power factor and high current draw • Very high noise • Torque ripple above base speed • Requires a special drive to control	• Generates low level voltage on the terminals without locked shaft • Requires shaft lockout to perform maintenance • Requires shaft ground for bearing currents	• Expensive rare-earth PM materials • Generates dangerous voltage on the terminals due to airflow duct • Requires shaft lockout to perform maintenance	• No application functionality • Limited low voltage dip performance • High harmonics • (= no choke VSD) • Not stocked, longer delivery times • Modbus RTU support only
Maintenance	• Easy • No magnetic forces • Test run can be done direct-on-line • Universally available from anywhere	• Easy • No magnetic forces • Test run requires a drive	• Average • Simple motor design and reliable • Complex drive not easy to service	• Easy • Low magnetic forces • Embedded magnets, magnet damage risk during rotor removal eliminated • Test run requires a drive	• Difficult • Strong magnetic forces • Removing rotor from the stator is difficult and requires special tools • Potential magnet damage in case of surface mounted magnets • Test run requires a drive	• Replace everything at once if any sub-component, such as bearings, semiconductors, capacitors, motor insulation, etc., fails • Not stocked widely, longer lead times

References

(1) Ibid., p. 35. 1. Overview on Energy Saving Opportunities in Electric Driven Systems Part 1: System Efficiency Improvement; Ferreira and Almeida; 2016-ESC-0071; IEEE 2016

(2) U.S. Industrial Motor Systems Energy Efficinecy Reports (2017)

(3) IEA WEO 2016

(4) Omdia 2020 Low Voltage motor report

(5) United States Industrial Electric Motor Systems Market Opportunities Assessment (energy.gov)

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ABB Motors and Mechanical Inc.
5711 R.S. Boreham, Jr. Street
Fort Smith, AR 72901
Ph: 1.479.646.4711

new.abb.com/motors-generators

9AKK108386 08.2021