WHITE PAPER

Small IPM Gearmotors: Not for Everyone, Ideal for Many

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Introduction

The design and characteristics of internal permanent magnet (IPM) electric motors have been covered extensively in engineering literature over the past several years. The primary focus, however, has been on the energy efficiency gains that can be achieved in electric vehicle traction motors, and larger stationary motor applications using this more robust motor topology. **Design engineers charged with specifying small motors and gearmotors are left wondering whether it makes sense for them to consider an IPM solution for their application.**

To start, it should be noted that an IPM motor or gearmotor requires a drive to operate. For that reason, IPM is a more likely candidate to replace AC induction motors operating with VFDs, Brushless DC motors, or Brush DC motors operating with a speed control. On the contrary, IPM is not likely to be a good alternative to a fixed speed AC induction or Brush DC unit. Depending on what needs to be accomplished in its application, an IPM gearmotor could be an enhanced alternative.

Therefore, the analysis that follows is targeted to engineers specifying brush or brushless DC, AC induction motors and gearmotors in the range of 1/8 to 3 horsepower, and in applications which are speed or torque controlled.

Is Increased Energy Efficiency Worth it in Small Motors?

Historically, small motor specifiers were more concerned with low motor cost than with high efficiency. That began to change a couple of years ago with the U.S. Department of Energy enacting both the Small Motor Rule and the Amended Integral HP Rule. The former required certain motors in the ¼ through 3 horsepower range to meet new minimum energy efficiency requirements. The latter required motors in the 1-500 horsepower range to meet the premium efficiency requirements set in NEMA MG 1, Table 12-12 while also covering a wider range of motor types than the Small Motor Rule. These changes came after many years of pushback from the motor industry itself. It is coincidental that during the same period many OEMs were expressing strong interest in increased efficiency for the small motors they used. This peak in interest was most often driven by their end customers' desire to reduce operating costs.

Efficiency Comparison

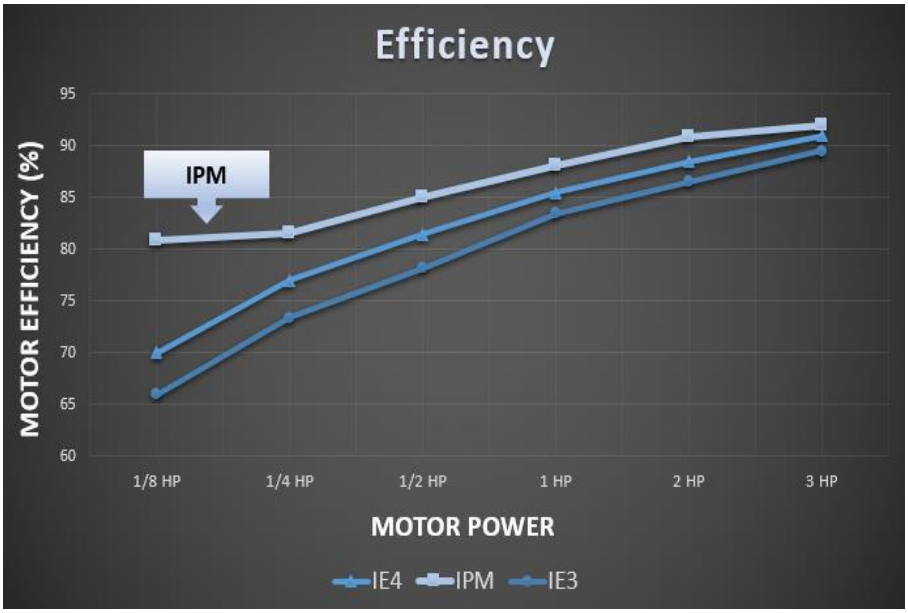


Figure 1: Motor Efficiency Comparison

The previously mentioned National Electrical Manufacturers Association (NEMA) efficiency levels are for use in the U.S. The International Electrotechnical Commission (IEC) has also developed standards which are comparable to the NEMA efficiency ratings. In the examples above IE3 meets NEMA Premium efficiency standards, while IE4 meets NEMA Super Premium Efficiency standards. IE3 is the currently mandated efficiency level for 3 Phase Induction motors of 1 HP and up. IE4 is a higher efficiency level designated by IEC but is yet to be regulated. IPM motors can reach efficiencies that surpasses IE4 ensuring reduced electrical consumption compared to IE4 and IE3 requirements (Figure 1.)

To meet these high efficiency levels, IPM motor design significantly reduces both secondary and primary copper losses by utilizing magnets embedded in the rotor. Since no electricity flows through the rotor, there is no secondary copper loss (Figure 2.)

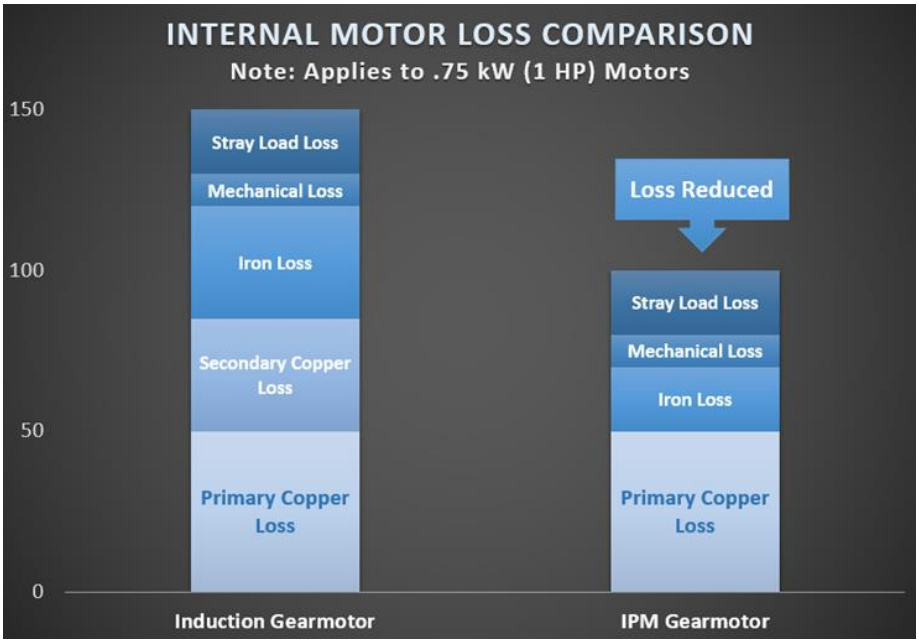


Figure 2: Internal Motor Loss Comparison

Since the magnetic flux that turns the motor is generated by permanent magnets, it's electrical consumption is reduced. Additionally, the IPM driver optimizes efficiency further by reducing current to the minimum required for the load applied. This is an important improvement over the standard squirrel cage induction motor, whose efficiency decreases as speed and/or load is reduced.

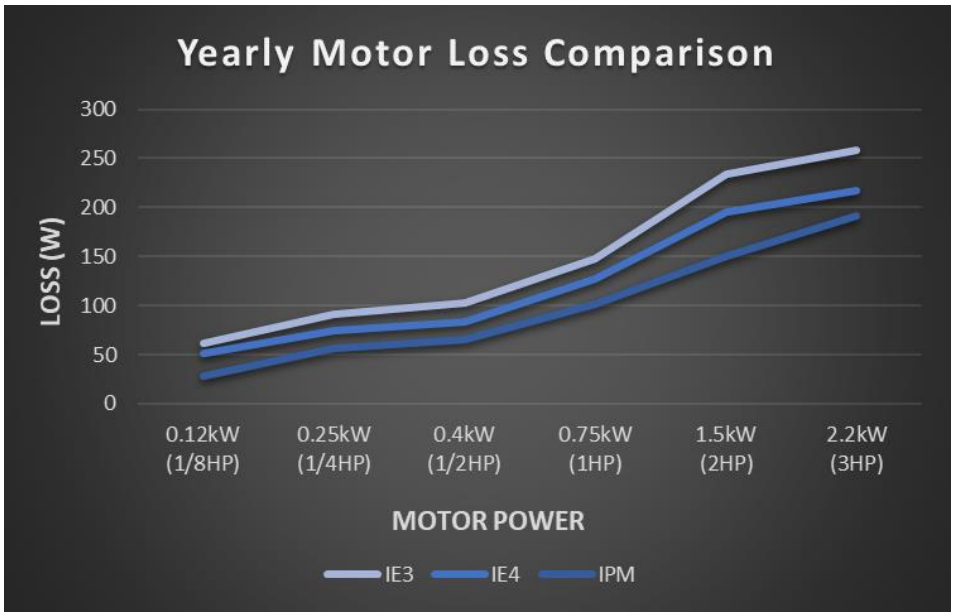


Figure 3: Yearly Motor Loss Comparison

It should be noted that while the motor used in an IPM gearmotor may operate at the NEMA Super Premium Efficiency (IE4) level, one must take into consideration the drive as well as gearing losses in assessing the overall system efficiency.

Therefore, it is equally important that the IPM gearmotor utilizes high efficiency gearing, such as a helical parallel shaft or hypoid right angle gearing with a properly matched drive, for optimum efficiency.

Achieving Green Initiatives and lower Total cost of ownership

Days per Year: **260**	Hours per Year: **4160**	Average Electricity Cost: **$0.1041**
Operation Hours per Day: **16**		C02 Emissions: **0.5542** (kg of CO_2 / kWh)
Gearmotor Units: **50**		

Green Initiatives

OEMs are also becoming aware that more of their customers are adopting initiatives to reduce greenhouse gases. IPM gearmotors' high efficiency operation reduces overall electrical consumption and can be major contributors to achieving those customers' green initiative goals.

When run 4160 hours per year, IPM motors can reduce electricity consumption by approximately 76-349 kwh per unit for 1/8 to 3 HP motors when compared to motors running at IE3 and IE4 efficiencies. When looking at the factory above with 50 units, 3800-17450 kWh would be spent on electricity per year (Figure 4.)

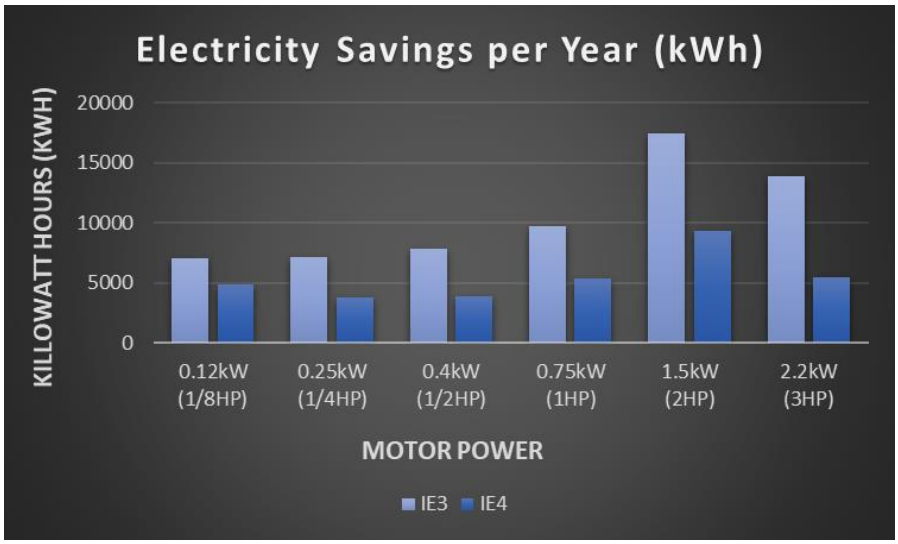


Figure 4: Electricity Savings per Year (kWh)

This reduction in electricity directly decreases the generation of CO_2 into the environment. As illustrated in the example, an industrial installation deploying 50 IPM gearmotors can reduce CO_2 emissions by approximately 9.6 metric tons per year over typical IE3 AC induction motors, and about 5.1 metric tons per year compared to IE4 efficiency gearmotors (Figure 5.)

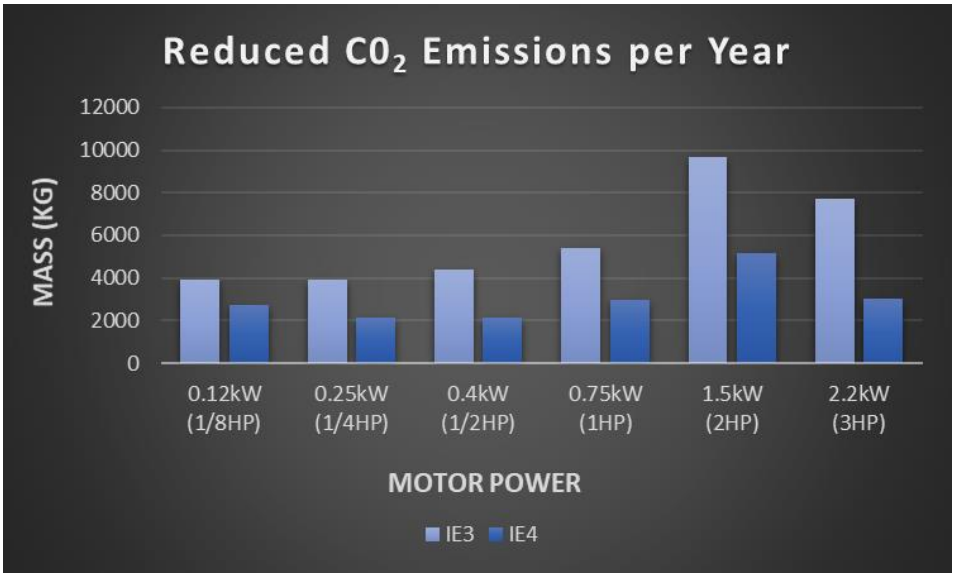


Figure 5: Reduced C02 Emissions per Year

Note on Shipping-C02 Production:

It's important to remember that reduced weight and length have a substantial effect on the amount of CO_2 produced when transporting motors from manufacturers of motors to OEMs. IPM motors can be can be up to 1/3 lighter and shorter as shown in Figures 6 & 7.

Figure 6: Weight Comparison

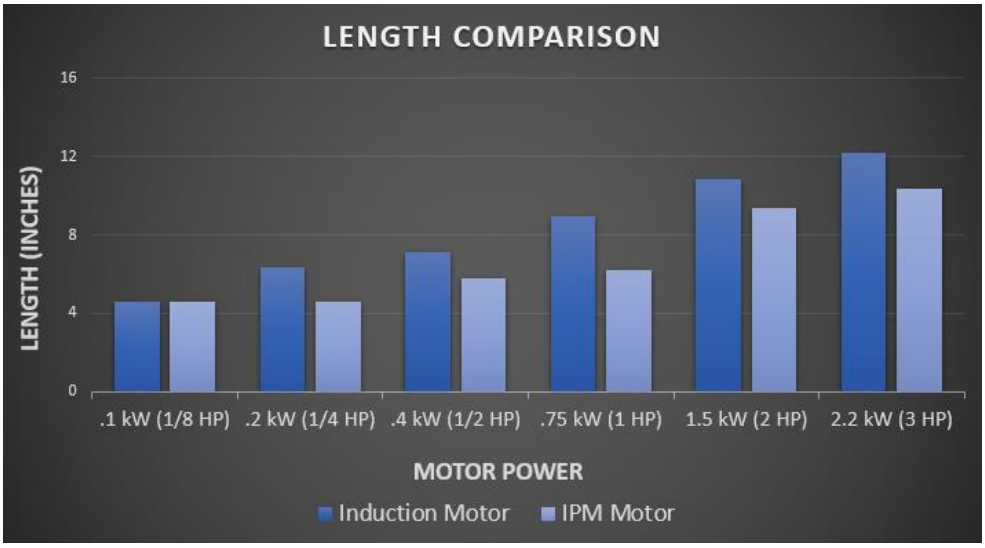


Figure 7: Length Comparison

When it comes to reduced emissions, a decrease in weight significantly reduces fuel consumption per trip, resulting in a decrease in CO_2 production. Additionally, smaller motor designs can allow for more optimal packaging, decreasing the footprint of each motor during transportation. The decrease in size results in fewer trips since more product can be shipped at once compared to Induction Motors.

Total Cost of Ownership

IPM motors are typically more expensive than comparable IE3 AC Induction gearmotors, making their initial cost higher. However, due to the efficiency advantage that IPM gearmotors have over IE3 and IE4 gearmotors, the long term total cost of ownership will be reduced for end users.

Using the same numbers as the above example, up to $1,800 can be saved on electricity per year when operating 50 units (Figure 8.) These electricity cost savings can then be carried through the life of the motor to achieve a reduced total cost of ownership. When looking at the New England territory, where electricity costs average $0.17 per kWh, savings can reach up to $3,000 per year. It becomes obvious why customers today are choosing OEM suppliers who offer equipment that can provide reduced operating costs.

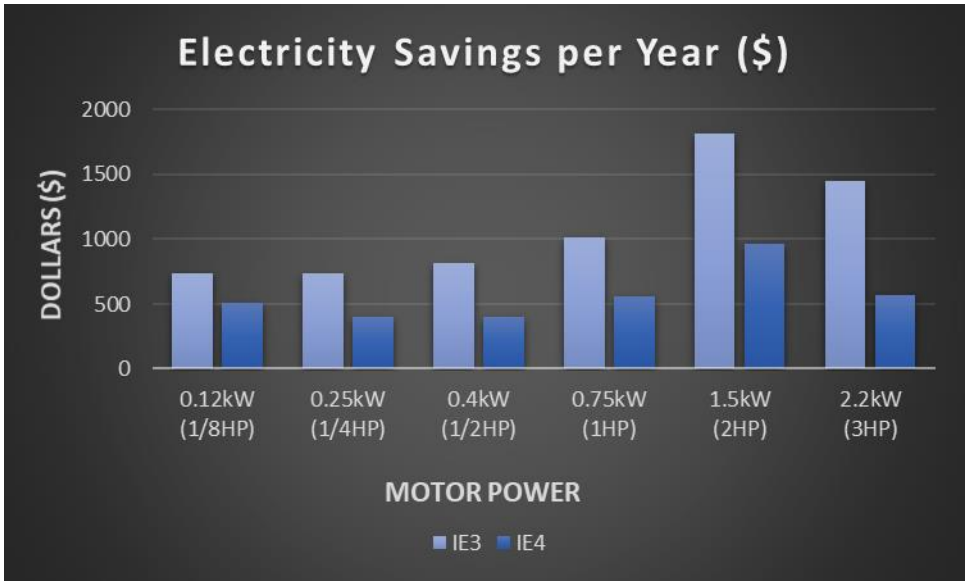


Figure 8: Electricity Savings per Year ($)

Note on Shipping-Costs:

Both weight and box dimensions directly affect the cost of shipping multiple motors to an OEM. The reduced size of IPM motors' packaging helps OEMs reduce overall shipping costs due to size efficiency when compared to AC Induction motors. The 30% lighter weight of the IPM motors also reduce costs since the per pound shipping cost will be lowered by the same percentage. This can result in vast savings depending on the method of shipment.

Other benefits of IPM...

Although its high efficiency is one of its more known attributes, the IPM motor and gearmotor offer other unique features and benefits the design engineer should consider.

Synchronous Speed

With magnets embedded in its rotor, an IPM motor rotates in synchronization with the revolving magnetic field. AC induction motors, however, require slip of up to 5% to induce rotor currents. Therefore, the AC induction motor will reduce speed as load increases, while a synchronous IPM motor will operate at the speed set by its drive under varying load conditions. Therefore, the IPM motor's synchronous operation is particularly beneficial in conveying and similar applications where loads vary.

Constant Torque

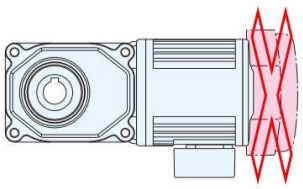
In addition, the IPM motor produces not only high starting torque capability, but also high continuous torque over virtually its entire speed range. This contrasts with the AC induction motor, which experiences a significant decrease in available torque at lower speeds.

Sensorless Speed Regulation

The IPM motor provides synchronous operation without the need for an encoder or other feedback device that would be required by a brushless DC motor. This also simplifies installation, reduces cost, and is a more robust solution.

Decreased Heat Generation, Size and Noise

In addition, the more efficient IPM designs can run up to 30% cooler than competing induction designs. This allows motors to be operated without a cooling fan which will reduce the overall length of the motor. The elimination of a fan can also significantly contribute to a reduction in ambient noise, which is another growing concern.



Quiet & Compact

Increased cleanliness

IPM designs can offer greater levels of convenience, especially when cleaning standard and high ingress protection motors, such as IP65, where the motor is exposed to dust, dripping liquids and even jet sprays. Since there is no fan, fan cover, encoder or encoder cables to be in the way, the motor stays cleaner longer since there are less areas in which dirt can be harbored. The cleaning process is also much simpler and easier due to the lack of extra components and crevices.

Future-Proofing Your Design and the Future of IPM Gearmotors

Predicting the future, particularly when government regulations are involved, can be problematic at best. However, it's likely that large motors will see another push toward regulation of higher efficiencies, and based on past experience, small motors will likely fall somewhere behind. From a design engineer's standpoint, all one needs to do is look at the macro trends driving customers' purchasing decisions.

The same thought behind the saying, "you can never be too rich or too thin" can be applied to motors and gearmotors in that "you can never be too efficient or too torque dense".

IPM gearmotors, like IPM motors themselves, are relatively new in terms of their widespread adoption in industry, and command a modest premium in line with their features and benefits.

Although they're up and coming, IPM's overwhelming advantages over AC Induction motors, DC motors, and gearmotors used with variable speed drives, in conjunction with continued OEM customer demand to reduce operating costs, will lead to significant growth in the motor topology market share.

As in most instances, as volumes go up costs go down. This is especially true for IPM motors, which typically use over 20% less steel and copper than comparable AC induction motors, with the magnet cost representing only about 10% of the total motor cost. Theoretically, IPM is a less expensive motor topology than AC induction. As for the electronic drives used with IPM motors, one only needs to look at how costs for electronics go down as features and performance go up.

If your design requirements call for fixed speed, and energy efficiency is of little concern, then IPM gearmotors are probably not for you. Otherwise, internal permanent magnet gearmotors are worthy of your consideration.

Brother Gearmotors – Maximizing Performance and Increasing Efficiency

Brother Gearmotors offers a family of gearmotors that increase operational efficiencies and reduce maintenance needs and downtime. Besides being highly efficient, its hypoid bevel gearmotors are compact in size and sealed for life. They are also permanently sealed with an electrostatic coating for a high-quality finish that assures consistently tough, water-tight, chemically-resistant units able to withstand harsh conditions. These gearmotors also have multiple standard specifications, options, and mounting positions to ensure compatibility.

Brother Gearmotors offers premium efficiency units for long-term energy savings. They are light, reliable and compact in size, offer high torque at low speed, and are sealed for life for maximum efficiency and reduced labor.

About the Author

As Motion Mechatronics' Principal Consultant, John Morehead brings 20+ years of motors and motion executive management experience, having held positions of Vice President, Sales & Marketing; Vice President, Strategic Planning & Marketing; Vice President, Business Development and National Sales Manager with leading companies in the industry. John acts as a consultant for Brother International Corporation's Gearmotor Division.

John has built a track record producing exceptional growth in the gearmotor, power transmission and motion control industry by building winning sales teams and marketing plans to achieve goals through strategic initiatives. He has been directly responsible for several successful new product introductions as well as building valuable strategic alliances as the basis for product line expansions and sales growth.