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Where internal permanent MAGNET GEARMOTORS *make sense*

Use of internal permanent magnet (IPM) electric motors abounds in electric vehicle traction motors and large stationary motor applications needing efficiency. As we'll explore, the motors work in more compact designs as well.

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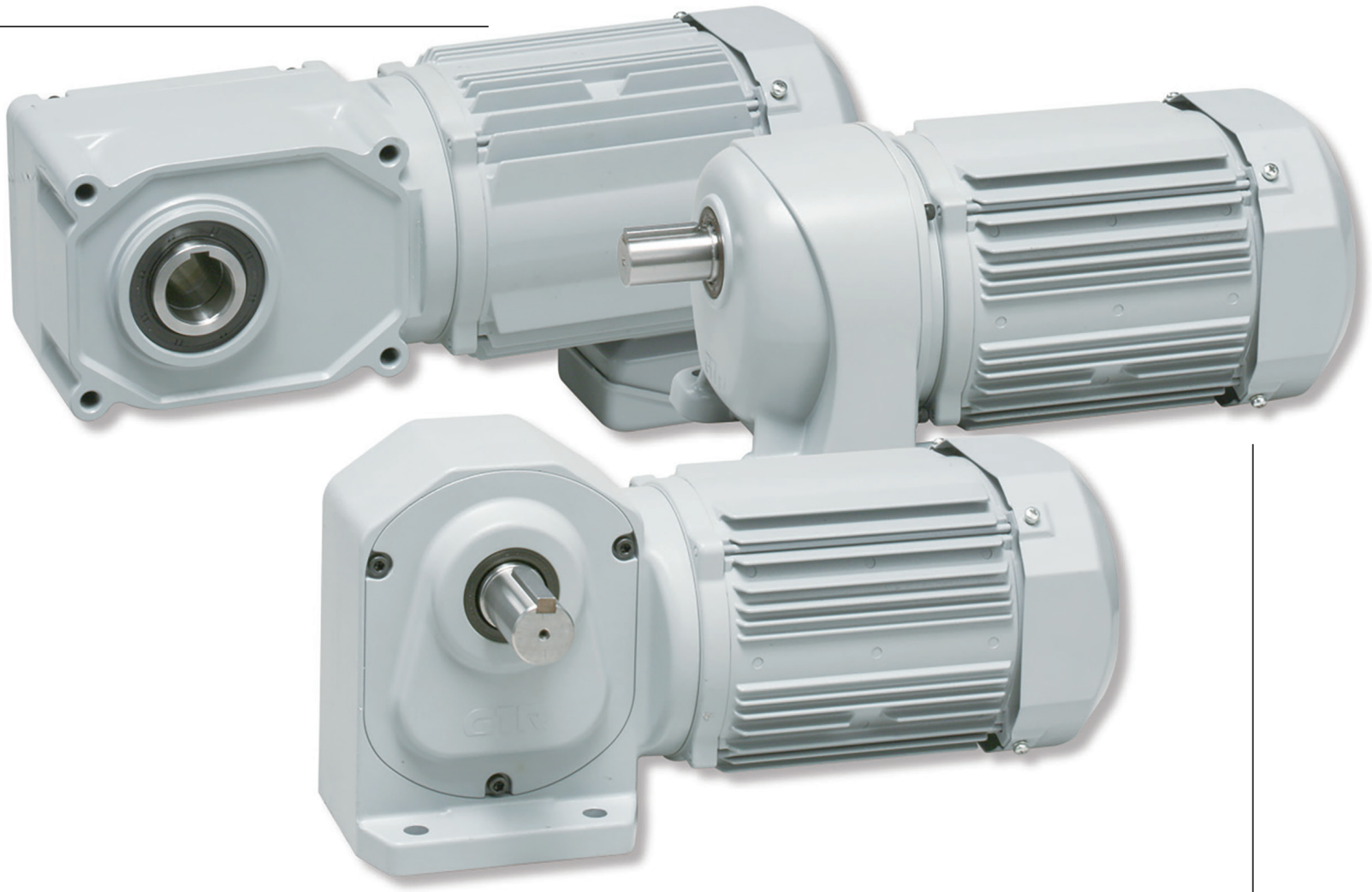
Brother Gearmotors of Brother International Corp.

IPM motors need a drive to operate, so aren't suitable alternatives to induction and brush motors used in fixed-speed designs. But it often makes sense to specify IPM motors in small motor and gearmotor applications — to replace ac induction motors (operating with VFDs) or brushless and brush dc motors under speed control.

Let's look at how IPM motors work in designs typically run on 1/8 to 3-hp brush motors, brushless dc motors, ac induction motors, and gearmotors under speed or torque controlled.

Justifying high efficiency in small motors

In the past, small-motor specifiers were primarily concerned with low motor cost. But a couple years ago, the U.S. Department of Energy Small Motor Rule (and Amended Integral HP Rule) spurred new interest in small-motor efficiency. The former required certain motors in the ¼ to 3-hp range to meet new energy-efficiency requirements. The latter required motors in the 1-to-500-hp range to meet premium-

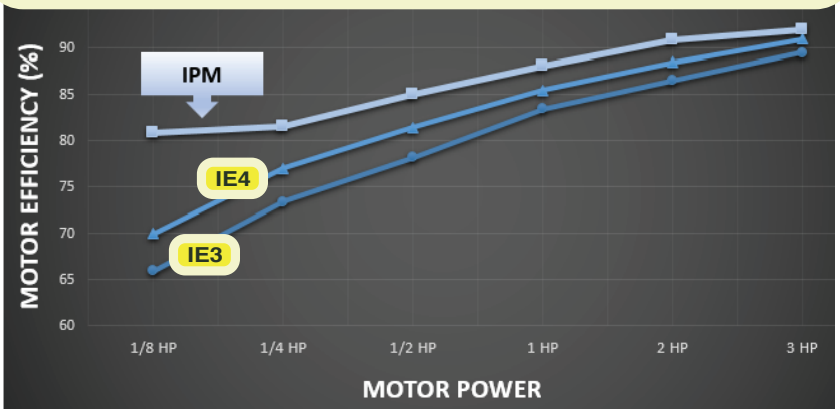


efficiency requirements set in the National Electrical Manufacturers Association (NEMA) MG 1, Table 12-12 … while also covering more motor types than the Small Motor Rule. The changes came after years of pushback from the motor industry itself — concurrent with new OEMs interest in efficiency for the small motors in their machine builds (to satisfy end users' aim to reduce operating costs).

Of course, NEMA ratings are for the U.S., and there are International Electrotechnical Commission (IEC) standards comparable to NEMA ratings. Case in point: IE3 meets NEMA Premium efficiency standards, while IE4 meets NEMA Super Premium Efficiency standards. IE3 is currently mandated for three-phase induction motors of 1 hp and larger. IE4 is a higher IEC standard but yet to be regulated.

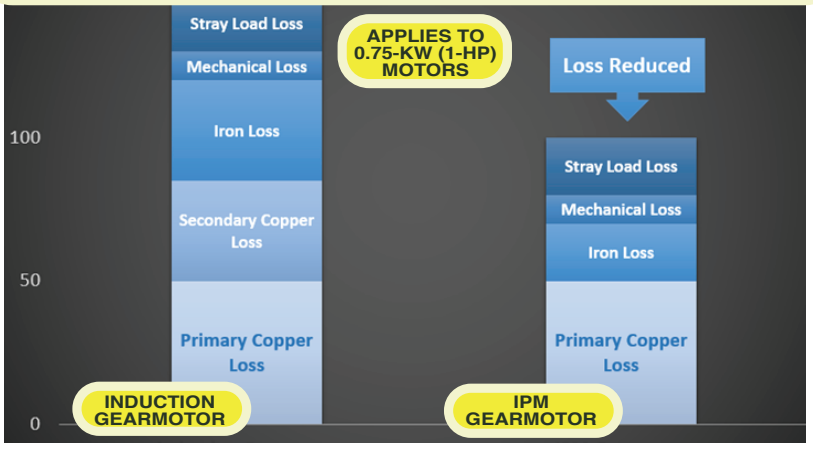
***Brother Gearmotors IPM offerings** boost operational efficiencies and reduce maintenance requirements. Some include hypoid bevel gearing for compactness and long life. An electrostatic coating ensures watertight and chemically resistant motors that withstand harsh environments. The gearmotors come in an array of standard variations for easy mounting and design compatibility. Shown here are IPMax interior permanent magnet gearmotors that maintain efficiency over wide synchronous speed ranges.*

MOTOR EFFICIENCY COMPARISON



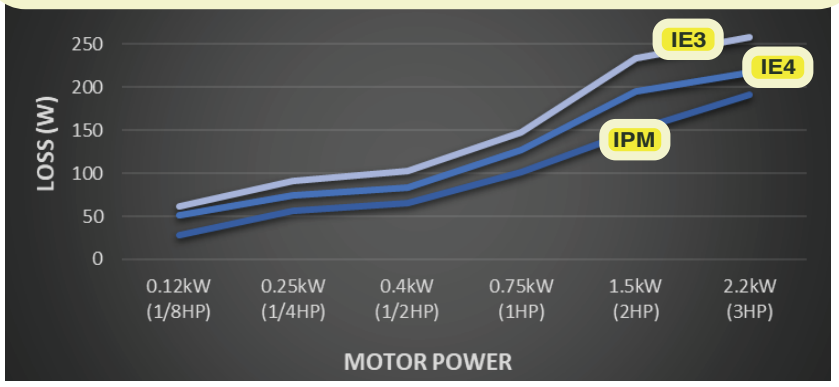
***IPM motors** can reach efficiencies that surpasses IE4 ensuring reduced electrical consumption compared to IE4 and IE3 requirements. Though IPM motors are typically more costly than comparable IE3 ac induction gearmotors, they're more efficient than IE3 and IE4 gearmotors so make for lower cost of ownership.*

INTERNAL MOTOR-LOSS COMPARISON



***Because no electricity flows** through the rotor of an IPM motor, there are no secondary copper losses.*

YEARLY MOTOR-LOSS COMPARISON



***Where designs only need fixed speed** (and energy efficiency is no concern) IPM gearmotors aren't a good fit.*

> *Because the magnetic flux that turns the motor originates from permanent magnets, electrical consumption is lower than that of other motors.*

IPM motors can reach efficiencies that surpass IE4 — for lower electrical consumption than motors meeting IE4 and IE3 requirements. IPM motors do this by having very low secondary and primary copper losses — thanks to magnets embedded in the rotor. Because no electricity flows through the rotor, there are no secondary copper losses.

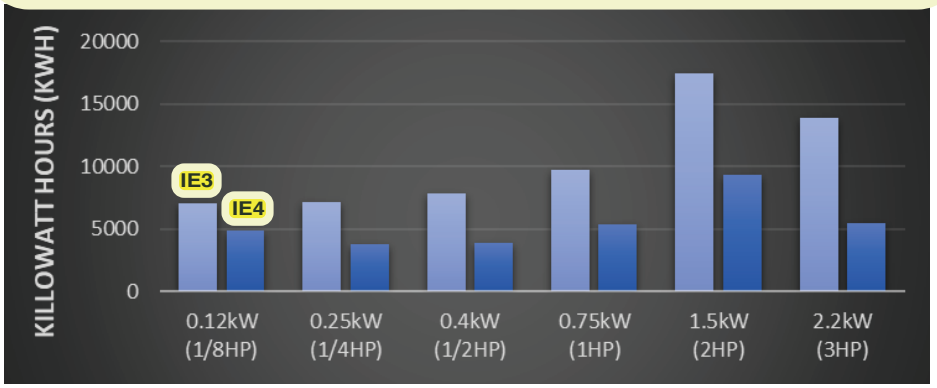
Because the magnetic flux that turns the motor originates from permanent magnets, electrical consumption is lower than that of other motors. What's more, IPM drivers often optimize efficiency by reducing current to a minimum needed for the load. That's an improvement over standard induction-motor operation, for which efficiency decreases with reduced speed or load.

Note that gearmotors with an IPM at their core may operate at NEMA Super Premium Efficiency (IE4) levels … but drive and gearing losses affect overall system efficiency. So IPM gearmotors should include efficient helical parallel-shaft or hypoid right-angle gearing (with a properly matched drive), for top efficiency.

Helping end users with green designs

OEMs today are increasingly involved with initiatives to reduce greenhouse gases. IPM gearmotors' high efficiency reduces overall electrical consumption and helps end users meet green-initiative goals.

ELECTRICITY SAVINGS PER YEAR (IN kWh)



***Our example facility** consumes 3,800 to 17,450 kWh per year. Every IPM motor in this setting (operating 4,160 hours annually) can reduce electricity consumption by up to 349 kWh compared to IE3 and IE4 motors.*

Consider this: When run 4,160 hours per year (16 hours a day) IPM motors can reduce electricity consumption by about 76 to 349 kWh (compared to IE3 and IE4 motors) for 1/8 to 3-hp variations. So a facility has 50 motor-driven axes would use 3,800 to 17,450 kWh per year. Such reduced electricity consumption decreases CO_2 generation. For an industrial installation employing 50 IPM gearmotors (and average emissions of 0.5542 kg of CO_2 per kWh) CO_2 emissions are reduced about 9.6 metric tons per year (when compared to that of IE3 ac induction motors) and 5.1 metric tons per year (compared to IE4 gearmotors).

What's more, IPM motors are compact and 30% lighter (on average) than comparable induction motors.

That allows for small and light packaging for shipment to the OEM — for lower freight costs than those associated with ac induction motors.

Other IPM motor and gearmotor benefits

Synchronous speed: With magnets embedded in its rotor, an IPM motor rotates in synchronization with the revolving magnetic field.

In contrast, ac induction motors need slip of up to 5% to induce rotor currents … so reduce speed as load increases. Synchronous IPM motors run at the speed set by the drive under varying load — for synchronous operation that's particularly helpful in conveying and similar applications.

Constant torque: IPM motors output high starting torque and high continuous torque over the entire speed range. In contrast, ac induction motors exhibit a decrease in available torque at low speeds.

Sensorless speed regulation: Internal permanent-magnet motors operate synchronously without the need for an encoder or other feedback required for brushless dc motors. simplifies installation and makes designs more robust.

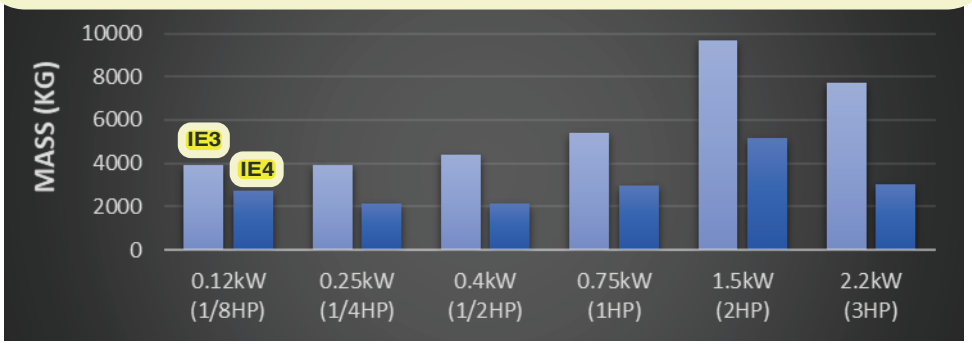
Cooler and quieter operation: Efficient IPM gearmotors and motors can run up to 30% cooler than comparable induction motors. This lets the motors run sans cooling fan — for a shorter overall length. Omission of a fan can also make the machine design quieter.

Cleanliness: IPM gearmotors and motors are easier to clean than comparable motors with standard and ingress-protected designs — as those rated to IP65, for example. IPM motors have no fans, fan covers, encoders, or encoder cables — so stay cleaner longer. When cleaning is required, the motors' streamlined design also makes the process simpler.

More internal permanent-magnet motors in the future

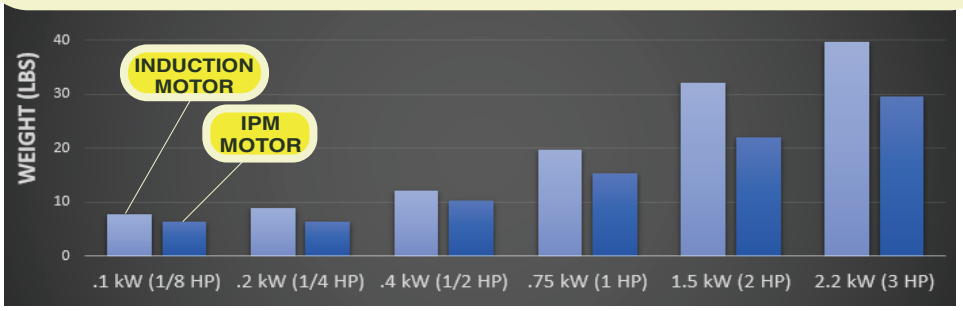
Predicting the future (particularly when government regulations are involved) can be problematic at best … but coming years will likely bring more regulation to get still-higher efficiencies from large motors. Then small motors will likely be subject to tighter regulation as well. Design engineers may observe macro trends driving motion-component purchasing to confirm: Just as "you can never be too rich or too thin" motors and gearmotors can never be too torque dense or too efficient.

REDUCED $C0_2$ EMISSIONS PER YEAR



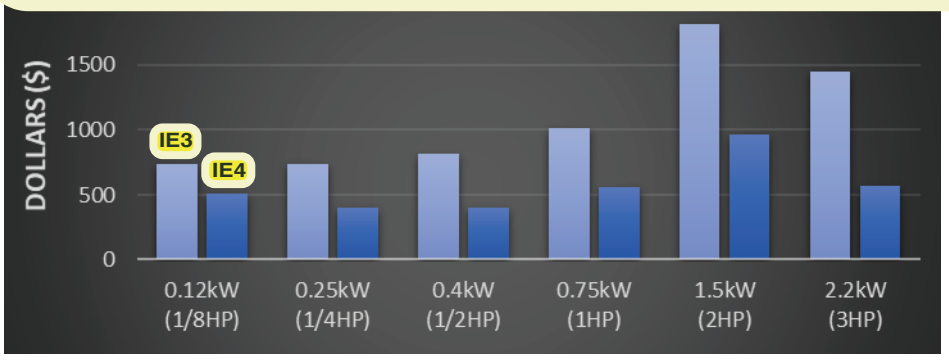
IPM gearmotors can reduce CO2 emissions by about 9.6 metric tons per year over typical IE3 induction motors — and by 5.1 metric tons per year over IE4 gearmotors.

MOTOR WEIGHT COMPARISON



Reduced weight and length have a substantial effect on the amount of CO2 produced when transporting motors from the motor manufacturer to the OEM. IPM motors can be up to one third lighter and shorter than competitive designs.

ELECTRICITY SAVINGS PER YEAR (IN DOLLARS)



Assuming 260 operating days a year and an average electricity cost of $0.1041 per kWh, 50-motor installations that switch to IPM motors can save about $1,800 on electricity annually. In New England (where electricity costs average $0.17 per kWh) savings can reach $3,000.

It often makes sense to specify IPM motors in small motor and gearmotor applications — to replace ac induction motors (operating with VFDs) or brushless and brush dc motors under speed control.

IPM gearmotors and motors are relatively new to industry, so not widespread … though worth the price premium for their features and benefits.

IPM advantages over more traditional motors paired with variable speed drives (and OEM demand for reduced operating costs) will bring increased use of IPM motors. This increased volume will in turn spur lower costs … especially considering how IPM motors include 20% less steel and copper than comparable ac induction motors (with the magnet cost only about 10% of total motor cost). That means IPM motors (and the electronic drives to go with them) could ultimately become a less expensive alternative to ac induction motors … in terms of both operating and upfront costs. DW

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