PRODUCT APPLICATION

A technical bulletin for engineers, contractors and students in the air movement and control industry

Understanding Motor Selection for Fans and Blowers to Minimize Energy, Maximize Controllability, and Minimize Replacement Downtime

Selecting and applying motors can be complex, especially when energy efficiency, controllability, and reduced maintenance are priorities. This paper outlines key considerations for successful motor applications, including new motor technology and the differences between international motor standards versus traditional standards that are familiar in North American markets.

NEMA and IEC Motors

Driven by the interest to reduce motor energy consumption, NEMA motor efficiency designations (traditionally used in the United States) now have competition from European motor efficiency designations (such as IEC standards). Each is based on its classification systems, efficiency levels, and regulatory frameworks. The following are the key distinctions:

National Electrical Manufacturers Association (NEMA) motor efficiency designations are typically based on Energy Efficiency Classes for motors. These are defined under NEMA MG 1 and are aligned with Institute of Electrical Engineers (IEE) standards. The NEMA Class designations include Standard Efficiency (SE), High Efficiency (HE), Premium Efficiency (PE), and Super Premium (SP) motors. For example, motors may be rated as NEMA Premium Efficiency (PE) which corresponds to a high level of energy savings.

International Electrotechnical Commission (IEC) European motor efficiency designations are based on the standard IEC 60034-30-2 standard and specify the motor efficiency classification through a series of International Efficiency (IE) classes. The IEC class designations include Standard Efficiency (IE1), High Efficiency (IE2), Premium Efficiency (IE3), Super Premium Efficiency (IE4), and Ultra-Premium Efficiency (IE5).

Summary of Comparison

Criteria	NEMA (U.S.)	IEC (Europe)
Efficiency Classifications	SE, HE, PE, SE	IE1, IE2, IE3, IE4
Efficiency Levels	Standard (NEMA SE), High Efficiency (NEMA HE), Premium Efficiency (NEMA PE), Super Premium (NEMA SP)	Standard (IE1), High (IE2), Premium (IE3), Super Premium (IE4), Ultra-Premium (IE5)
Regulatory Framework	Based on DOE and state-level regulations	Enforced by Ecodesign Directive and EU regulations
Testing Conditions	Primarily full-load conditions	Full load, no-load, and other standardized lab conditions
Global Use	Primarily in North America	Used globally, particularly in Europe and other regions

The designations are specific to the efficiency levels that motors can achieve at full load under certain operating conditions such as voltage, load, and frequency. Comparing efficiency levels between NEMA and IEC-designated motors can be a bit of a challenge.

NEMA Premium Efficiency corresponds roughly to IE3 in the IEC system. This is the highest standard of efficiency for motors in the NEMA system, with well-defined efficiency percentages at rated load conditions. NEMA also has different efficiency levels for different frame sizes and motor designs, and these can vary depending on the motor's application and power rating.

IEC Efficiency designation IE3 is considered Premium Efficiency under the IEC classification and is similar to NEMA's Premium Efficiency. IE4 is considered Super but the IEC includes higher levels: IE4 (Super Premium Efficiency) and IE5 (Ultra-Premium Efficiency).

NEMA sets voluntary guidelines and efficiency standards, but some states and countries may require compliance with these standards as part of local energy-efficiency programs. NEMA's standards are often harmonized with U.S. federal regulations and energy standards set by organizations such as the U.S. Department of Energy (DOE).

In the European Union, motors must meet IE2 efficiency standards as a minimum for new motors sold, with regulations driving further efficiency improvements (IE3 and IE4). The Ecodesign Directive in the EU enforces energy efficiency requirements, and in many cases, motors need to meet IE3 or higher standards to be legally sold in the market.

In summary, the key difference in efficiency classification lies in the terminology and regulatory context, with NEMA being more regionally specific (North America) and focusing on practical operational conditions, while IEC's classifications (used in Europe and globally) are broader in scope, with stricter efficiency standards for certain motor types and applications.

Efficiency comparison designations between NEMA and IEC motor types

Motor Type	Efficiency Designation	
	NEMA*	IEC
Shaded Pole	SE	IE1
PSC	SE	IE1
Split Phase	SE	IE1
Capacitor Start	SE	IE1
Three Phase Induction	PE	IE3
SynRM - Synchronous Reluctance	SP	IE4
EC - Electronically Commutated	SP	IE4 - IE5
FASR - Ferrite-Assisted Sync Reluctance	SP**	IE5+
*SE = Standard Efficiency	*PE = Premium Efficiency	
*SP = Super Premium	**with Variable Frequency Drive	

A regional practical consideration to note in the case of motor replacement and availability is that NEMA motor frame sizes and IEC European frame sizes are **not directly** interchangeable (which can be a maintenance replacement headache). This is due to differences in the way the dimensions are defined and standardized. While both standard systems provide a set of frame sizes for electric motors, the specific dimensions, tolerances, and mounting configurations can vary significantly. Here's a breakdown of the key differences:

NEMA Frame Sizes: NEMA frame sizes are based on the diameter of the motor’s shaft centerline and the distance from the shaft centerline to the mounting surface (flange or foot), which determines the motor's overall dimensions. For instance, a NEMA frame size 184T indicates the motor has a shaft height of 1.84 inches.

European Frame Sizes (IEC): European frame sizes, as specified by the International Electrotechnical Commission (IEC), use a metric-based system. The IEC system is more standardized globally and often includes frame size designations such as IEC 71, IEC 80, or IEC 112. IEC frame sizes typically follow the convention of the motor's shaft height in millimeters (e.g., an IEC frame size of 80 would indicate a shaft height of 80 mm).

Be aware of the following dimensional differences between NEMA and IEC motors.

NEMA frame sizes often use inches for specifying the dimensions, and these measurements typically describe the motor's mounting characteristics and shaft center. IEC (European) frame sizes use millimeters and generally provide more precise tolerances and mounting information.

Mounting holes (such as the bolt-hole pattern for mounting the motor) are different between the NEMA and IEC systems, which means a motor's mounting flange dimensions are not interchangeable without adapters.

In NEMA, a larger frame size often corresponds to a higher horsepower rating for the motor. In the IEC system, the frame size is correlated with the motor's shaft height and is also linked to certain power outputs, but the size ranges and motor ratings can differ between the two systems.

NEMA motors typically feature mounting systems where the feet or flange are designed for imperial measurement standards, and they have a consistent bolt pattern based on the motor’s frame size. IEC motors have mounting patterns based on metric measurements, with standard hole placements for IEC frame sizes.

While the NEMA and IEC systems do provide a method for categorizing motors by size, again **they are not directly interchangeable** without significant adaptation. Motors designed in accordance with the NEMA system will not fit into IEC standard mounting systems without adjustments, and vice versa.

Electronically Commutated Motors (ECM)

Electronically Commutated Motors (ECM) can comply with NEMA standards under certain conditions, but they are generally designed with different characteristics and technologies compared to traditional AC induction motors that are typically covered by NEMA standards.

NEMA standards, particularly NEMA MG 1, apply to most types of AC induction motors (such as squirrel-cage motors) and some types of DC motors. These standards focus on the motor's construction, performance, efficiency, and safety.

NEMA's motor standards primarily address motors with mechanical commutation (such as induction motors) and do not explicitly define ECMs, since ECMs are built using brushless DC motors (BLDC) with an integrated electronic controller to convert AC current to DC current and manage their operation.

ECMs are commonly used for energy-efficient applications, especially in HVAC systems, fans, blowers, and pumps, and the primary difference is that ECMs use an electronic controller that regulates the motor speed, torque, and other operational parameters, typically through inverter technology and permanent magnets. This gives them a higher efficiency and the ability to provide variable speed control compared to traditional AC motors.

In contrast, NEMA standards primarily focus on AC induction motors and their performance under specific load conditions, including power ratings, efficiency, and design types, without addressing the unique characteristics of ECMs, i.e., speed control and direct current operation.

While ECMs are not specifically covered under NEMA MG 1 (which is focused on AC motors), ECMs often comply with similar or more stringent efficiency standards. ECMs are designed for high efficiency and can be considered compliant with NEMA Premium Efficiency levels (similar to IE3 or IE4 standards used in the IEC system).

ECMs typically have performance characteristics (e.g., voltage ratings, current ratings, power ratings) that may not always align with NEMA frame sizes and motor ratings (such as horsepower or full-load speed). However, ECMs are often used in applications where motor ratings in NEMA terms (like 1/4 hp, 1 hp) are not always a strict requirement, especially since ECMs often run at variable speeds and provide different torque characteristics.

Although ECMs are not typically described under NEMA MG 1 construction standards, they must comply with safety standards such as Underwriters Laboratories (UL) or Canadian Standards Association (CSA) for electrical equipment and motor safety. In these cases, they would follow equivalent safety, testing, and construction regulations for electrical components, ensuring that they meet safety standards applicable in the U.S.

While ECMs do not directly fall under the NEMA motor classifications, they typically exceed the performance of Premium Efficiency (NEMA Premium) motors in many applications, due to their ability to vary speed based on load conditions.

For example, an ECM can adjust its speed automatically to match the load, which leads to substantial energy savings, whereas a traditional NEMA Premium motor generally runs at a constant speed regardless of load, leading to potential energy waste during part-load conditions.

While NEMA standards are primarily for motors that operate on AC power, ECMs (operating on DC power) are more closely aligned with regulations from agencies such as the U.S. Department of Energy (DOE) and Energy Star.

Addressing the Application of NEMA Motors to Meet IEC Super Premium (IE4) and Ultra-Premium (IE5) Motor Efficiencies

Premium Efficiency (PE) and (SP) NEMA motors when paired with a variable frequency drive (VFD) or integrated inverters can achieve efficiencies that meet or exceed the IEC IE4 Super Premium Efficiency and IE5 Ultra-Premium Efficiency levels, depending on the specific motor design, application, and operational conditions.

When a Premium Efficiency and a Super Premium NEMA motor is used with a VFD, the motor operates at a variable speed, which means it will not always be running at full load and will be adjusted to match the required demand. This variable-speed operation significantly reduces energy consumption, especially during partial-load conditions, which is when most traditional fixed-speed motors waste energy. Additionally, there are reduced starting losses as a VFD eliminates the inrush current typically experienced during motor start-up, which reduces energy consumption at the start of operation.

For more information on Fan Motor Applications, reference Greenheck's Motor Application Guide for Ventilation Products (FA/113-25).

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