WHITEPAPER

HVAC Energy Conservation:

A New Approach That Outperforms VFD Retrofits

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1. Intro

Technology plays a key role in HVAC optimization, and variable frequency drives (VFDs) have become an industry standard for HVAC energy efficiency since their introduction in the 1980s. They offer speed modulation, enabling facilities managers to operate HVAC motors at variable speeds, improving energy efficiency while greatly reducing energy costs.

However, in today's business landscape, facilities managers face business challenges from all directions, such as variable energy costs and regulations. The energy reductions from VFDs may help with reducing initial HVAC operating costs but are no longer the best approach available for long-term energy conservation and sustainability.

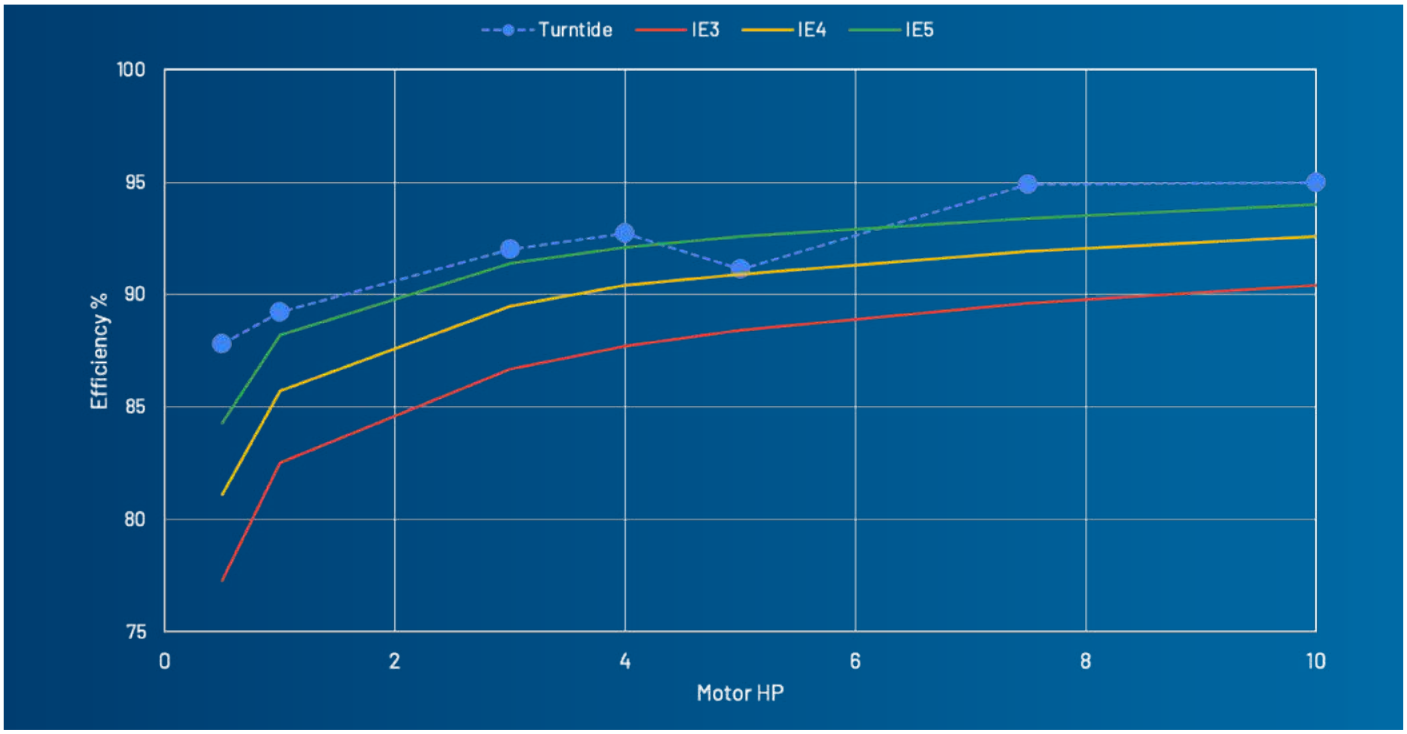
Breakthrough innovations and technologies have emerged, and facilities managers can now lead their businesses to a better foundation for long-term energy conservation and sustainability. Through advances in motor and system design, the Turntide Smart Motor System™ outclasses VFD retrofits in energy efficiency and system performance.

2. Turntide Smart Motor System

The Turntide Smart Motor System uses high-rotor pole switched reluctance motor (HR-SRM) technology, running on patented sensorless control algorithm in the Turntide motor controller. The Turntide Smart Motor System can be commissioned, controlled, and adjusted through the Turntide Technician App.

Key Benefit: Efficiency

Through years of R&D, Turntide has optimized the HR-SRM to achieve optimal torque and efficiency, while maintaining robust motor durability by reducing the effects of torque ripple, noise, and vibrations. As a result, Turntide motors can offer long-term motor operation while exceeding IEC IE5 efficiency levels across most HP ranges.



Key Benefit: Energy Savings Reporting

A key consideration of adopting energy conservation measures (ECMs) is its ability to track its own performance to report kWh and carbon savings, which can help with tracking ESG goals, reporting compliance, and qualifying for rebates and other incentives.

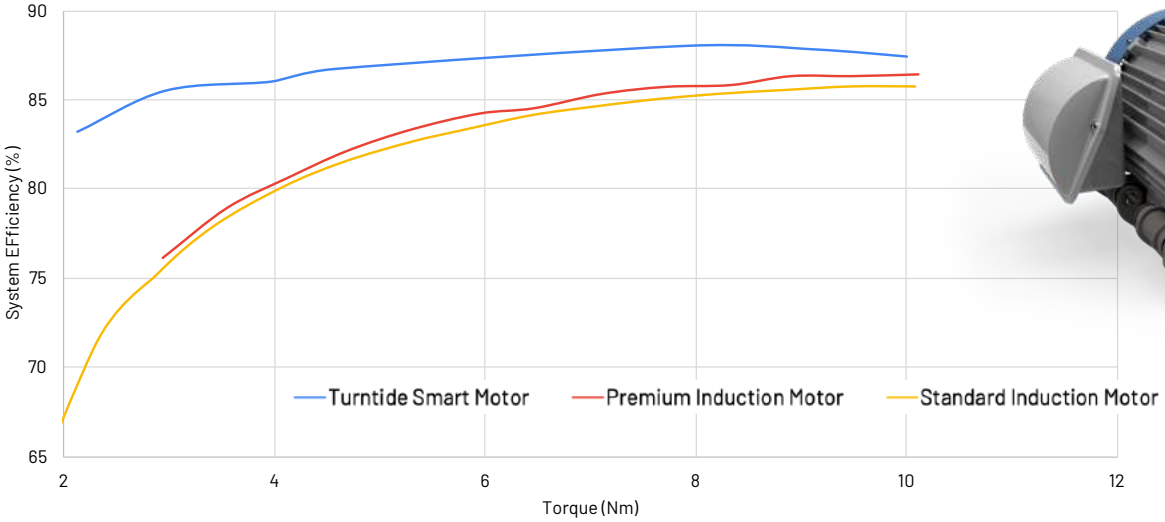
Turntide's motor system is designed with these considerations in mind, as motor performance is easily monitored and tracked. Users can view and analyze cumulative $/kWh savings and CO2 reduction attributed to retrofitting Turntide smart motors through third-party BMS platforms with Turntide's BACnet Motor Gateway.

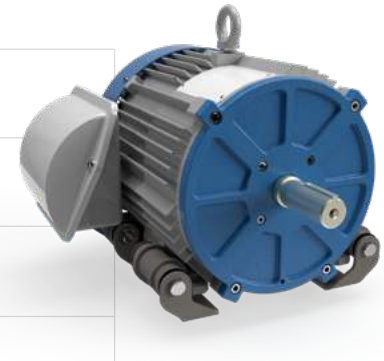
3. How Does a Turntide Smart Motor System Retrofit Compare with a VFD Retrofit?

A VFD retrofit typically involves connecting a VFD to the existing AC induction motor on the RTU. In contrast to conventional induction motors, Turntide HR-SRM motors are not capable of operation on line power, so they must be paired with a discrete power drive. A Turntide Smart Motor System retrofit will consist of a swap of the motor alongside a specially engineered motor controller. This requires more components, but a fully integrated motor system provides better overall performance through a system that has been engineered to work together.

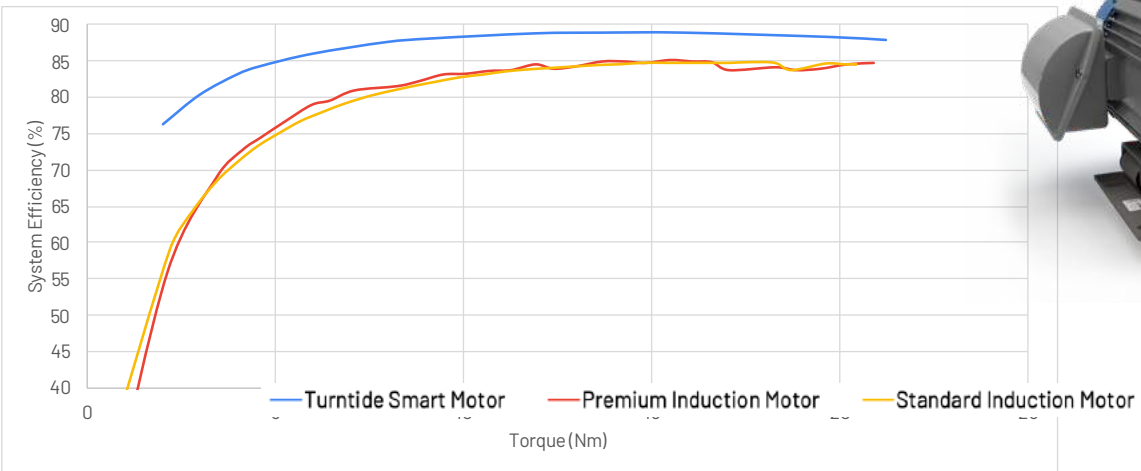
Efficiency Comparison

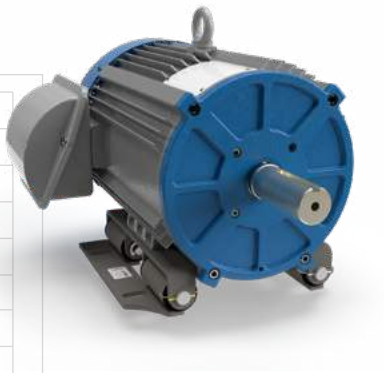
System Efficiency vs. Torque - V01 (3HP) at 1800 RPM



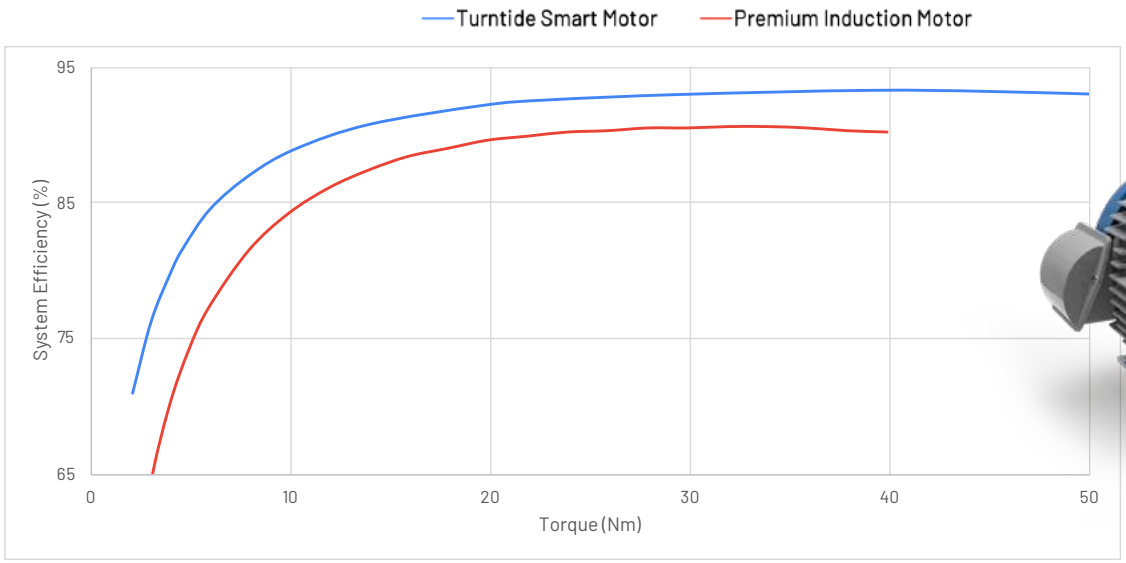


System Efficiency vs. Torque - V02 (5HP) at 1800 RPM



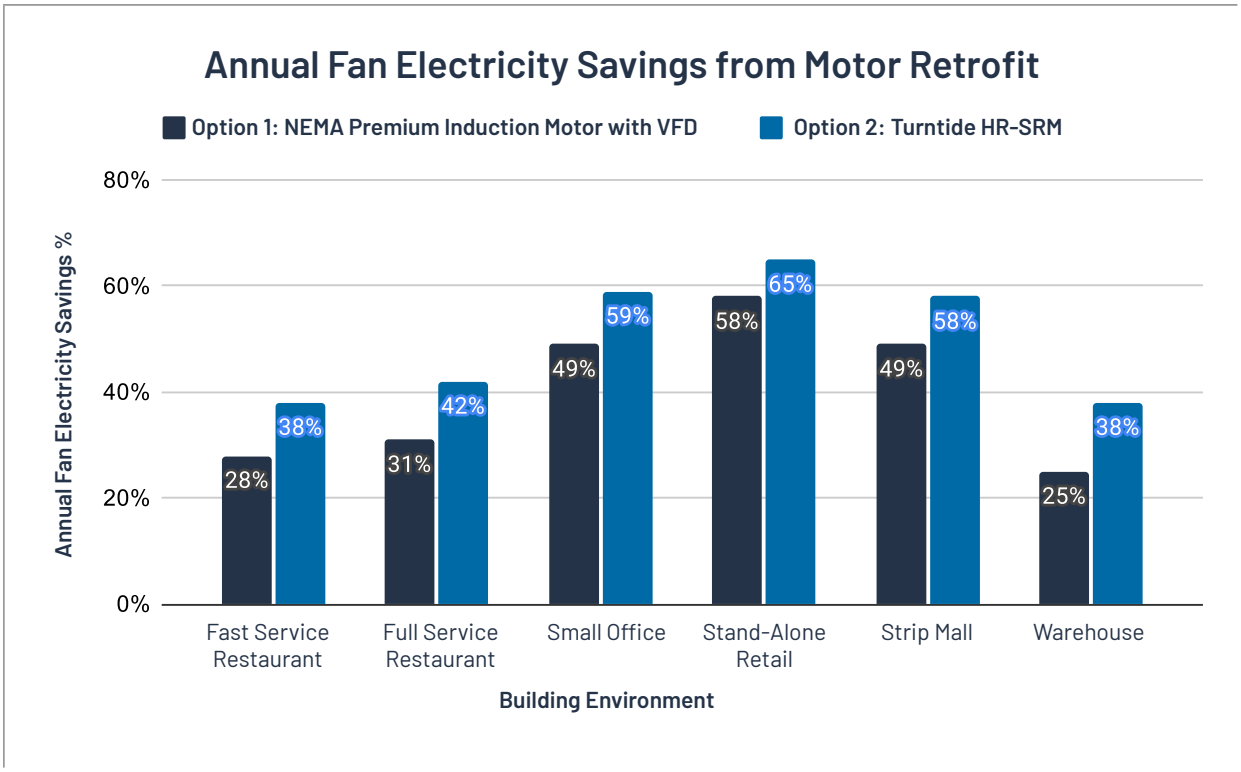


System Efficiency vs. Torque - V03 (10HP) at 1800 RPM



These graphs (generated from Turntide internal benchmarking) show how Turntide motors compare with standard and premium induction motors retrofitted with a VFD, across different HP ratings. Across lower and higher HP, the Turntide motor always runs at higher system efficiency, providing all of the benefits of a VFD retrofit at a higher performance envelope.

Turntide's internal benchmarking has been corroborated with a third-party NREL and ComEd Study from December 2020 titled "Performance Evaluation of 3 RTU Energy Efficiency Technologies". In the study, the energy savings from Turntide HR-SRM motors were directly compared with the savings from VFDs paired with NEMA premium induction motors. In every building environment tested in the study, the retrofit from Turntide motors proved to demonstrate higher levels of annual fan energy savings compared with a retrofit of a VFD on a NEMA premium induction motor. On average, the study found that Turntide motors provided 9% extra fan energy savings.



Reliability Comparison

Turntide HR-SRM (left) vs. Induction Motor (right)

Motor Design

Induction motors typically have distributed windings, which makes them susceptible to electrical shorts, leading to a higher risk of motor mechanical failure. Turntide HR-SRM motors have concentrated windings, designed with stators consisting of bobbin wound coils, which reduces the risks of winding failures found in AC induction motors.

VFDs

VFDs are in many HVAC efficiency retrofit projects. While they reduce energy consumption, they send peak voltages that can break through motor insulation and short motor windings, which in turn leads to lower product longevity. Additionally, VFDs can overheat induction motors past their thermal design limits. Some variations of induction motors (fan-cooled) are designed with a shaft mounted cooling fan to dissipate heat, but operating at reduced speeds, the fan may provide insufficient cooling airflow before the induction motor reaches its turndown ratio. Therefore, by aiming to prevent excessive temperatures that result in shortened bearing life or failure, facility managers are unable to maximize fan affinity laws to achieve optimal motor efficiency; for example, a 1740 RPM induction motor motor may only be capable of a minimum speed of ~580 RPM before risking thermal issues. In contrast, a 1740 RPM Turntide HR-SRM motor can turn down all the way to 100 RPM, without impact to bearing life.

Moreover, programming VFDs can be difficult and prone to more human error. VFDs require a great deal of precision to operate, and a high level of nuanced equipment and industry knowledge to operate correctly. VFD configuration errors often lead to motors running incorrectly below the motor's turndown ratio, which creates severe thermal management issues when the motor's stator and rotor insulation break down at temperatures operating above its thermal design limits. Without alerts or notifications, facilities managers may not realize their equipment has failed until it is too late to act.

Unlike VFDs, which can work with different motors within given operating specifications, Turntide motor controllers work exclusively with Turntide HR-SRM motors and cannot work with other motor types. Operating schedules can be adjusted on the fly, and issues can be detected through alerts so that facilities managers can take corrective action before issues become more severe. Also, through algorithms built into the Turntide motor controller, Turntide is designed for optimal operation at both lower and higher motor speeds, providing optimal efficiency and reliability across all modes of operation.

User Experience Comparison

VFD interface examples

VFDs are primarily controlled and programmed locally via a keypad on the device itself, which results in a cumbersome, complicated menu structure with limited flexibility due to the display and physical buttons. For VFD users who want connectivity, the VFD must connect to a third-party building management system, requiring complex BACnet integrations to make sure disparate systems can communicate with each other.

Turntide Technician App

The Turntide Smart Motor System is designed to allow facilities managers and installers to commission and troubleshoot Turntide motors easily with the Turntide Technician mobile app. Unlike VFDs, Turntide motors do not require a long and tedious learning curve, and Turntide provides training programs and resources through Turntide Academy to help users become product experts in no time.

Noise Comparison

Noise can be an important consideration for facilities managers deploying energy efficiency solutions in certain environments. The addition of electronics to any motor system can affect the noise profile due to frequency parameters and other factors. Manufacturers generally factor these considerations to ensure their systems operate at optimal frequency settings to reduce system noise.

When induction motors are connected to a VFD, the VFD inherently adds noise due to the carrier frequency of the signal delivering power to the motor. The Turntide motor controller is similar when it operates Turntide motors; however, Turntide has paid particular attention to mitigate any effects of noise coming from Turntide's motor system, including designing our motors in accordance with NEMA MG1 (Pt. 31). For example, Turntide has integrated features to minimize the impact of acoustic noise, such as skip speeds, In addition, over the years, Turntide has also perfected a mechanical foot solution that prevents the Turntide motor from creating vibrations and harmful frequencies to the environment, ensuring noise levels remain negligible to building occupants.

NEMA Standards Publication MG1-2011 (Motors and Generators)

Machine sound and vibration are influenced by the following parameters:

- Electromagnetic design
- Type of inverter
- Resonance of frame structure and enclosure
- Integrity, mass, and configuration of the base mounting structure
- Reflection of sound and vibration originating in or at the load of shaft coupling
- Windage

Today, most induction motor standards and data on induction motor noise only measure induction motors running across the line, without a load. This means this data only applies for motors running at 100% speed without external sources of noise. Therefore, it doesn't account for the effects that real-world VFD operation add into the system. Whether or not the system will produce noise varies on several factors, including the installation environment, HVAC design parameters, and the motor and VFD manufacturer.

In conclusion, the addition of electronics into a motor system to modulate motor speed will inherently add noise - if no action is taken to mitigate its effects. With Turntide, noise mitigation is more consistent and reliable as both Turntide motors and motor controllers work together in every Turntide HVAC retrofit. With a VFD retrofit, results have a higher degree of variance as VFD and motor manufacturers and systems may not always be tuned together the same way.

Description	VFD Retrofit	Turntide Smart Motor System Retrofit
Typical Scope of Retrofit	1. Installing a VFD to the existing AC induction motor	1. Removal of existing AC induction motor 2. Installing Turntide Smart Motor System (motor, motor controller, Remote Monitoring Kit, RTU sensors)
Max System Efficiency*	86.5%^	92%
Intelligence and Monitoring	• No built-in connection to Wi-Fi or the cloud • A user interface for logic programming is only available through a keypad and buttons on the device • Requires BMS connection for connected insights	• Integrates with thermostats and RTU controllers out of the box • Built-in 802.11/a/b/g Wi-Fi connectivity • Interfaces with BMS platforms via BACnet for integration as needed

Reliability	• Induction motors are susceptible to winding failures due to their complex distributed winding design • VFDs send peak voltages that can accelerate winding failures • At lower speeds, VFDs can push motors to their critical thermal design limits. • No built-in alerts for immediate action on fault conditions, leaving equipment issues undetected	• Unique concentrated bobbin stator coil winding design reduces the risk of winding failures found in induction motors • With all components engineered to work together, works just as reliably at both lower and higher speeds
User Experience	• Programmed and controlled locally only through the keypad and buttons on the VFD, in a limited interface requiring a complex learning curve • Requires integration with third-party BMS for cloud connectivity	• Modern and intuitive mobile app interface enables simple workflows for system commissioning and monitoring • As an option: can integrate with third-party BMS systems
Noise	• Depends on factors such as the installation environment, HVAC design parameters, and the motor and VFD manufacturer • Noise can be kept to a minimum through careful HVAC system design during the installation process	• The Turntide system comes equipped with noise mitigation built into the solution, in accordance with NEMA MG 1, Part 31 • Results are consistent as Turntide motors and motor controllers work together in every Turntide HVAC retrofit

*comparison at 3hp

^for NEMA premium induction motor with VFD

4. Conclusion

The Turntide Smart Motor System represents the latest breakthrough technology in HVAC, surpassing the VFD in performance and capabilities. Unlike VFDs, Turntide products come with continuous firmware and software upgrades that further add functionality and performance over time. The Turntide Smart Motor System is the new standard that facilities managers can rely on for HVAC efficiency and performance in the short and long term.

Best of all, the Turntide Smart Motor System pays for itself quickly. An investment in the Turntide Smart Motor System has saved businesses an average of 64% in energy use, and can typically pay for itself in around 3 years. Furthermore, an increasing number of utility rebates are now available, reducing the payback period and making the Turntide Smart Motor System a win-win solution for every facilities manager.