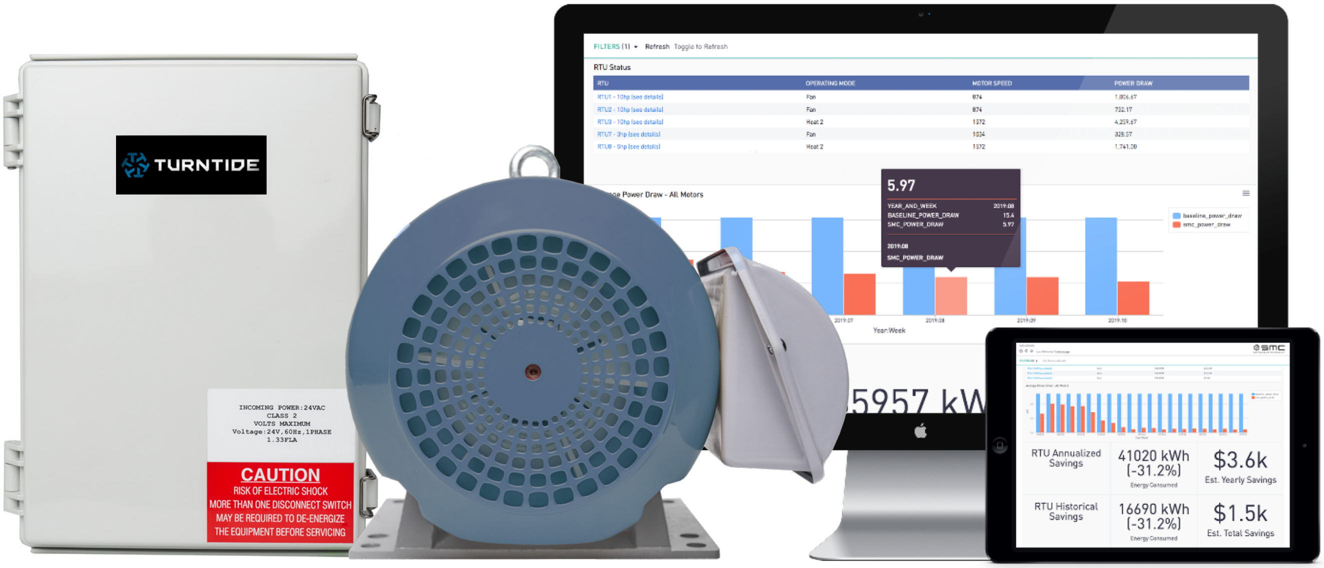
Motor Comparison Study



The Smart Motor Advantage:

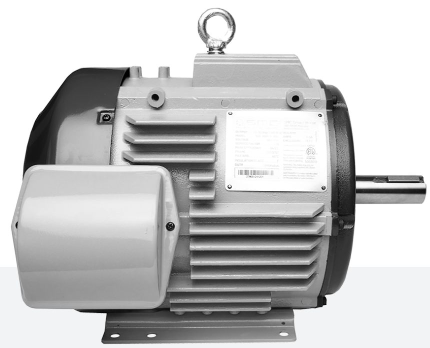
More energy savings, durability, and intelligence for the digital age

Becoming more energy efficient and reducing costs are twin goals for most companies. The ultra-efficient, software-driven Smart Motor System reduces HVAC system energy use by 40-60% compared to commonly used AC induction motors, which have changed little over the past 100 years.

The innovative Turntide™ Smart Motor System is designed specifically for multi-speed performance that is essential to the HVAC, refrigeration, and pumping applications used in millions of buildings around the world.

With built-in sensors and connectivity, the Smart Motor provides real-time, actionable data about system performance along with the precise control, maintenance, and efficiency you need. And because it's connected you can integrate and manage it through your building management system.

Get the electric motor designed for the digital age. Here's how the Turntide Smart Motor compares to conventional induction motors paired with variable frequency drives (VFD) and electrically commutated motors (ECM).



It's time to let go of 100-year-old electric motor technology.

Upgrade to the digital age with the Smart Motor advantage:

- Unprecedented energy efficiency
- Highly reliable motor design to minimize HVAC maintenance costs
- Remote monitoring and control to limit false alarms and service calls
- Customizable platform
- Easy to integrate into standard NEMA platforms

Metrics Represented	Smart Motor System	Standard Induction w/ No VFD	Standard Induction w/ VFD	Permanent Magnet Motor	Synchronous Reluctance Motor w/VFD
Efficiency - Peak	●●●●●	●●○○○	●●○○○	●●●●●	●●●○○
Efficiency - Across Full Speed/Torque Range	●●●●●	●○○○○	●●○○○	●●●●●	●●●○○
Power Density [kW/kg]	●●●●○	●●○○○	●●○○○	●●●●●	●●●○○
Reliability & Fault Tolerance	●●●●●	●●●○○	●●●○○	●●○○○	●●●○○
In-Rush Current/Start-up Torque	●●●●●	●○○○○	●●○○○	●●●●●	●●●○○
Ease of Manufacturing	●●●●●	●●○○○	●●○○○	●○○○○	●●○○○
Speed, Range, & Operating Capability	●●●●●	●○○○○	●●●○○	●●●●●	●●●●○
Torque Density/Capability	●●●●●	●○○○○	●●○○○	●●●●●	●●●○○
Temperature Handling Capability	●●●●●	●●●○○	●●●○○	●○○○○	●●●●●
Problems with Bearing Currents	●●●●●	●●●●●	●○○○○	●○○○○	●○○○○
Material Cost	●●●●●	●●●○○	●●●○○	●○○○○	●●●●○
Supply Chain Volatility	●●●●●	●●●●●	●●●●●	●○○○○	●●●●●

Turntide vs. Standard Induction Motor with NO VFD

Metric		Turntide Smart Motor	Standard Induction Motor with No VFD
Efficiency	Peak	Turntide has very high peak efficiency at rated speed and rated torque.	Premium efficiency IMs have average efficiency at rated speed and rated torque.
	Across Full Speed/ Torque Range	Turntide has high efficiency over a wide operating speed range - important in variable flow applications where, unlike the fixed speed induction motor, throttling of the flow can be avoided.	The efficiency of IMs drops drastically when operated away from rated conditions.
Power Density [kW/kg]		Owing to the higher efficiency and a rotor that is free of bars and permanent magnets, the Turntide motor is capable of absorbing higher current and therefore has very good power density.	Because of the bars in the rotor and longer end turns on stator, cooling can be a challenge, which leads to lower power density.
Torque Density/ Capability		Due to the very high copper fill in the stator, high current densities are achieved leading to excellent torque density.	The IM has very limited torque capability and cannot be operated significantly beyond rated torque conditions due to the increased losses at high slip conditions.
Reliability and Fault-tolerance		Simple construction and stator/rotor structure make the Turntide motor more robust. Also, each phase is individually controlled so electrical faults can be readily identified, isolated, and compensated to resume operation.	Distributed windings decrease reliability/life due to proximity of interphase windings and winding forming during the manufacturing process.
In-Rush Current/ Start-up Torque		Turntide does not have a large inrush current problem because the motor controller regulates current. It has high starting and overloading torque capability.	The in-rush current of an IM is typically 5 to 7 times the continuous value. The IM has significantly lower starting torque capability than the Turntide motor.
Ease of Manufacturing		Windings in the stator are concentrically wound around the stator pole with short end turns. These are inherently easier to wind and insert. The rotor is a laminated stack of steel with no slip rings, brushes, bars, magnets, or other secondary manufacturing steps than just stamping.	The IM uses distributed winding in the stator, which requires additional tooling and assembly time. The rotor laminations have insulated copper or aluminum bars inserted or cast into the rotor laminations. This is considerably more complex.
Speed, Range and Operating Capability		The Turntide motor is designed to operate across a very wide speed and torque range and still maintain high efficiency.	The IM is only designed to run at a fixed speed.
Temperature Handling Capability		Owing to the ease of heat extraction and a rotor that is free of copper and permanent magnets, Turntide is capable of handling significantly higher temperatures.	The inability to effectively extract heat from the rotor bars are a limiting factor in the thermal capabilities of the IM.
Problems with Bearing Currents		Exhibits robust operation and is immune to bearing currents/faults from common mode voltages.	This is not an issue for an IM without a VFD.
Material Costs		With no exotic materials or processes involved in manufacturing, the Turntide motor has the lowest material cost.	The material costs are relatively low, but the distributed windings and rotor bar casting/insertion add to manufacturing complexity and thus costs. Additionally, high efficiency IMs use cast copper vs. cast aluminum which impacts cost.
Supply Chain Volatility		There are no rare earth materials which create supply chain volatility.	There are no rare earth materials which create supply chain volatility.

Turntide vs. Standard Induction Motor WITH VFD

Metric		Turntide Smart Motor	Standard Induction Motor with VFD
Efficiency	Peak	Turntide has very high peak efficiency at rated speed and rated torque.	Premium efficiency IMs have average efficiency at rated speed and rate torque.
	Across Full Speed/ Torque Range	Turntide has high efficiency over a wide operating speed range - important in variable flow applications where, unlike the fixed speed induction motor, throttling of the flow can be avoided.	The VFD allows the speed of the IM to be varied, but the efficiency drops significantly when operated away from rated conditions.
Power Density [kW/kg]		Owing to the ease of heat extraction and a rotor that is free of copper and permanent magnets, the Turntide motor is capable of absorbing higher current and therefore has very good power density.	Because of the bars in the rotor and longer end turns on stator, cooling can be a challenge, which leads to lower power density.
Torque Density/ Capability		Due to the very high copper fill in the stator, high current densities are achieved leading to excellent torque density.	With the VFD, slip can be managed but the system is still limited to operation well below the motor speed/torque breakdown point which is well below the Turntide motor for the same frame size motor.
Reliability and Fault-tolerance		Simple construction and stator/rotor structure make the Turntide motor more robust. Also, each phase is individually controlled so electrical faults can be readily identified, isolated, and compensated to resume operation.	Distributed windings decrease reliability/life due to proximity of interphase windings and winding forming during the manufacturing process.
In-Rush Current/ Start-up Torque		Turntide does not have a large inrush current problem because the motor controller regulates current. It has high starting and overloading torque capability.	The in-rush is limited by the VFD. The IM with VFD has better starting torque than a line feed IM, but still significantly lower starting torque capability than Turntide.
Ease of Manufacturing		Coil windings in the stator are concentrically wound around the stator pole with short end turns. These are inherently easier to wind and insert. The rotor is a laminated stack of steel with no slip rings, brushes, copper, or magnets that need to be inserted/ wound.	The IM uses distributed winding in the stator, which requires additional tooling and assembly time. The rotor laminations have copper or aluminum bars inserted or cast into the rotor laminations. This is considerably more complex.
Speed, Range and Operating Capability		The Turntide motor is designed to operate across a very wide speed and torque range and still maintain high efficiency.	The IM with VFD can be operated over a wide speed range, but the system efficiency drops considerably at light load and low speed.
Temperature Handling Capability		Owing to the ease of heat extraction and a rotor that is free of copper and permanent magnets, Turntide is capable of handling significantly higher temperatures.	The inability to effectively extract heat from the rotor bars are a limiting factor in the thermal capabilities of the IM.
Problems with Bearing Currents		Exhibits robust operation and is immune to bearing currents/faults from common mode voltages.	This is an issue for an IM with a VFD because of the common mode currents induced in the motor shaft.
Material Costs		With no exotic materials or processes involved in manufacturing, the Turntide motor has the lowest material cost.	The material costs are relatively low, but the distributed windings and rotor bar casting/insertion add to manufacturing complexity and thus costs. Additionally, high efficiency IMs use cast copper vs. cast aluminum which impacts cost.
Supply Chain Volatility		There are no rare earth materials which create supply chain volatility.	There are no rare earth materials which create supply chain volatility.

Turntide vs. Permanent Magnet Motor

Metric		Turntide Smart Motor	Permanent Magnet Motor
Efficiency	Peak	Turntide has very high peak efficiency at rated speed and rated torque.	Rare earth permanent magnet motors have very high peak efficiency at rated speed and rated torque.
	Across Full Speed/ Torque Range	Turntide has high efficiency over a wide operating speed range - important in variable flow applications where, unlike the fixed speed induction motor, throttling of the flow can be avoided.	Rare earth permanent magnet motors typically have high efficiency over a wide operating speed range.
Power Density [kW/kg]		Owing to the ease of heat extraction and a rotor that is free of copper and permanent magnets, Turntide is capable of absorbing higher current and therefore has very good power density.	The permanent magnets reduce or eliminate the need for the magnetizing current required by IMs which leads to excellent power density.
Torque Density/ Capability		Due to the very high copper fill in the stator, high current densities are achieved leading to excellent torque density.	Due to the rare earth permanent magnet field flux, the stator current is used directly for torque production leading to excellent torque densities and capability.
Reliability and Fault-tolerance		Simple construction and stator/rotor structure make the Turntide motor more robust. Also, each phase is individually controlled so electrical faults can be readily identified, isolated, and compensated to resume operation.	Distributed windings decrease reliability/life due to proximity of interphase windings and winding forming during manufacturing. Additionally, PM motors have demagnetization vulnerability at elevated currents/ temperatures as well as magnet retention issues.
In-Rush Current/ Start-up Torque		Turntide does not have a large inrush current problem because the motor controller regulates current. It has high starting and overloading torque capability.	The in-rush is limited by the drive. Operated within the current/temperature limitations of the rare earth permanent magnets, these motors have excellent start-up torque.
Ease of Manufacturing		Coil windings in the stator are concentrically wound around the stator pole with short end turns. These are inherently easier to wind and insert. The rotor is a laminated stack of steel with no slip rings, brushes, copper, or magnets that need to be inserted/ wound.	These motors typically use distributed windings in the stator, which requires additional tooling and assembly time. The rotor typically has high energy product magnets which necessitates special tooling for assembly.
Speed, Range and Operating Capability		Turntide is designed to operate across a very wide speed and torque range and still maintain high efficiency.	The rare earth permanent magnet motor operates across a wide speed and torque range while maintaining high efficiency.
Temperature Handling Capability		Owing to the ease of heat extraction and a rotor that is free of copper and permanent magnets, Turntide is capable of handling significantly higher temperatures.	The permanent magnetics restrict high temperature operation. Elevated temperature operation leads to a cascading failure as the magnet strength decreases and additional current is required to compensate, thereby increasing losses and further reducing performance.
Problems with Bearing Currents		Exhibits robust operation and is immune to bearing currents/faults from common mode voltages.	This is an issue for the permanent magnet motor because of the common mode currents induced in the motor shaft.
Material Costs		With no exotic materials or processes involved in manufacturing, The Turntide motor has the lowest material cost.	Permanent magnets add significant cost to the motor price. Use of SmCo or AlNiCo have high temperature capability, but lower energy densities and increase cost. Use of Ceramic magnets can lead to lower cost motors, but they typically have lower output torque due to lower flux densities.
Supply Chain Volatility		There are no rare earth materials which create supply chain volatility.	Motors which use NdFeB permanent magnets, containing rare-earth materials, will create supply challenges for five rare earth metals (dysprosium, neodymium, terbium, europium and yttrium). These materials are expected to create major problems in the years ahead.

Turntide vs. Synchronous Reluctance Motor (SynRM)

Metric		Turntide Smart Motor	Synchronous Reluctance Motor (SynRM)
Efficiency	Peak	Turntide has very high peak efficiency at rated speed and rated torque.	SynRM have good peak efficiency at rated speed and rated torque.
	Across Full Speed/ Torque Range	Turntide has high efficiency over a wide operating speed range - important in variable flow applications where, unlike the fixed speed induction motor, throttling of the flow can be avoided.	SynRM have good efficiency over a wide operating speed range.
Power Density [kW/kg]		Owing to the ease of heat extraction and a rotor that is free of copper and permanent magnets, Turntide is capable of absorbing higher current and therefore has very good power density.	Owing to comparatively lower efficiency, the power density is limited by heat dissipation capabilities. Additionally, the "rotor web" wastes more active material and is susceptible to local magnetic hotspots.
Torque Density/ Capability		Due to the very high copper fill in the stator, high current densities are achieved leading to excellent torque density.	Low saliency ratio, magnetic saturation, and lower efficiency limit the torque production capabilities beyond the rated torque and thus resulting into lower torque densities.
Reliability and Fault-tolerance		Simple construction and stator/rotor structure make the Turntide motor more robust. Also, each phase is individually controlled so electrical faults can be readily identified, isolated, and compensated to resume operation.	Distributed windings decrease reliability/life due to proximity of interphase windings and winding forming during the manufacturing process.
In-Rush Current/ Start-up Torque		Turntide does not have a large inrush current problem because the motor controller regulates current. It has high starting and overloading torque capability.	The in-rush is limited by the drive. Start-up is on par with premium IMs.
Ease of Manufacturing		Coil windings in the stator are concentrically wound around the stator pole with short end turns. These are inherently easier to wind and insert. The rotor is a laminated stack of steel with no slip rings, brushes, copper, or magnets that need to be inserted/ wound.	The SynRM motors typically use distributed windings in the stator, which require additional tooling and assembly time. Also, SynRM motors have complex rotor laminations for flux manipulation, which adds special requirements on rotor lamination stamping and stacking.
Speed, Range and Operating Capability		Turntide is designed to operate across a very wide speed and torque range and still maintain high efficiency.	A challenge in the design of the airgap channels is to combine optimization of reluctance with mechanical strength to endure the forces at high rotational speeds, especially for larger machines.
Temperature Handling Capability		Owing to the ease of heat extraction and a rotor that is free of copper and permanent magnets, Turntide is capable of handling significantly higher temperatures.	Owing to the ease of heat extraction and a rotor that is free of copper and permanent magnets, the SynRM is capable of handling significantly higher temperatures. However, the distributed winding has higher losses than the Turntide motor leading to greater temperature restrictions.
Problems with Bearing Currents		Exhibits robust operation and is immune to bearing currents/faults from common mode voltages.	This is an issue for the SynRMs because of the common mode currents induced in the motor shaft.
Material Costs		With no exotic materials or processes involved in manufacturing, the Turntide motor has the lowest material cost.	The material costs are on par with Turntide, but the distributed windings add to manufacturing complexity and thus costs. Additionally, there is a slight increase for rotor lamination costs due to their complexity.
Supply Chain Volatility		There are no rare earth materials which create supply chain volatility.	There are no rare earth materials which create supply chain volatility.

Indemnity

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Turntide Technologies (formerly Software Motor Company) has developed the world's most efficient and intelligent electric motor system. The revolutionary Smart Motor System is based on proven switched reluctance technology, now managed with advanced cloud software and connected to precise controls via IoT. Turntide's vision is to eliminate the 25% of global electricity consumption that is wasted by legacy motors, thus accelerating the world's transition from fossil fuels. Turntide is based in Sunnyvale, Calif., with offices in San Francisco; Arlington, Wash.; and Kennesaw, Ga. Turntide has installed Smart Motor Systems with dozens of customers, reducing their motor electricity consumption by an average of 64%, and is powering the systems of leading OEMs. For further information, visit www.turntide.com.

POWER IS VALUABLE. USE IT INTELLIGENTLY.