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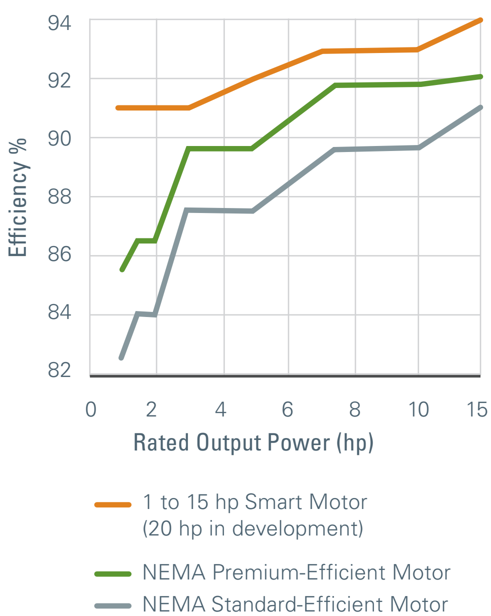
SOFTWARE-CONTROLLED SWITCHED RELUCTANCE MOTOR

Lower Costs, Greater Efficiency

Electric motors, like those found in many heating, ventilation, and air-conditioning (HVAC) applications, account for 38% of electricity used in commercial buildings.[1] More than half of those motors are 5 horsepower (hp) in size or smaller,[2] and the vast majority are based on a century-old technology—the AC induction motor. A variable-frequency drive (VFD) can be added to an AC induction motor to improve efficiency, but this increases equipment costs. Also, throttling back the motor, as VFDs do, causes electrical resistance, which reduces overall system efficiency and longevity. A new, small (1-to-15 hp) software-driven "smart motor" offers inherent variable-speed capability by combining a switched reluctance motor, used for decades in zero-fault-tolerance applications like nuclear reactors, with a built-in microprocessor and sensors. GSA's Center for Emerging Building Technologies (CEBT) and the Oak Ridge National Laboratory put a 10 hp smart motor to the test in a chilled-water pump application at the Land Port of Entry in San Ysidro, California. Researchers found that, compared to a premium-efficiency induction motor combined with a VFD, the smart motor was 4% more efficient on average. Lower-power induction motors are generally less efficient than higher-power induction motors, and a concurrent assessment by the National Energy Renewable Laboratory of a 1.5 hp smart motor found savings of 33%, when compared to a VFD-controlled standard induction motor.[3] Because the 10 hp smart motor is about half as expensive as a premium-efficiency motor combined with a VFD, when replaced at end-of-life, payback is immediate. Researchers recommend end-of-life replacement for 1-to-15 hp motors. Retrofits are also worth considering for constant-speed fan motors, where payback is estimated under 3 years.

INTRODUCTION

SMALLER MOTORS OFFER GREATER RELATIVE SAVINGS



> *"Usually, better performance costs more. But in this case, we're paying about half as much for better performance under all circumstances. It would be helpful to have remote monitoring and control and hope that GSA's IT Security clears this capability."*
>
> — Mike Green
> Chief Engineer
> Land Port of Entry
> San Ysidro, California

What Is This Technology?

HIGH-ROTOR-POLE SWITCHED RELUCTANCE MOTOR WITH PROGRAMMABLE VARIABLE-SPEED DRIVE

The smart motor evaluated in San Ysidro combines a high-rotor-pole switched reluctance motor with a programmable variable-speed drive and software that provides real-time cloud-based monitoring and control. The smart motor does not rely on rare-earth materials and has no rotor windings, magnets, or overlapping coils, making it simpler, more robust, and less expensive to manufacture. Also, since no electrical current is induced in the rotor, there is no electrical arcing across the motor bearings, and thus premature bearing failure is eliminated. A built-in microprocessor and sensors that measure speed, torque, and temperature allow for precise control and continuous monitoring for signs of degradation or faults. Typically, switched reluctance motors have not been as efficient as induction motors but because of a combination of hardware improvements and new control approaches, makers of the smart motor claim increased efficiency at all loads. The motor is manufactured to comply with standard National Electrical Manufacturers Association (NEMA) frame sizes and dimensions and can be dropped into an existing pump or HVAC application. The technology assessed was from the Software Motor Company and is available in sizes ranging from 1-to-15 hp. Currently, the smart motor is manufactured in China and will need a waiver to comply with the Buy American Act. The 10 hp motor tested in San Ysidro was an early production system. During the evaluation, its average sound level was a noisy 94 dBA, while the sound level of the baseline induction motor was 79 dBA. The manufacturer has worked to resolve this issue, and third-party verification shows that noise levels for a prototype 20 hp motor with a 10 hp load have dropped to 81 dBA. The manufacturer predicts that a 10 hp motor using this same design should be as quiet as, or quieter than, the 20 hp motor.

What We Did

SIDE-BY-SIDE LABORATORY AND SEQUENTIAL TESTBED MEASUREMENTS

Oak Ridge National Laboratory (ORNL) tested a 10 hp smart motor in both a laboratory setting and a chilled water pump application at the Land Port of Entry in San Ysidro, California. At the lab, the smart motor and a NEMA premium-efficiency induction motor with a VFD were tested side-by-side and evaluated under the same operating conditions at a variety of motor loads and speeds. In the field, testing was sequential and operating conditions changed after a new building was added to the chilled water system and the flow configuration was modified. Results were normalized to account for this change. The smart motor was a drop-in replacement for a baseline NEMA premium-efficiency motor and VFD in a chilled water pump application that served three air-handling units. In addition to measuring energy performance, researchers spoke to facility staff about ease of installation and ongoing maintenance and operations. A concurrent testbed evaluation of a 1.5 hp smart motor was conducted by National Energy Renewable Laboratory (NREL) on condenser fans in a commercial supermarket refrigeration system at a Walmart in Lakeside, Colorado.[3]

FINDINGS

MORE EFFICIENT UNDER ALL CIRCUMSTANCES In the laboratory, the smart motor (94% nameplate efficiency) was on average 4.5% more efficient than a premium efficiency induction motor (91.7% efficiency) and VFD. In the field, for any given operating condition, the smart motor was between 3.7% and 5.3% more efficient than the baseline premium efficiency induction motor and VFD. A concurrent assessment by NREL of a smaller 1.5 hp motor (93% nameplate efficiency) found savings of 33%, compared to a standard induction motor (73.5% efficiency) and VFD.

DROP-IN INSTALLATION The installation of the smart motor on the chilled water pump application was identical to that of other motors and took 12 hours. Installation on HVAC fans, where laser alignment is not required, takes far less time, between 2 and 4 hours, according to the manufacturer. Facility staff did make one modification to the junction box by drilling an additional hole in order to separate power from controls wiring.

REDUCED MAINTENANCE The bearings of the smart motor are permanently sealed, so no regular lubrication or maintenance is required.

LIMITED DIRECT ACCESS TO SETTINGS; REAL-TIME MONITORING AND CONTROL POTENTIAL Unlike the incumbent VFD controller, the smart motor does not have an LCD to display parameters, such as energy use and rotational speed. Facility staff deemed this a limitation, though parameters can be viewed and set by directly connecting the smart motor to a computer. Remote real-time monitoring and control are also possible, but this capability was not tested in San Ysidro. The concurrent testbed evaluation by NREL, at a Walmart in Lakeside, Colorado, included real-time monitoring and control. During the NREL evaluation, the smart motor prevented possible motor damage when motors were remotely turned off after a piece of foam lodged in the fan.

ABOUT HALF AS EXPENSIVE AS INCUMBENT STATE-OF-THE-ART TECHNOLOGY With high installation costs on the chilled water pump, retrofitting the motor results in a simple payback of 14.8 years at the testbed energy rate of $0.17/kWh. End-of-life replacement results in immediate payback, since the smart motor is about half as expensive as a premium-efficiency NEMA motor combined with a VFD.[4] Payback for retrofitting constant-speed motors that control fans is estimated at less than 3 years.

END-OF-LIFE REPLACEMENT, RETROFIT CONSTANT-SPEED MOTORS At end-of-life, consider replacing all 1-to-15 hp motors with smart motors. Retrofits are also worth considering for constant-speed motors, motors less than 5 hp, and applications with lower installation costs, such as motors that control fans.

Immediate Payback When Replaced at End-of-Life

< 3-year payback estimated for retrofit of constant-speed fan motors

	Premium Motor + VFD	Smart Motor (End-of-Life)
10 hp motor cost ($)[+]	$4,375	$2,430
Installation ($)[++]	$948	No additional cost
Motor electricity use (kWh/yr)	31,700 kWh	30,400 kWh
Motor electricity @ GSA avg. $0.11/kWh ($/yr)	$3,516	$3,371
Simple payback (yrs)		Immediate

[+] Premium motor ($1,756) and VFD ($2,619) cost provided by San Ysidro LPOE. Smart motor cost provided by manufacturer; does not include volume discounts. [++] Labor cost provided by San Ysidro LPOE: 12 hours @ $79/hr. Pump installation requires laser alignment of pump and motor. Fan installation takes 2-4 hours.

CONCLUSIONS

These Findings are based on the report, "Lab Evaluation and Field Demonstration of High Rotor Switched Reluctance Motor Technology," which is available from the GSA website, www.gsa.gov/cebt

For more information, contact GSA's Center for Emerging Building Technologies cebt@gsa.gov

What We Concluded

ATTRACTIVE INVESTMENT OPPORTUNITY

During the evaluation, the smart motor was more efficient than a VFD-controlled premium-efficiency motor under all circumstances. And with lower first costs, the smart motor is an attractive investment opportunity for GSA. Smart switched reluctance motors should be used for all end of life replacements and should be considered for retrofits. Retrofits will be most cost-effective for constant-speed motors, motors less than 5 hp, and applications with lower installation costs, such as motors that control fans.

Deployment Recommendations

Smaller motors offer greater relative savings In general, efficiency levels become higher as motor horsepower increases, greater relative energy savings will result from retrofitting motors less than 3 hp.

Savings more than double for motors without VFD control In independent evaluations by NREL and Southern California Edison Emerging Products Group, savings were more than double for baseline motors without VFD control. The NREL assessment found savings of 71%, compared to a constant-speed induction motor (nameplate efficiency 73.5%), and of 33% when compared to the same motor with VFD control. The Southern California Edison assessment found savings of 57% when the smart motor was compared to a constant-speed induction motor (nameplate efficiency 84%) and 11% when it was compared to the same motor with VFD control.[5]

Replacement of small motors more cost-effective than repair The repair cost for motors less than 25 hp is equivalent to or exceeds the cost of a new premium-efficiency motor.[6]

Cloud-based connectivity could be beneficial to GSA Remote monitoring and control and the ability to directly read motor parameters, monitor system performance, and receive alerts when performance degrades or faults are detected, could be beneficial. Smart motor cloud-based connectivity should be evaluated by GSA IT Security.

Large potential for RTUs Though GSA has limited commercial rooftop units (RTUs), the majority of commercial office space is conditioned by them. Given that most RTU motors are small, there is significant deployment opportunity for these smart motors. In addition, retrofitting fan motors can be more cost-effective than the pump-motor retrofit because installation takes between one fourth and one-third of the time, between 2 and 4 hours versus the 12 hours needed to install and align the motor for the chilled-water pump application.

Footnotes

[1] *Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems*, International Energy Agency, Paul Waide and Conrad U. Brunner, 2011, p.11.

[2] *Premium Efficiency Motor Selection and Application Guide*, U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, February 2014, p.1-5.

[3] *Evaluation of High Rotor Pole Switched Reluctance Motors to Control Condenser Fans in a Commercial Refrigeration System, Grant Wheeler, Michael Deru (NREL), June 2019, p.18*

[4] The Energy Independence and Security Act of 2007 mandates the purchase of 1-to-200 hp premium efficiency motors. GSA's facilities standards guide, the P100, requires a VFD on all motors larger than 5 hp.

[5] *Software-Controlled Switch Reluctance Motors*, Southern California Edison Emerging Products Group, August 2018, p.iii.

[6] *Premium Efficiency Motor Selection and Application Guide*, U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, February 2014, p.4-5.

Technology for testbed measurement and verification provided by Software Motor Company.

Reference above to any specific commercial product, process or service does not constitute or imply its endorsement, recommendation or favoring by the United States Government or any agency thereof.