GPG Outbrief 21

Software-Controlled Switched Reluctance Motor

Emerging Building Technologies, GPG Program | U.S. General Services Administration | November 20, 2019

GSA

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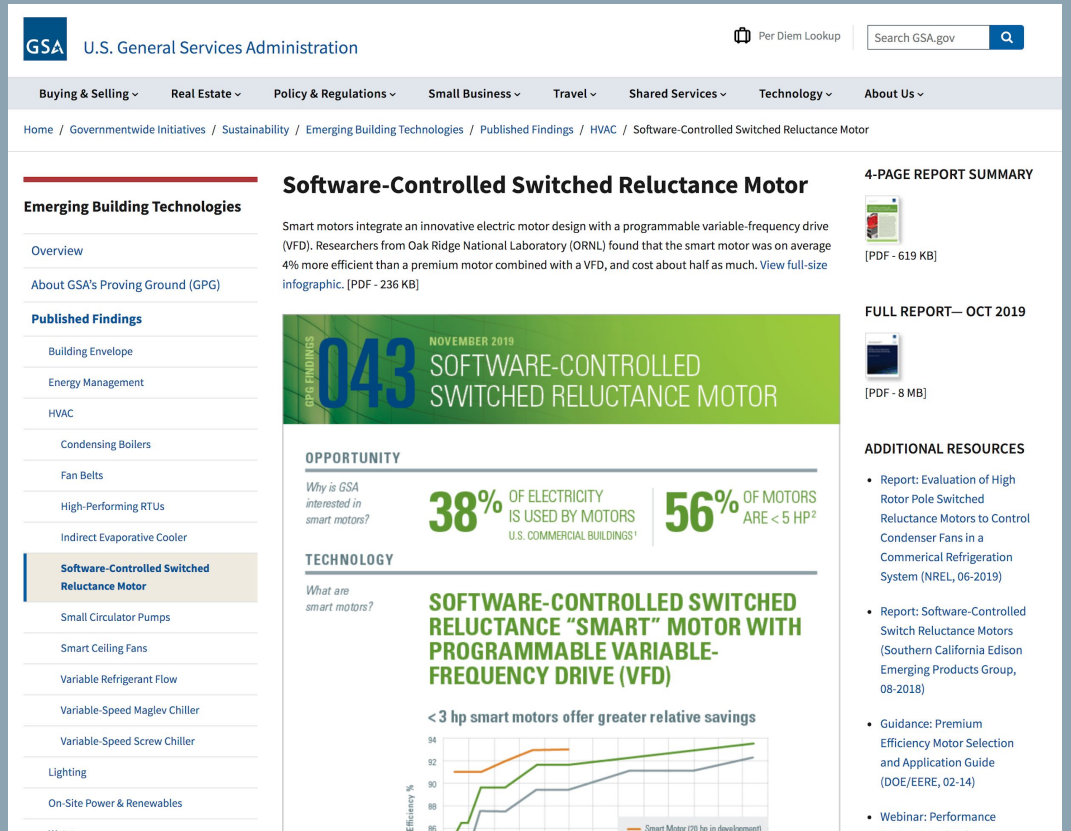
GPG-043 Software-Controlled Switched Reluctance Motor

- Infographic
- 4-page Findings
- Full Report
- Additional Resources



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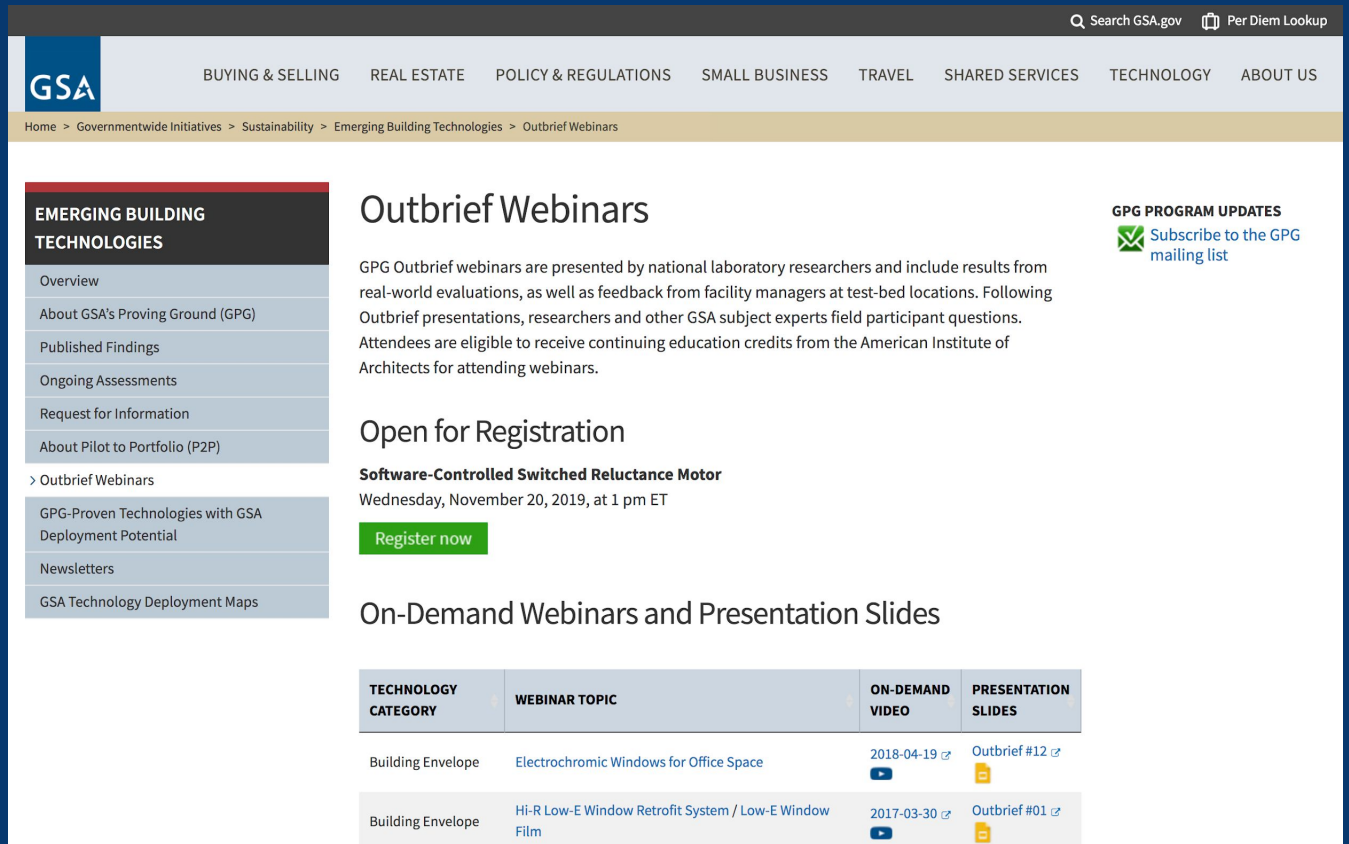

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Software-Controlled Switched Reluctance Motor
Wednesday, November 20, 2019, at 1 pm ET

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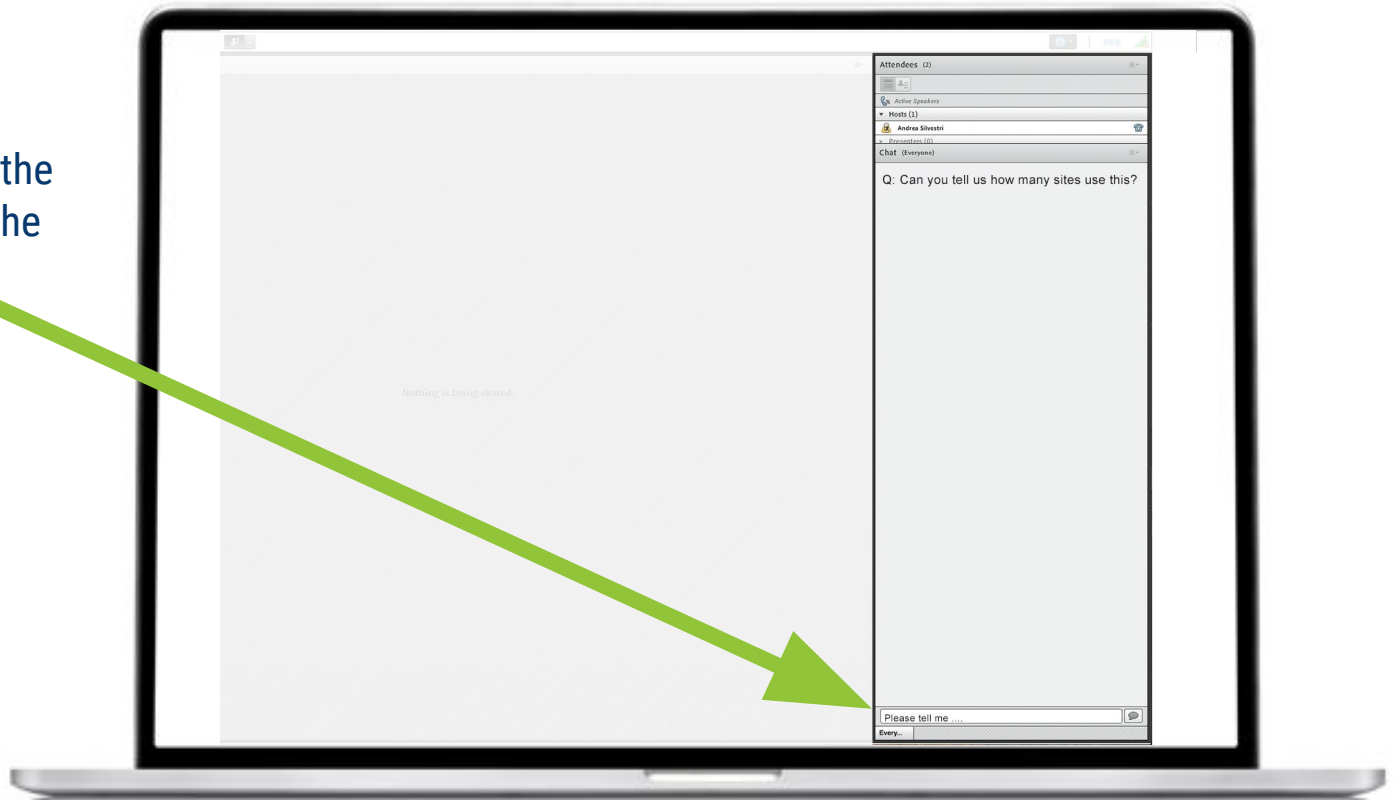

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Introduction

Michael Hobson
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Webinar Agenda

- Introduction (5 minutes)
  Kevin Powell, Director, Center for Emerging Building Technologies
- Software-Controlled Switched Reluctance Motor (20 minutes)
  Brian Fricke and Mahabir Bhandari, Oak Ridge National Laboratory
- On-the-ground Feedback (10 minutes)
  Mike Green, Chief Engineer, Land Port of Entry, San Ysidro, California
- Q & A (20 minutes)

Introduction

Kevin Powell
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Opportunity

38% OF ELECTRICITY IS USED BY MOTORS IN U.S. COMMERCIAL BUILDINGS[1]

56% OF MOTORS ARE < 5 HP[2]

GPG-043

Software-Controlled Switched Reluctance Motor

General Services Administration
Public Buildings Service

GSA

GPG-043 | NOVEMBER 2019

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 the motor as VFDs do causes electrical resistance, which reduces overall system efficiency and longevity. A new small (1-to-10 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 Proving Ground 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 drive, the smart motor was 4% more efficient on average. Lower-power induction motors generally have lower efficiencies 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-10 hp motors. Retrofits are also worth considering for fixed-speed motors, motors of < 5 hp, and applications with lower installation costs, such as motors that control fans.

The GPG program enables GSA to make sound investment decisions in next-generation building technologies based on their real-world performance.

Measurement & Verification

Brian Fricke
R&D Staff
Oak Ridge National Laboratory

Mahabir Bhandari
R&D Staff
Oak Ridge National Laboratory

AC Induction Motors

100-year old design

- Constantly draws electricity
- Electromagnetic induction to create magnetic field
- Alternative technology: Premium-efficiency permanent magnet motors rely on rare-earth materials

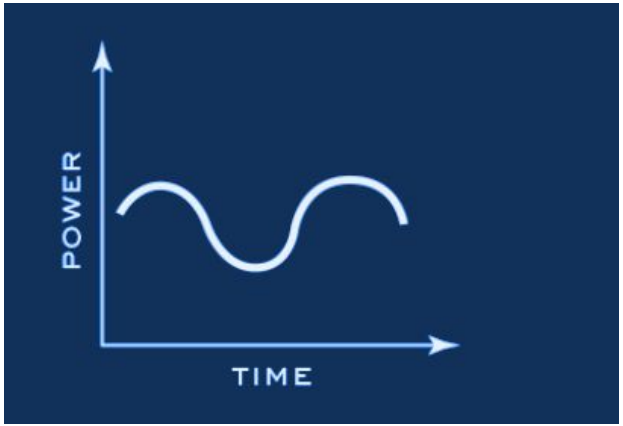
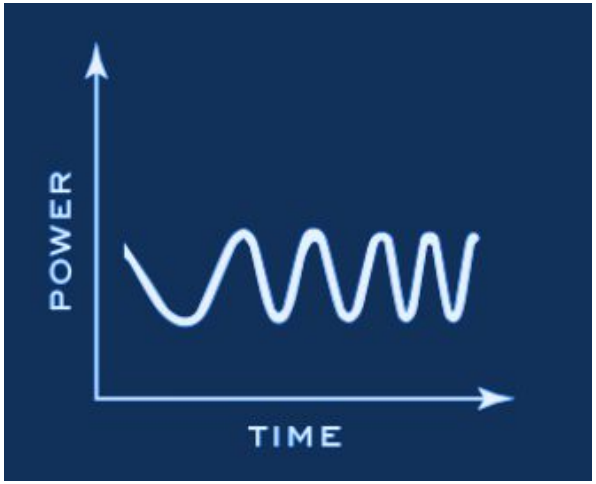


Image Courtesy of Software Motor Company

AC Induction Motors with Variable-Frequency Drive (VFD)

In 1980s, VFDs introduced

- Throttling back the motor creates electrical resistance
- Reduces overall system efficiency
- Reduces longevity
- Adds expense



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Switched Reluctance Motors

1990 Switched-Reluctance Motor

- Reliable design used in zero-fault tolerance applications like nuclear reactors
- Historically not as efficient as induction motors
- Have had issues with control, noise and vibration so have not been used in building applications
- Do not rely on rare-earth materials

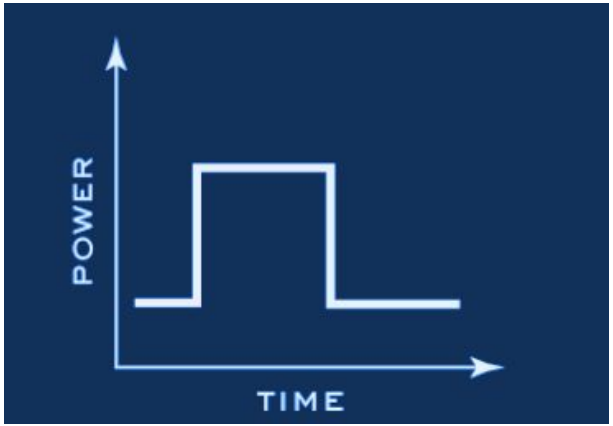


Image Courtesy of Software Motor Company

Software-Controlled High-Rotor Pole Switched Reluctance Motor

Hardware and software improvements

- Simpler and more robust rotor design
  - No rotor windings, magnets, or overlapping coils
  - No electrical current in the rotor, prevents premature bearing failure
- Precise motor control
  - Built-in microprocessor & sensors that measure speed, torque, & temperature

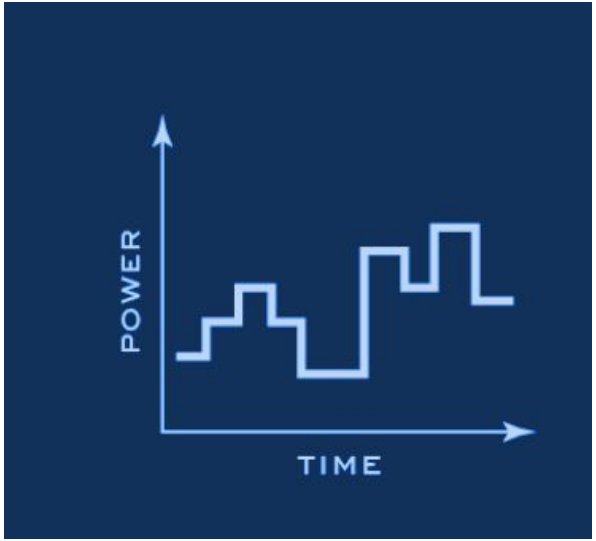
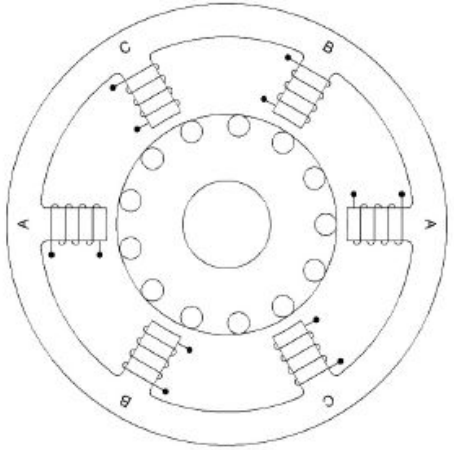
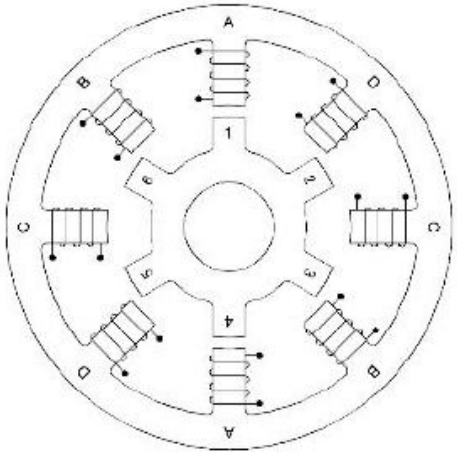


Image Courtesy of Software Motor Company

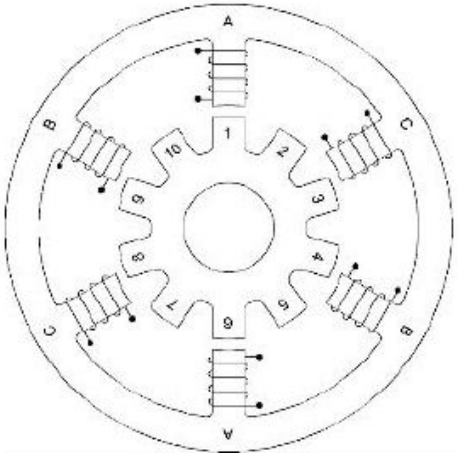
Stator and Rotor Configuration



AC Induction Motor

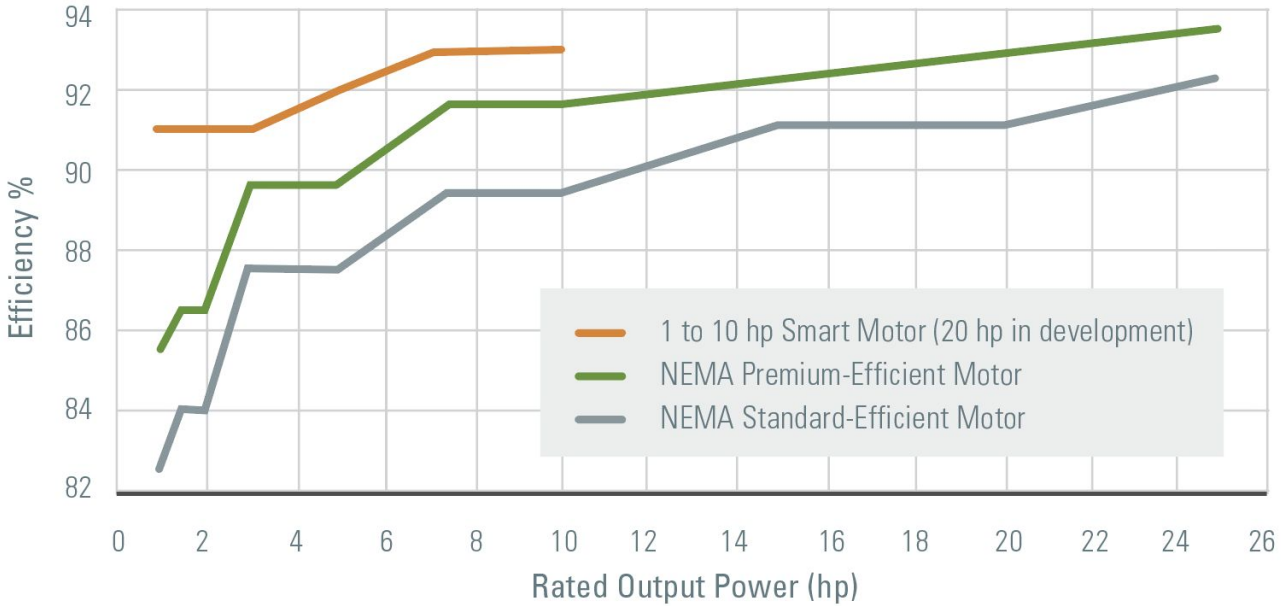


Switched Reluctance Motor



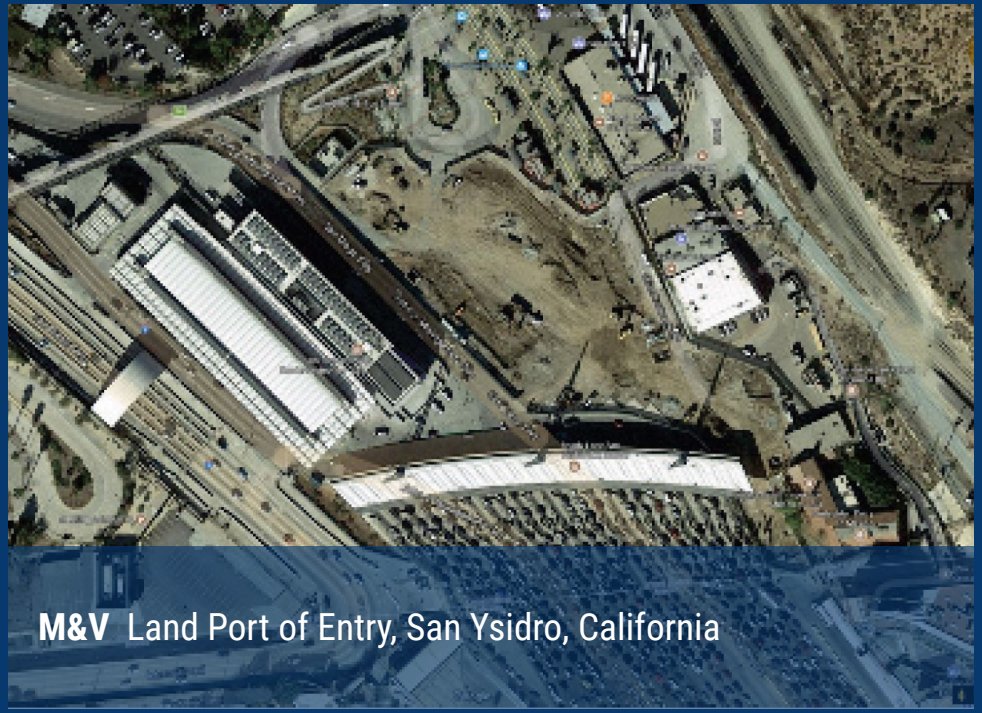
High-Rotor Pole Switched Reluctance Motor

Rated Efficiency – Smaller Motors Offer Greater Relative Savings



Measurement & Verification

Technology for M&V, 10 hp motor
provided by Software Motor Company



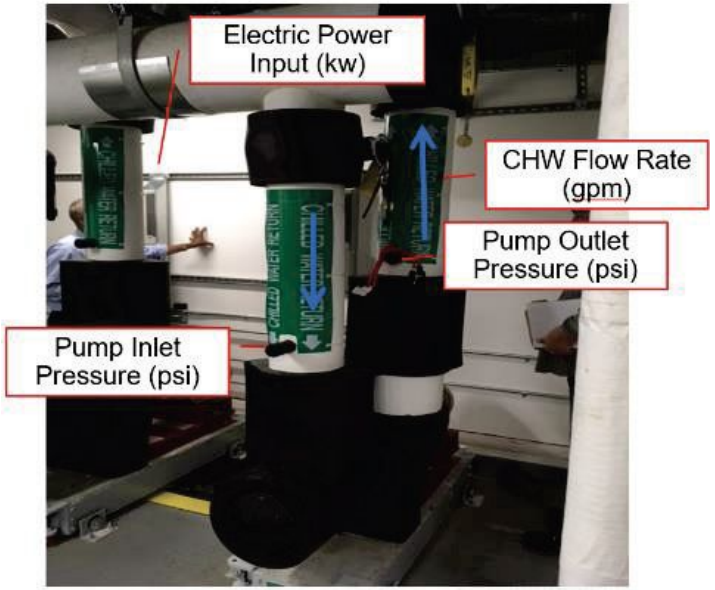
M&V Land Port of Entry, San Ysidro, California

M&V Design

Side-by-side laboratory and sequential testbed measurements on 10 hp motor

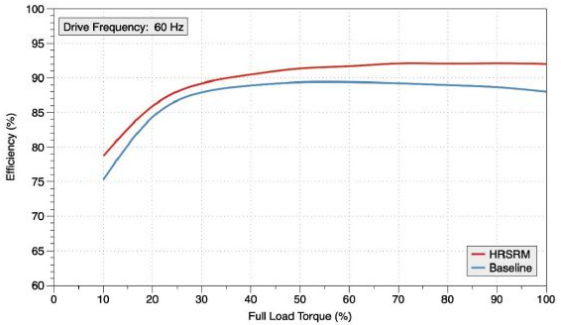
Lab: compared to NEMA premium-efficiency motor with a VFD

Testbed: compared to NEMA premium-efficiency motor with a VFD on a chilled water pump application that served 3 air handlers

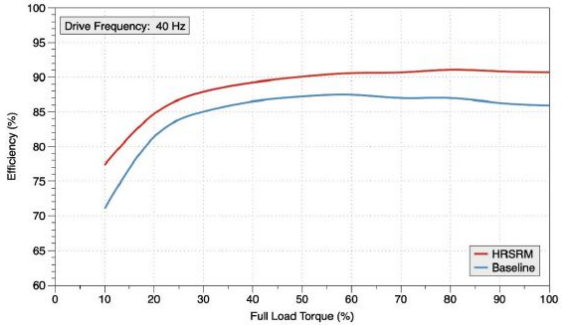


Testbed Measurement Points

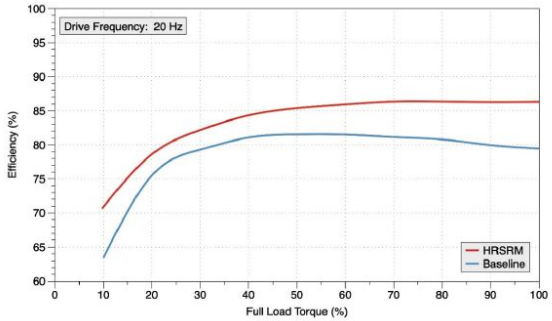
On Average 4.5% Efficient in Lab Testing



3% more efficient at 60 Hz



4.6% more efficient at 40 Hz



6.3% more efficient at 20 Hz

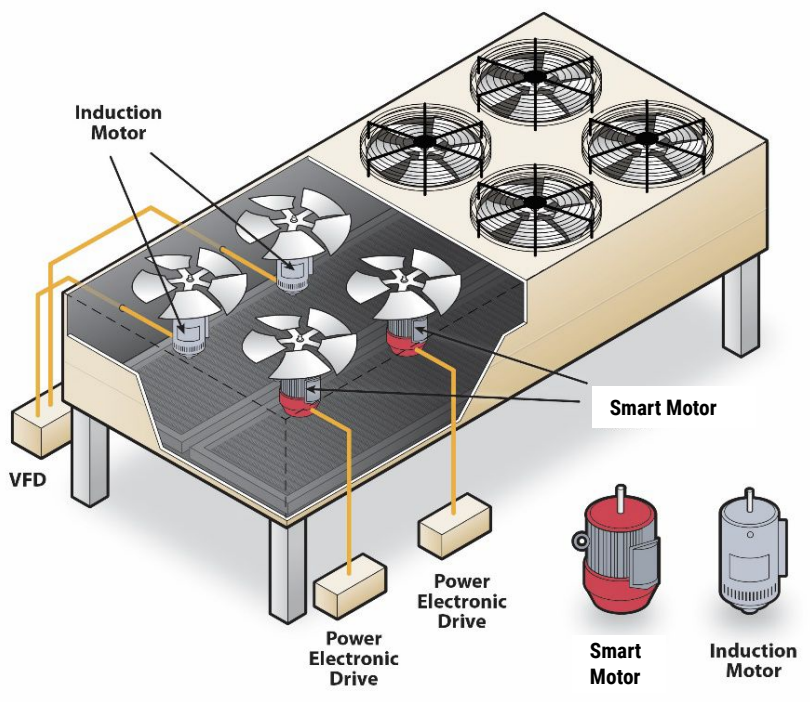
3.7% to 5.3% More Efficient in the Field

Performance metric	Smart Motor & drive	Baseline motor & drive	Difference	
			Absolute	Relative
Overall average				
Hydraulic power (hp)	2.42	2.54	−0.12	−4.7%
System input power (kW)	3.43	3.50	−0.07	−2.0%
System efficiency (%)	51.6	52.7	−1.10	−2.1%
Low dP mode average				
Hydraulic power (hp)	3.26	3.02	0.24	7.9%
System input power (kW)	4.04	3.93	0.11	2.8%
System efficiency (%)	59.1	56.1	3.00	5.3%
High dP mode average				
Hydraulic power (hp)	2.33	2.10	0.23	11.0%
System input power (kW)	3.36	3.04	0.32	10.5%
System efficiency (%)	50.7	48.9	1.80	3.7%

NREL Assessment: 1.5 hp motors on refrigeration fans

Nine 1.5 hp smart motors

- Installed parallel to baseline induction
- Smart motor more efficient regardless of baseline control



NREL Assessment 33%–71% More Efficient than Standard-Efficiency

1.5 hp motor	73.5% efficiency Baseline Energy use (kWh)	93% efficiency Smart Motor Energy use (kWh)	Savings (kWh)	Savings (%)
VFD baseline	2,641	1,775	866	33%
Constant speed baseline	6,186	1,775	4,411	71%

Adding variable-speed control to the baseline induction motor saved **57%**

Swapping to the smart motor with VFD control saved an additional **14%**

Drop-In Installation

Installation identical to other motors

- 12-hours for chilled water pump application; requires laser alignment to align pump and motor
- 2 to 4 hours for HVAC fans

Image Courtesy of Software Motor Company

O&M Comparable

Reduced maintenance

- Bearings are permanently sealed, no regular lubrication or maintenance required

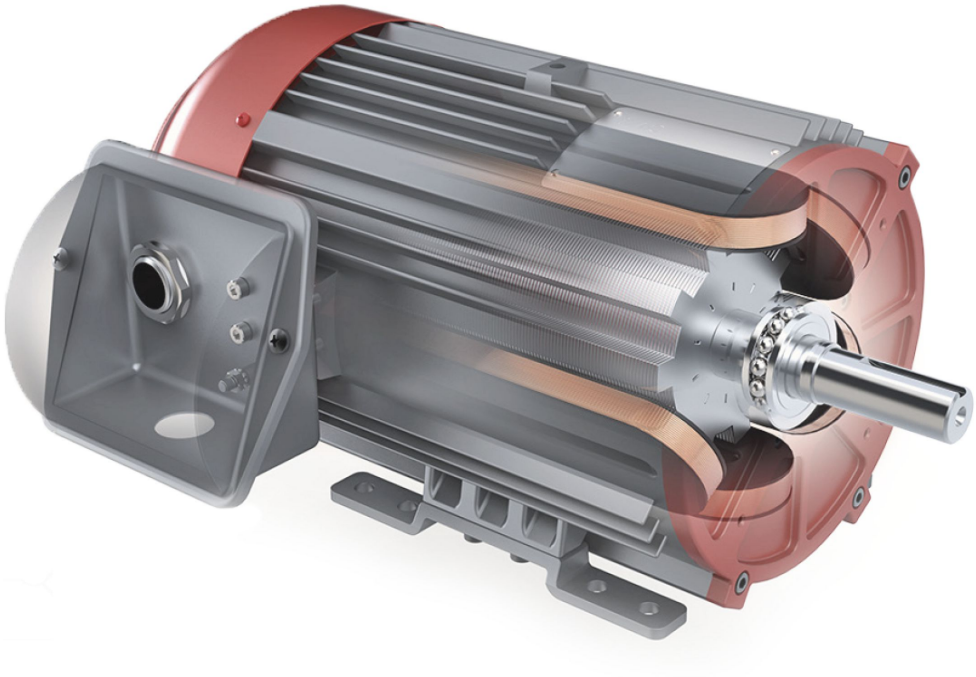
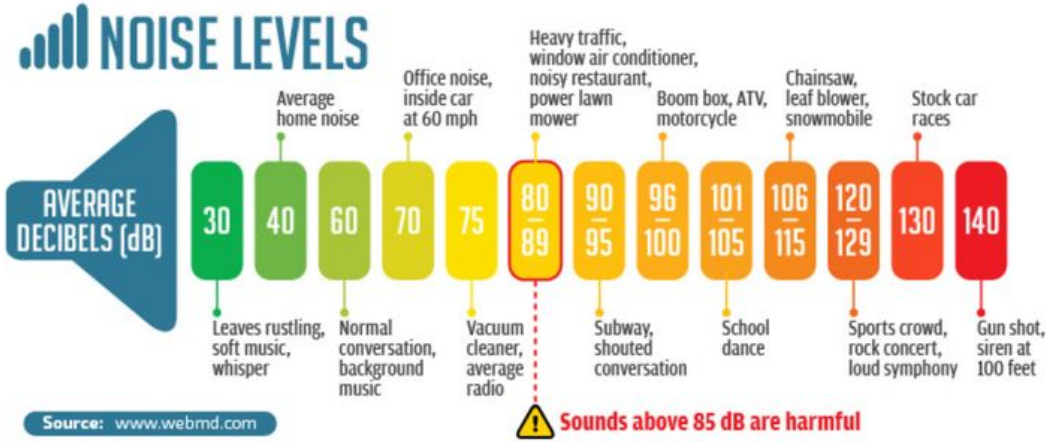


Image Courtesy of Software Motor Company

Early-production system louder than baseline

94 dBA for smart motor; baseline motor 79 dBA

- Facility staff said hearing protection would be needed to work in enclosed space
- Manufacturer has worked to resolve this issue. Prototype 20 hp motor with a 10 hp load, 81 dBA



Limited Direct Access to Settings

Can’t read settings directly on motor

- Facility staff missed being able to directly read parameters with VFD drive
- Can connect motor directly to computer to view and set parameters

Baseline VFD Drive

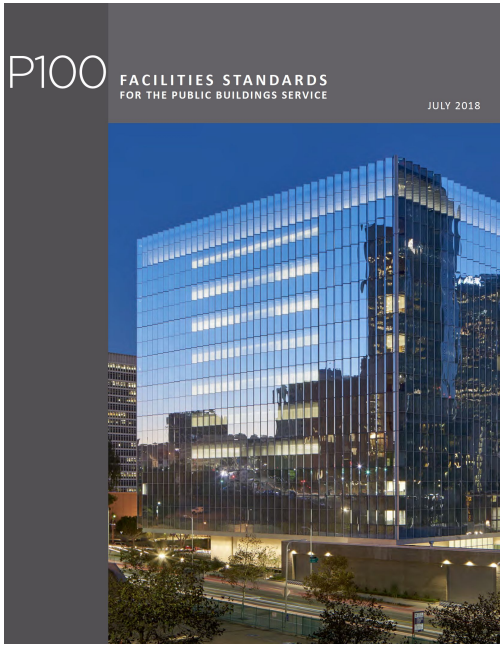
Real-Time Monitoring and Control

Provides access to all parameters as well as fault detection and diagnostics

- Not tested in GSA evaluation due to timeline for IT-Security clearance
- Tested in NREL evaluation. Motor remotely turned off after a piece of foam lodged in the fan preventing possible motor damage

About Half as Expensive as Incumbent State-of-the Art

- EISA 2007 mandates 1-to-200 hp premium efficiency motors
- GSA's facilities standards guide, the P100, requires a VFD on all motors larger than 5 hp.
- Testbed Costs:
  - Baseline: 10 hp motor ($1,756) + VFD ($2,619) = $4,375
  - 10 hp smart motor = $2,430
    (made in China, needs Buy American Waiver)



Immediate Payback at End of Life

	Premium Motor + VFD	Smart Motor (Retrofit)	Smart Motor (End-of-Life)
10 hp motor cost ($)+	$4,375	$2,430	$1,945 less expensive
Installation ($)++	$948	$948	$0, no change
Technology electricity use (kWh/yr)	31,700 kWh	30,400 kWh	1,300 kWh annual energy savings
Technology electricity @ $0.11/kWh ($/yr)	$3,516	$3,371	$145 annual cost savings @ $0.11/kWh
Simple payback (yrs)		**23**	**Immediate**

+ Premium motor ($1,756) & 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 application requires laser alignment to align pump and motor.

Deployment Recommendations

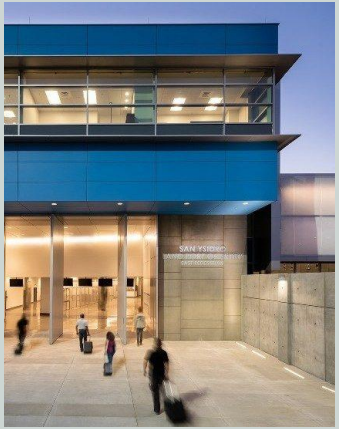
- Smaller motors offer greater relative savings
- Savings more than double for motors without VFD control
- Replacement of motors < 25 hp more cost-effective than repair
- Large potential for RTUs in commercial office space
- Cloud-based connectivity could be beneficial to GSA

Deployment Recommendation

Best Use Cases

- End-of-life replacement
- Retrofits
  - Constant-speed motors
  - Motors < 5 hp
  - Applications with lower installation costs, such as fans

GSA Feedback—San Ysidro Land Port of Entry



Mike Green
Chief Engineer
Land Port of Entry
San Ysidro, California

Jeremy Sawicki
Building Manager
Land Port of Entry
San Ysidro, California

Installation

- Installation more time consuming for a motor on a pump
  - 12 hours to use laser alignment for pump & motor
  - Had existing VFD that we kept for the evaluation so needed additional mounting hardware
- Fan motor installation would be 2-4 hours

Maintenance

- Less maintenance because bearings sealed
- No electrical arcing across the bearings

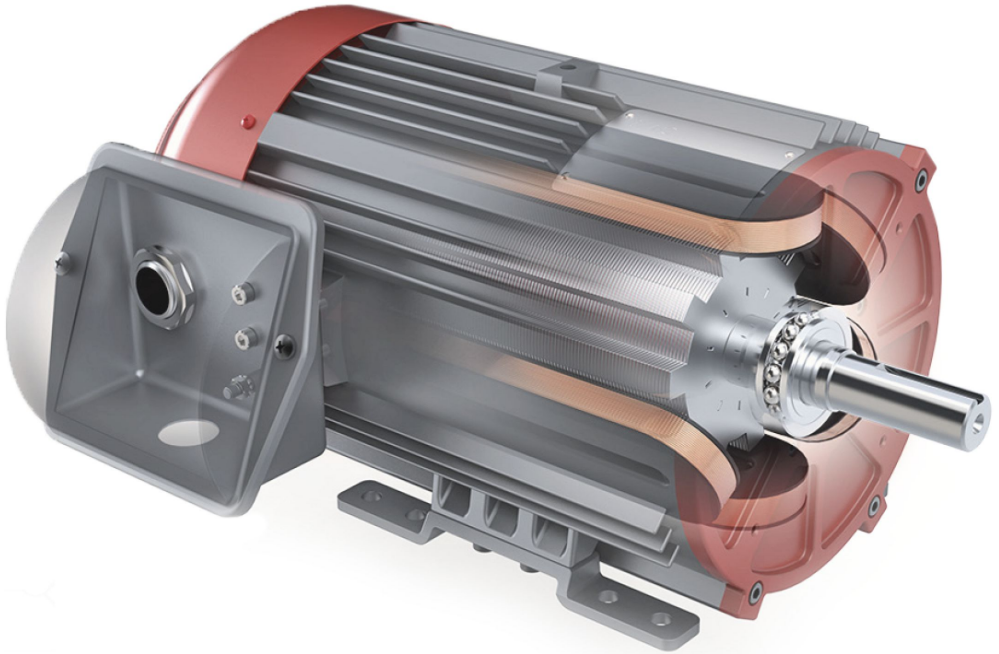


Image Courtesy of Software Motor Company

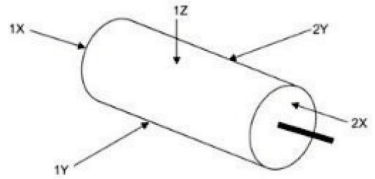
Operations

- Noise definitely an issue. More than 1 smart motor would be unacceptable at current levels; might not be an issue if it was on a rooftop unit away from occupied spaces.
- Missed real-time visual output from LCD screen. Biggest complaint on VFDs is that someone changes parameters without us knowing. Visualizing performance can head off problems before they occur.

Sound Results (Full Load)

Test Motor	Sound (dB)				
	2X	1Y	2Y	1X	1Z
Baldor Motor	N/A	78.0	N/A	80.0	79.7
SMC Motor	N/A	96.2	N/A	92.5	92.2

*All readings taken 1m away from center of motor



Recommendations

- Deploy based on performance and cost savings and potential long-term savings from a more robust motor design with less maintenance.
- Test new design to ensure that the the noise issue has been resolved.
- Clear software with GSA IT-Security to enable remote monitoring and control.

Q & A

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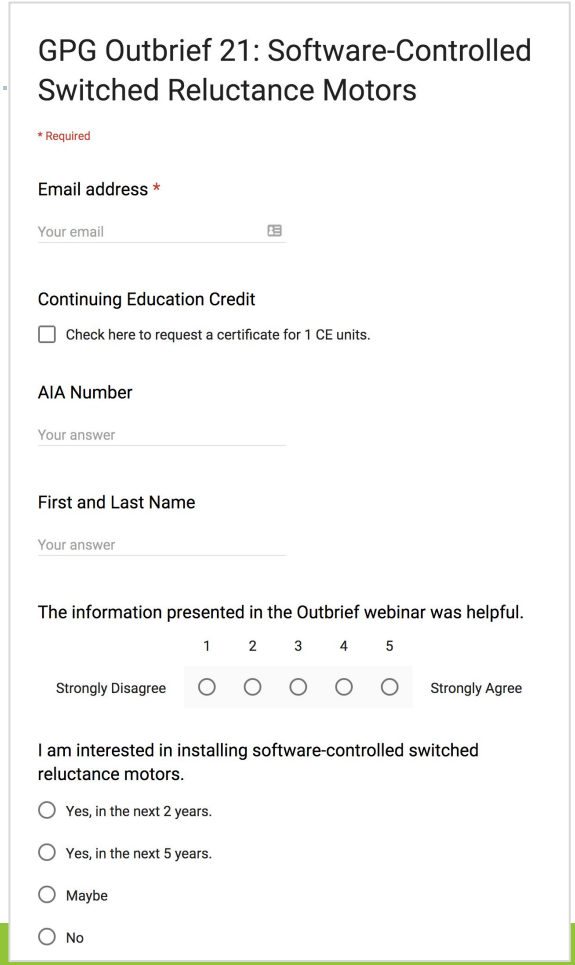

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Your answer

First and Last Name

Your answer

The information presented in the Outbrief webinar was helpful.

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

I am interested in installing software-controlled switched reluctance motors.

- ○ Yes, in the next 2 years.
- ○ Yes, in the next 5 years.
- ○ Maybe
- ○ No

Thank you

For more information: gsa.gov/GPG

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