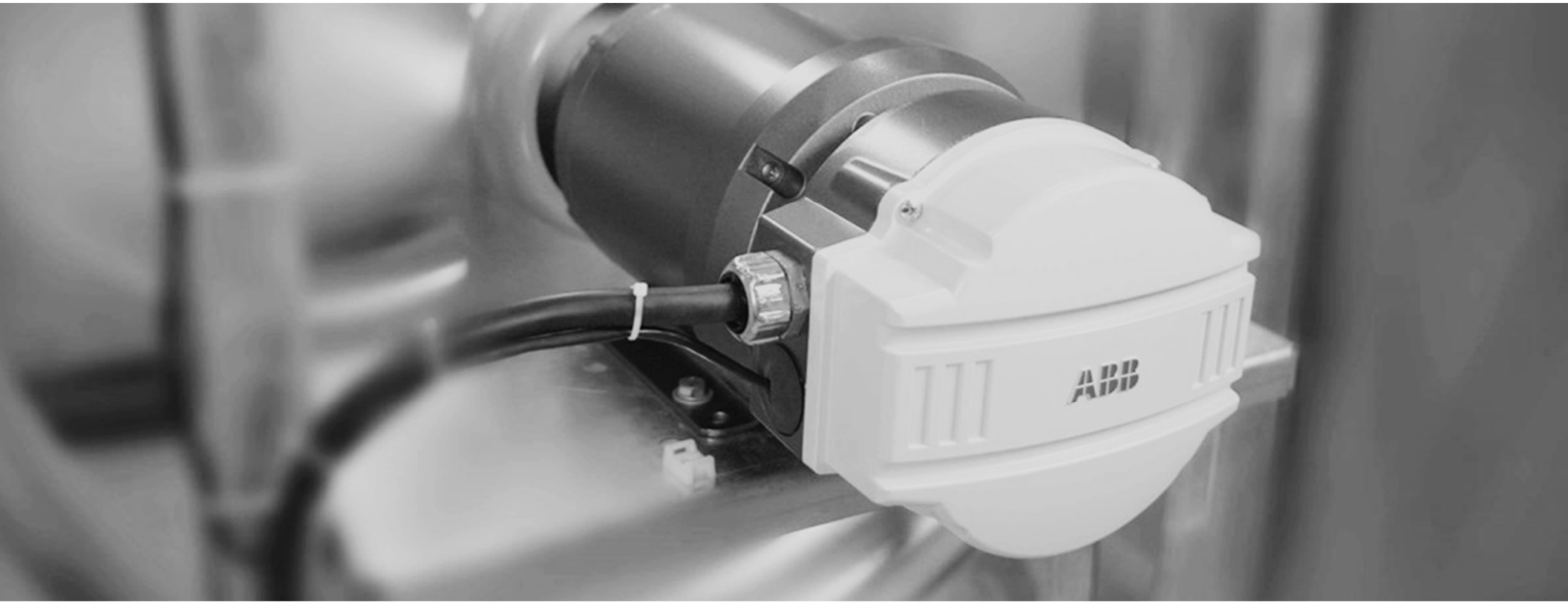


MARCH 2021

Basics of Ferrite-Assisted EC Titanium Motors

Next-generation motors to optimize system design and performance

Mark Gmitro, Global Product Manager – Variable Speed AC Motors

EC Titanium™

Beyond EC Efficiency and Performance

Product Information Link

Mark Gmitro, Global Product Manager
Variable Speed AC Motors, ABB Motors & Generators

Greenville, SC
(864) 270-8496
mark.gmitro@us.abb.com

EC Titanium Web Page

The all-new Baldor-Reliance® EC Titanium™

Ultra Efficient - Innovative Magnet Technology – Sustainable – Reliable - Wirelessly Connected

Top Mount IMD			Motor only		Axial Mount IMD		
1 – 10 HP	NEMA 140, 180 & 210 frames		1 – 20 HP	NEMA 140, 180, and 210 Frames	1 – 7.5 HP	NEMA 140 and 180 frames	
1-Phase Input	1 HP 115V	1-2 HP 230V		230V/460V 3-Phase input	1-Phase Input	1 HP 115V	1-2 HP 230V
3-Phase Input	1-5 HP 230V	1-10 HP 460V			3-Phase Input	1-5 HP 230V	1-7.5 HP 460V

The all-new Baldor-Reliance® EC Titanium™

Features that improve performance

IE5 Efficiency – Stay Ahead of the Curve
- High Total System Efficiency at full and partial load

Minimizing your Environmental Impact
- Sustainable Non-Rare Earth Magnet Material
- IE5+ Efficiency – Low Energy Use

Together as One – Cut the Cord
- Integrated motor & drive
- Eliminate expensive wiring and installation time
- Reduce personnel risks and access hazards
- Reap the benefits of pairing the drive together for better energy efficiencies

Plug and Play
- Pre-programmed motor & drive to run out of the box
- Easy Start-up – Keypad, PC or Mobile Tools (option)
- Bluetooth Option for ABB Ability™ and Mobile Tools

Reliability & Low Noise
- Extremely low starting current and less cogging
  Reduces mechanical stress and produces ultra- quiet operation

Power Density
- Higher ratings per frame size than traditional motor designs
- Reduces cost and saves valuable space

EC Titanium™

IP54 Rated Enclosure
Conformal coated drive components

Drive Pre-Wired & Programmed
Designed to Run out of the box

Bluetooth Setup & Control
ECM Tools PC & Mobile

Built-in ABB Ability
Web portal data and trending information

IE5+ Efficiency Guaranteed
Ferrite Assisted Synchronous Reluctance Rotor (FASR)

Shaft grounding brush standard
Eliminates bearing damage concerns

Low Noise Fan and Cover
designed for maximum cooling and quiet operation

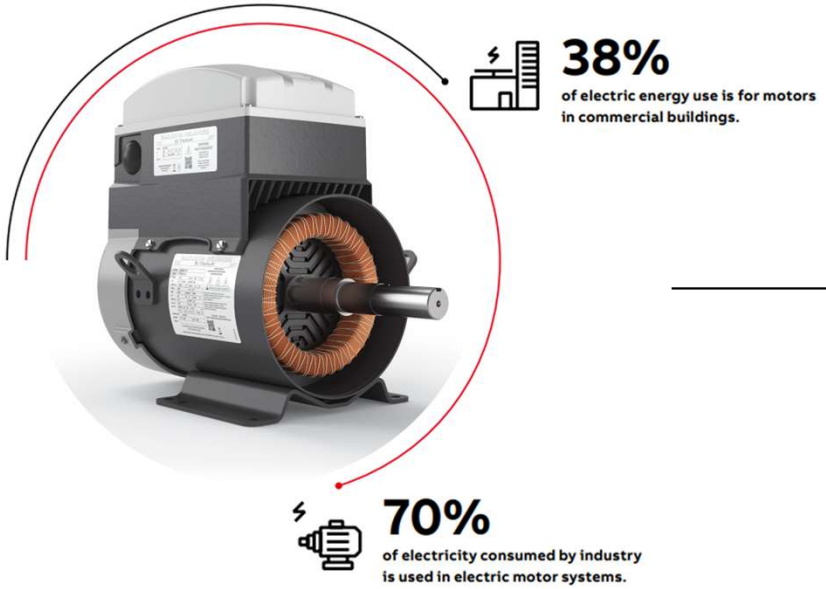
QR Coded Nameplate
easy access motor and drive technical data

Class B Temperature Rise
Longer component life & reliability for the product

Sealed Bearings & IP54 Rated Motor
No maintenance or re-greasing required
Resistance to water and dust ingress

EC Titanium™

IE5+ Super premium efficient design



Replacing 80% of industrial motors with IE5 class technology saves more energy than the annual power consumption of Poland.

Motor-driven applications are found throughout buildings to provide heat, ventilation and air conditioning.

Energy efficiencies

PUMP SYSTEMS account for **40%** of the total industrial motor systems electricity consumption in the U.S.

FAN SYSTEMS account for **20%** of the total industrial motor systems electricity consumption in the U.S.

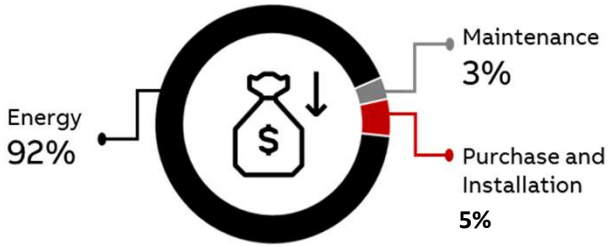
COMPRESSED AIR SYSTEMS account for **22%** of the total industrial motor systems electricity consumption in the U.S.

Is it worth upgrading? Savings and payback

Ultra-Premium IE5+ variable speed motors are highly efficient at full and partial loads.

- Up to 16% efficiency gain at partial load and speed compared to IE3.
- Up to 40% energy savings when combining drives to control motors.

The purchase price of a motor and drive is just a few percent compared to the energy spent to run the equipment over its lifetime.

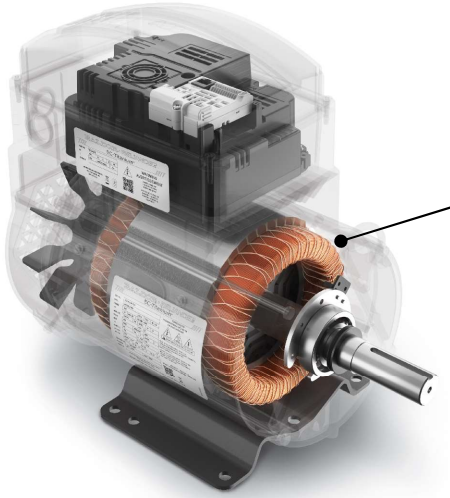


For low voltage motors, the **payback time is typically 2-3 years** in the case of a replacement. When considering a new investment, the typical payback time for a higher IE efficiency class is less than one year.

FASR Motors

Synchronous Reluctance - Ferrite Assisted Rotor Design

- FASR Motors operate on the same principle as induction motors for rotation
- Utilizes a standard induction motor stator winding
- SynRM rotors have flux barriers (air gaps in rotor)
  - Flux gaps direct the flow of current in the rotor
  - Eliminates losses normally associated with induction solid rotors
  - No Loss Rotor = higher efficiency (only losses in stator)
  - Power factor is low in the 70% range
- FASR adds Ferrites to Rotor
  - Ferrite materials add to torque generation and field strength
    - No current required ferrites = no losses and added field strength further improves overall efficiency (less losses)
    - Less work stator = lower losses overall = higher efficiency
    - Stator just supplies “torque on demand” beyond ferrite field strength allows optimization of current and partial loads
  - Improves PF to at least 92% and up to 98% range



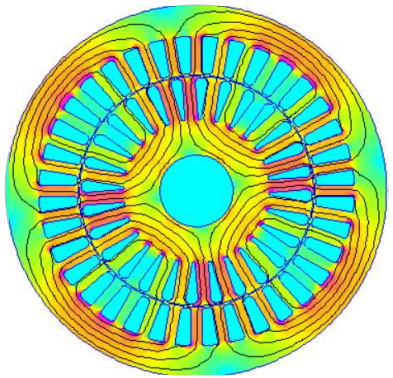
SynRM Rotor

Ferrite Material Added
FASR Rotor

Energy efficiency bands

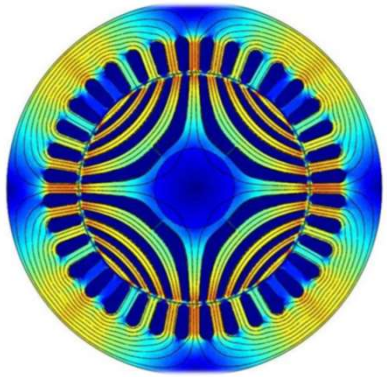
Each band of efficiency = 10% less losses in motor

Induction Motor — IE3

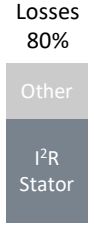


- Slip losses in rotor (I^2R)
- Heats up bearings and motor
- Lower efficiency adds to heat

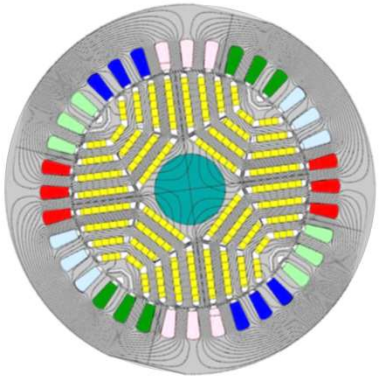
Synchronous Reluctance — IE4



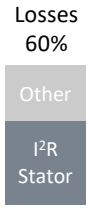
- Air gaps rotor direct magnet field lines
- Eliminates circulating currents
- Synchronous, no slip losses in rotor
- High efficiency and low motor temperature



FASR - Ferrite Assisted — IE5



- Same SynRM rotor benefits with the addition of ferrite material in rotor
- Increases field strength (more lines of flux) less work required stator
- Less overall losses, lower current draw and lower motor temperatures



Increasing density magnetic lines of flux (torque per amp)

FASR Motor Temperature Rise

Less Losses = Cooler Running Motor

Low temperature and reduced current draw

EC Motors have the advantage over induction motors and are cool running plus draw lower current than either induction or synchronous reluctance designs.

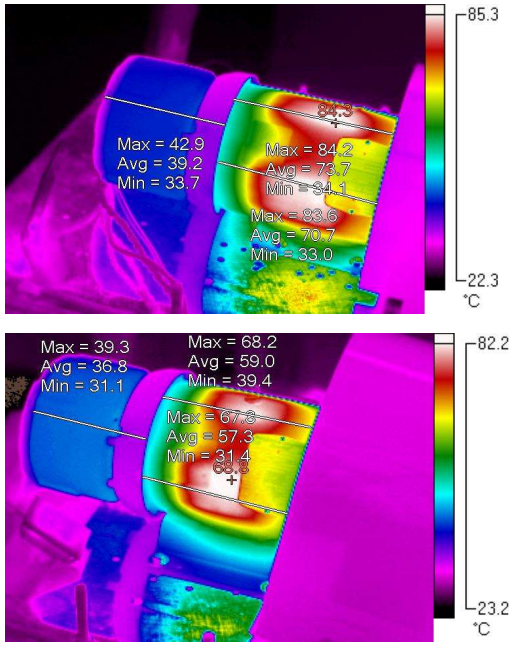
3 HP 1800 RPM FASR & Induction to 3.45 HP 2200 RPM EC Motor

Lab tested data, system efficiency (includes drive losses)

Lab Data	EC Motor	FASR	Induction
Amps	3.94	3.72	4.27
PF	90%	95%	66%
System Eff	88.1%	88.9%	86.4%
FRAME (°C)	36.64	38.27	46.64

FASR Motor

Max Temperature 68.2 °C



Induction Motor

3 HP TEFC 1800 RPM

Max 84.2 °C

4.27 Amps

EC Titanium Motor

3 HP TEFC 1800 RPM

Max 68.2 °C

16.2 °C lower temperature (20% cooler)

3.72 Amps

Motor Technology Comparison

Induction Motor (IE3)

Benefits

- Familiar and proven technology
- Starts Direct Across Line
- Easy to use and maintain

Limitations

- Speed accuracy difficult without sensors
- Slip losses in rotor (I^2R) adds heat to motor and bearings
- Lower efficiency at lower speed and partial loads
- Drive less efficient at lower loads due no load current

SynRM Motor (IE4)

Benefits

- High Efficiency IE4 to IE5
- Synchronous Speed
- Low bearing / winding temp.
- High power density
- Magnet Free – No losses rotor
- Easy to use and maintain

Limitations

- Requires Drive (VFD)
- Higher current demand
- Low power factor (~70%)

ECM (IE4 to IE5)

Benefits

- High Efficiency IE4
- Easy to use and maintain
- Well recognized in market
- Compact / light / built in control
- Packaged fan, motor & drive

Limitations

- Requires DC Drive Rectifier
- Lower efficiency at part speed / load inefficient power converter
- Must replace entire unit with fan, restricts OEM fan designs

– Rare earth magnets

Interior PM (IE5)

Benefits

- Very high efficiency IE5
- High torque density
- Excellent torque to inertia ratio
- Excellent PF
- Excellent partial load efficiency
- Low noise levels

Limitations

– Rare earth magnets / high cost / limited availability

- Difficult service (high magnet strength)
- High back-EMF (safety concern)
- Requires VFD

FASR (IE5)

Benefits

- High Efficiency: IE5+
- Synchronous Speed
- Sustainable Ferrite material
- Low bearing / winding temp.
- Excellent Power Density
- Lower current draw requires smaller power converter
- Maintains efficiency at low speed and partial loads
- High PF (above 90%)
- Drop in NEMA replacement

Limitations

- Requires VFD

FASR™ Motors

Fort Smith Manufacturing – same manufacturing – what you expect from Baldor

FASR motors share the **same building blocks as standard induction motors**.

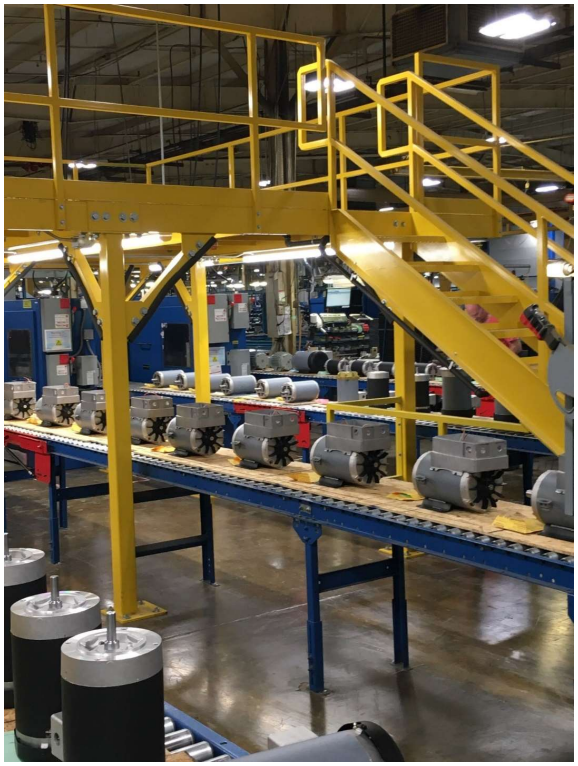
- Guarantees extreme high production capacity, manufactured Fort Smith, AR
- High product configurability and versatility for applications

Baldor Fort Smith Facility

- 303,000 square feet
- Moved to Ft Smith in 1956
- Current location since 1972
- ISO certified in 2006

Products

- 1-15 HP AC motors
- NEMA 140 -210 frame AC motors
- Steel band, cast iron, and aluminum housings



IEC Nominal Efficiency Limits

IEC 60034-30-1 Standard

IEC Efficiency Standards

IEC 60034-30-1 **Standard**

- Direct Line Motors or VFD
- Standard Induction Motors & Line Start PM
- IE1, 2, 3, 4

IEC 60034-30-2 **Technical Standard (New)**

- Frequency Converter Only
- SynRM, FASR (FA), Permanent Magnet Motors
- IE1, 2, 3, 4, 5

The purpose of IEC/TS 60034-30-2 is to create a level playing field between established and new, innovative motor technologies in order to enable fair competition and market development.

Efficiency Bands

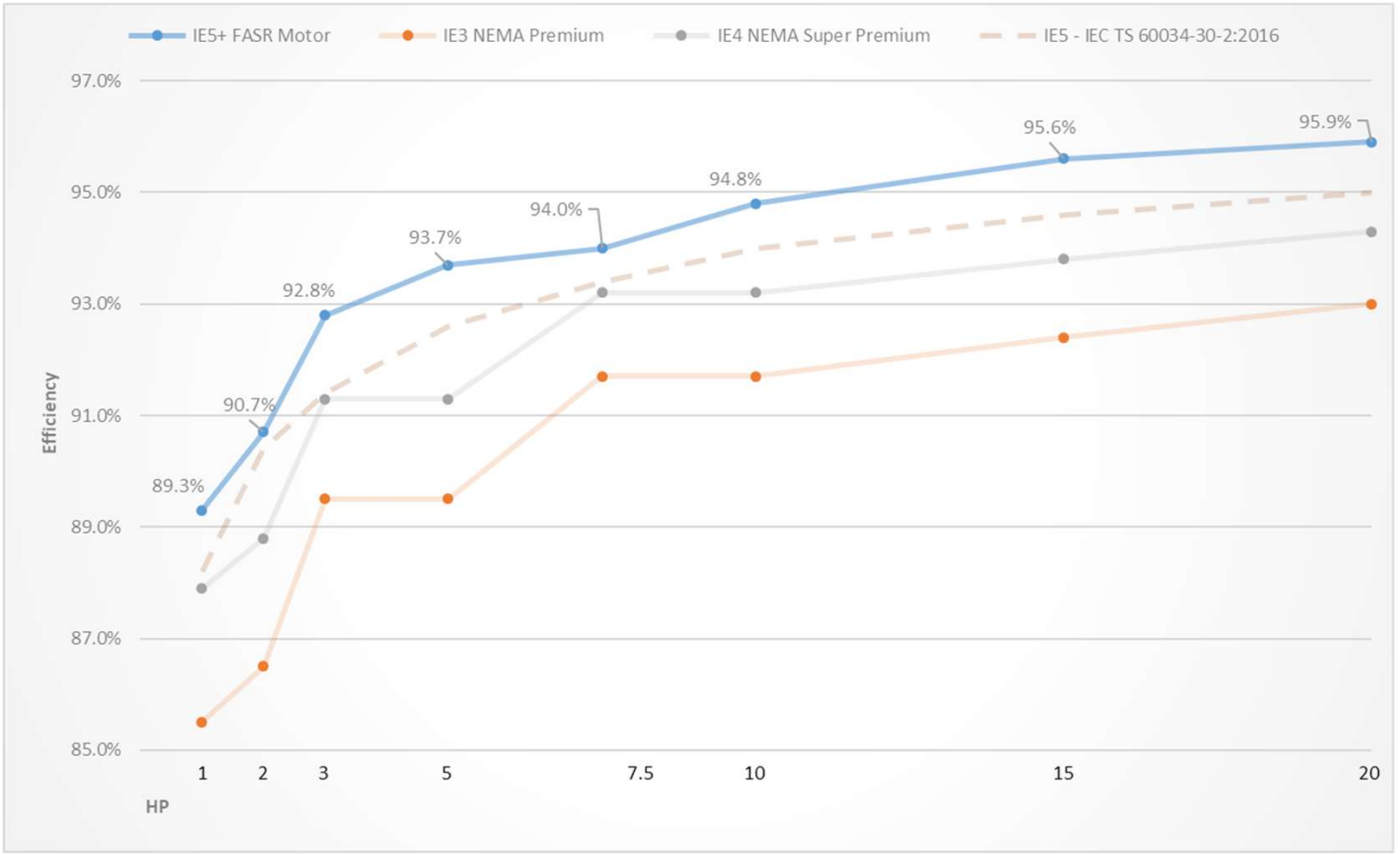
- IEC Defines Efficiency Bands Internationally
- NEMA Energy Efficiency in United States
- Each efficiency class equates to 20% less motor losses

IEC	NEMA
IE1	Standard Efficient
IE2	High Efficiency
IE3	Premium Efficiency
IE4	Super Premium
IE5	No Standard

Each band of efficiency = 20% less motor losses

FASR motors meet or exceed IE5 efficiency level

IE5+ Motors for variable speed drive applications



FASR Motor

Energy efficiency system savings

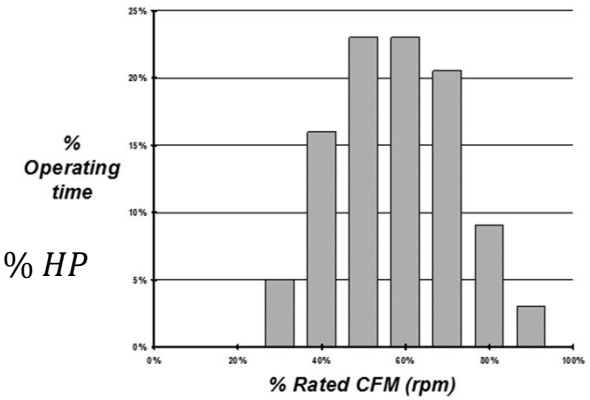
Affinity laws and energy savings

Variable speed control takes advantage of the affinity laws:

Flow is proportional to speed

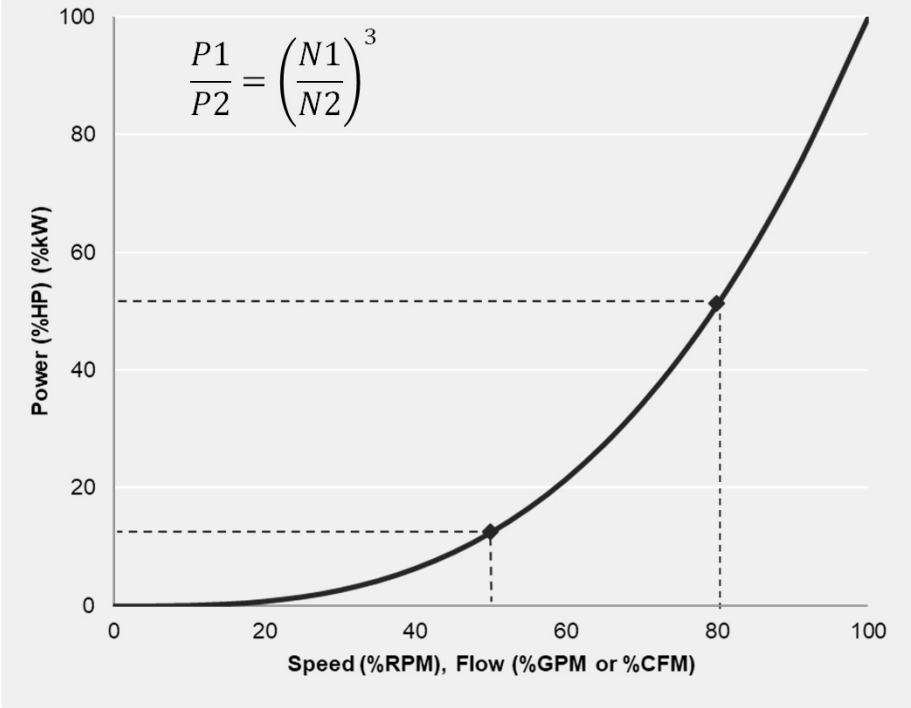
Power is proportional to the cube of speed:

$$\frac{P1}{P2} = \left(\frac{N1}{N2}\right)^3$$



Example: 80% flow:

$$(0.8)^3 = 0.512 \; or \; 51\% \; HP$$



Efficiency versus load

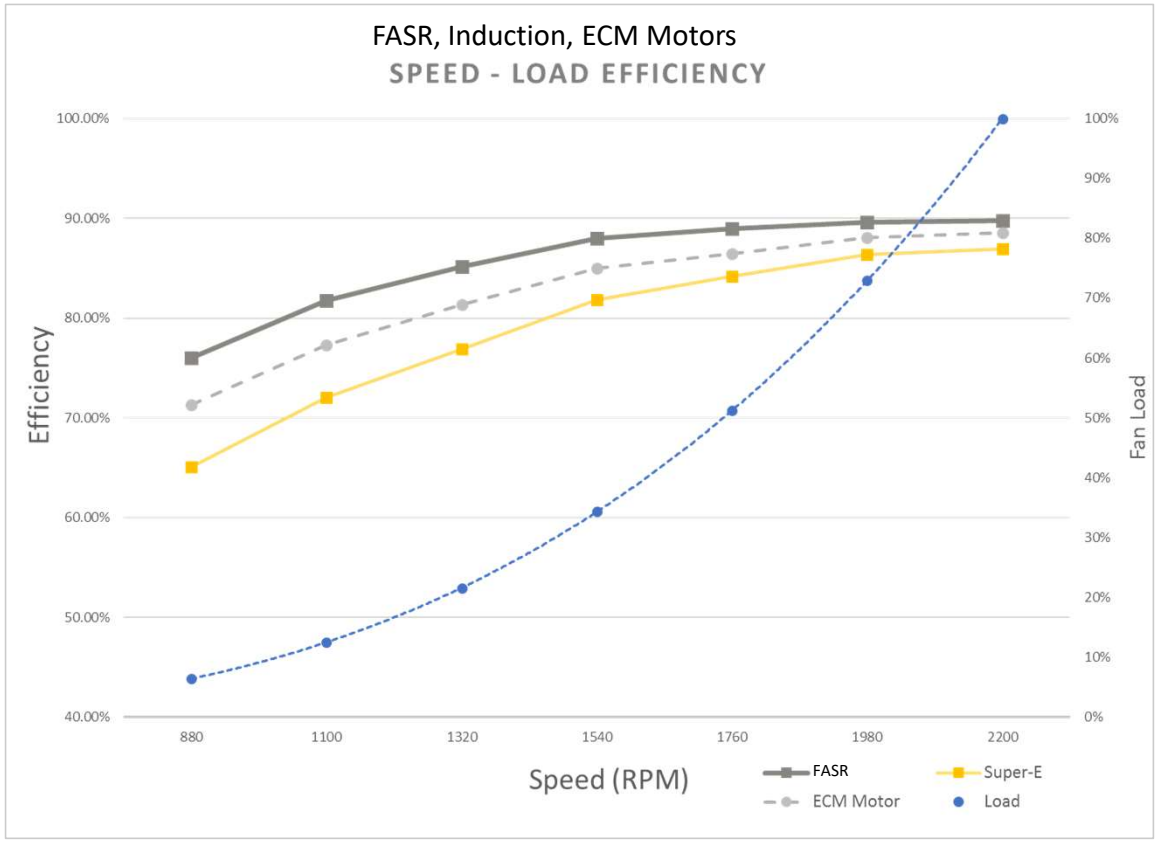
FASR, ECM, Induction Efficiency

System Efficiency (Motor + Drive)

Lab test including losses in power converter

3 HP, 1800 RPM base speed, 2200 RPM top speed
Variable Torque Load Profile

- Superior efficiency performance over other motor technology at rated and partial load speed points
- FASR wider speed torque range with higher efficiency allows more flexibility to match a fan impeller and reach a nominal fan duty point
- Other motor technology may have high efficiency, however it may be over a more a restrictive speed and torque range
- Potential to operate at higher speeds (constant horsepower range)



Large European Pump OEM

IE5+ EC Titanium test results

Customer – what did they test?

ABB ACS480 test drive both motors
400V, 50 HZ Power

Baldor's IEC IE5
EC Titanium Motor
11kW, 3000RPM

ABB's IEC IE5
SynRM Motor
11kW, 3000RPM

Test results and feedback

Pump wire to water

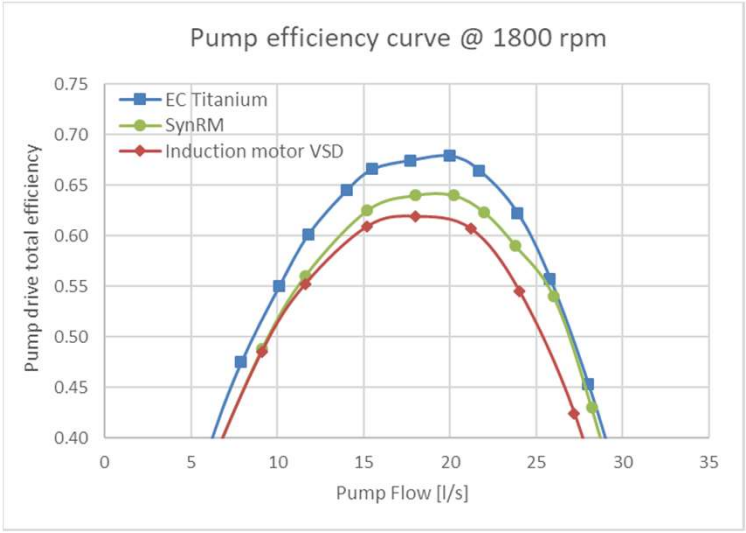
OEM efficiency test results:

67.9%	IE5 EC Titanium motor
64.0%	IE5 SynRM motor
60.7%	IE3 induction motor

Customer feedback:

"This high 67.9% was unexpected and it shows how much of a difference the ferrite assisted synchronous reluctance rotor (FASR) provides in overall
system efficiency."

"Even the same IE5 motor efficiency, can make a big difference in overall system efficiency performance."



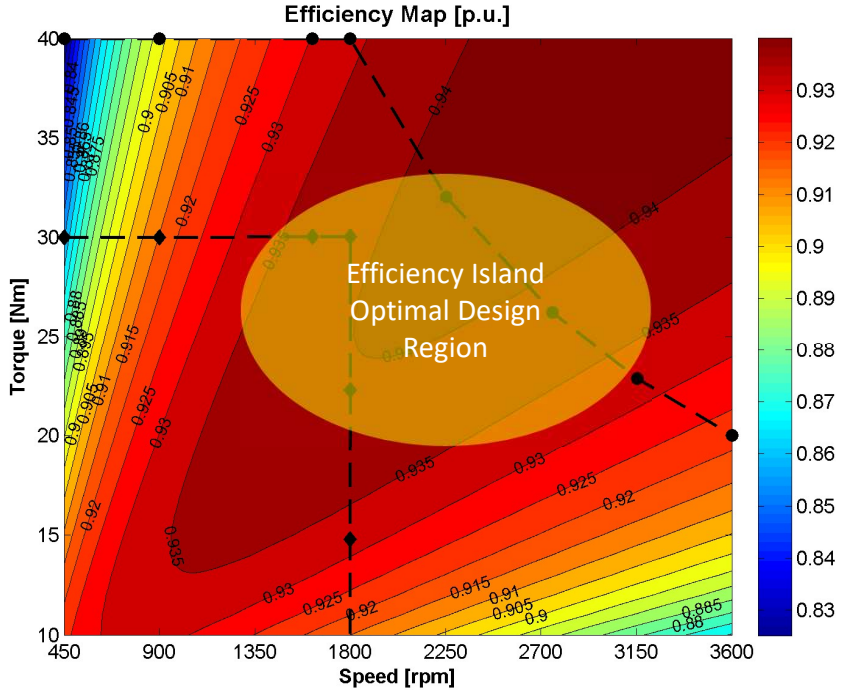
FASR Motor Efficiency Map

Best Efficiency Region – Efficiency Island

NEMA 180 – 7.5 Hp – Efficiency Map – 1800 RPM

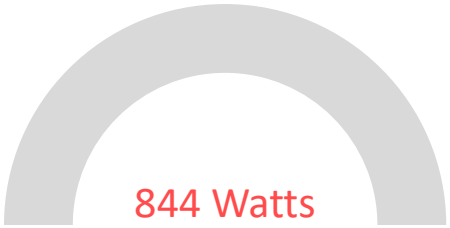
- Use of a lower base speed to run up to the fan speed is ideal for applications that run full speed and load the majority of the time.
- In this region, the fan can take advantage of the widest maximum efficiency band of any product available.
- Flexibility to choose more total combination of equipment and offer the best performance to OEMs designing air handling applications.
- The best total efficiency is built from the usage of best components in combinations that have been verified as IE5+ like FASR design.

$$\eta system = \eta drive \cdot \eta motor \cdot \eta coupling \cdot \eta fan \cdot \eta coil$$



EC Titanium™

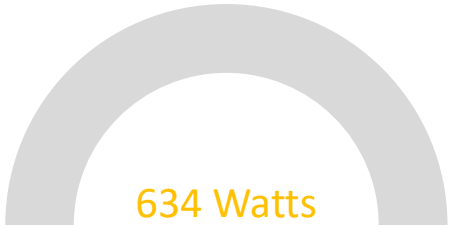
Customer Value High Return on Investment & Short Payback Analysis



844 Watts

NEMA Premium Induction Motor

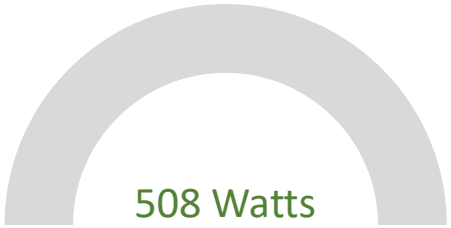
$725 Annual Cost Operation



634 Watts

Traditional EC Motor

$550 Annual Cost Operation



508 Watts

NEW EC Titanium

$445 Annual Cost Operation

Savings Annually
$110 to $290
20 to 39%

Note: calculations based on typical fan system duty cycle and lab verified test data

Voice Customer

Market Input

"We needed a product that allows us to **expand our HP offering range** resulting in a **30% sales increase**."

"The product has been instrumental in pushing back against packaged EC Fans and was **key in securing new business & customers**."

"As it came time to do the next gen - we decided to look at our fan design. Looked at competition with integrated fan/motor combination -- we knew we could have a better fan.

Decided on the EC Titanium -- **better performer and less expensive**, even adding the drive to it, and **better efficiency**. And it's more of a **standard motor** that is less restrictive for our fan designs, **allowing us to innovate**."

"**Compact design** allows airflow & less turbulent, and where space limited. Integrated **unit saves time** in total fan **assembly** by up to 35% 60% cost reduction.

Cell phone connectivity / easy to program / no cables / no special software and excellent technical support from ABB."

"We are replacing all competitor motor with EC Titanium motors, they are hard to source we prefer to use a **domestically manufacturing** product that is **in stock and available**"