



EPRI

ELECTRIC POWER
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Advanced Motor Technologies: why utilities are interested in them?

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How to approach motor technologies?

Why EPRI?

- We have in-house expertise on power electronics, motors and ASDs
- We have huge inventory of technical documents on motor/drive efficiency including best-seller “ASD Applications Handbook” which needs to be updated
- We are being asked by EPRI member utilities to effectively coordinate our efforts with organizations like CEE, NEMA
- We are being directed to seek opportunities to work with motor manufacturers and to establish demo projects to document the quantifiable benefits of different motor technologies

What is needed now?

- Development of guidelines for specifying and integration of existing technologies and/or those that are expected to be commercialized within the next 2-3 years
- The current trend indicates interest in new motor-based technologies as applied in the pump systems and industrial ventilation (e.g. fans)
- Utility target are small and medium industrial as well as commercial customers

How to do it?

Our customer expectations:

- Demonstration to be done at host utility service territory and that way technology can adapt to local/regional market conditions or rules
- Full-scale implementation will be phased in: over time, geography and systems integration

Deliverables to demonstrate:

- Lower Cost
- High Performance
- Less Disruptions
- Greater Satisfaction and Flexibility
- Efficient Use of Energy
- Greater Reliability

How to do it?

Key points for further consideration:

- **Present interest in new motor designs is in the small HP range (residential?)**
- **Could they offer a significant improvement for small motor-driven appliances and low HP (<10HP) commercial and industrial applications?**
- **How to match the current interest in motor efficiency with ongoing (upcoming?) new energy efficiency standards?**
- **How to explain the combination of motors and drives for better system integration?**
- **How to create opportunity for utilities to create their own energy efficiency programs around motors and drives, and applications?**

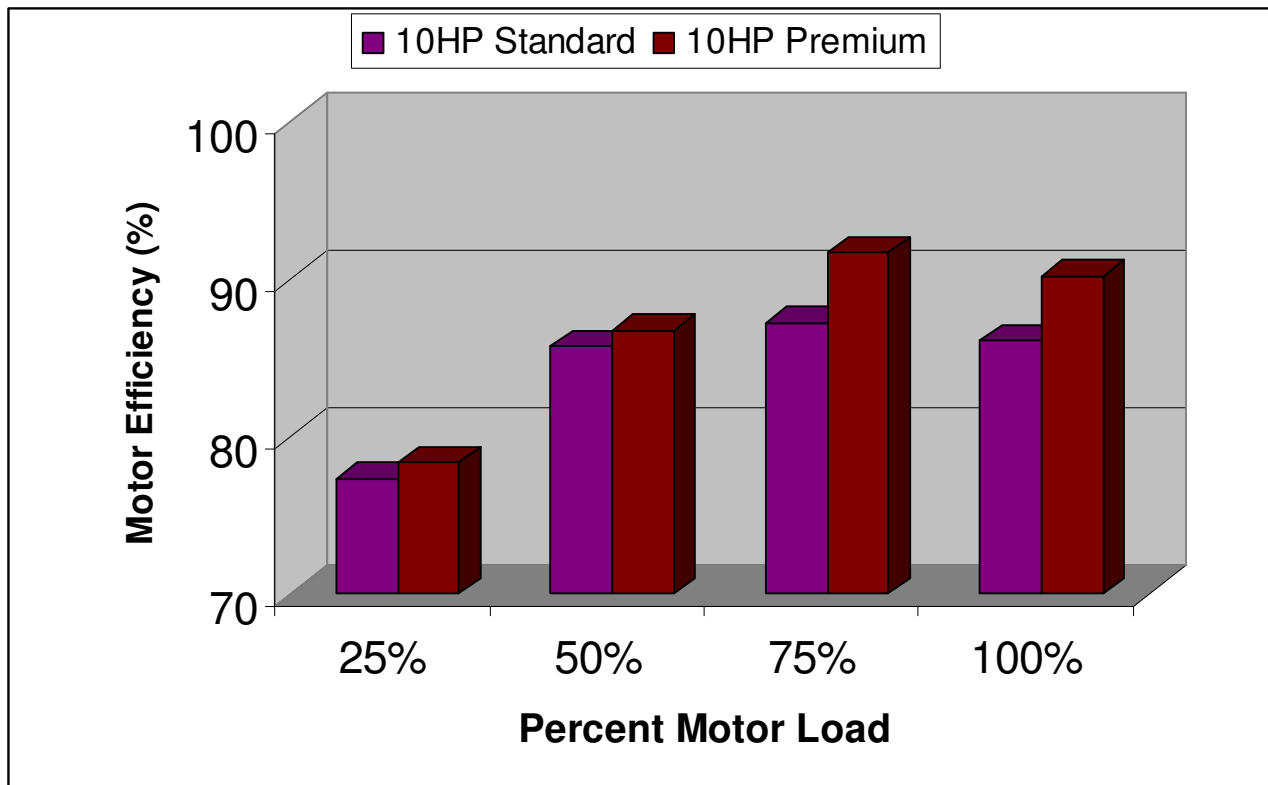
Advanced Motor Technologies: current questions

- What are the motor characteristics?:
 - Switched Reluctance
 - Vector Controlled
 - Permanent Magnet
 - Brushless DC
- What are the most likely applications?
- Why utilities should be familiar with these technologies?

Current Questions: What are Levels of Motor and Process Efficiency?

First Level Improvement

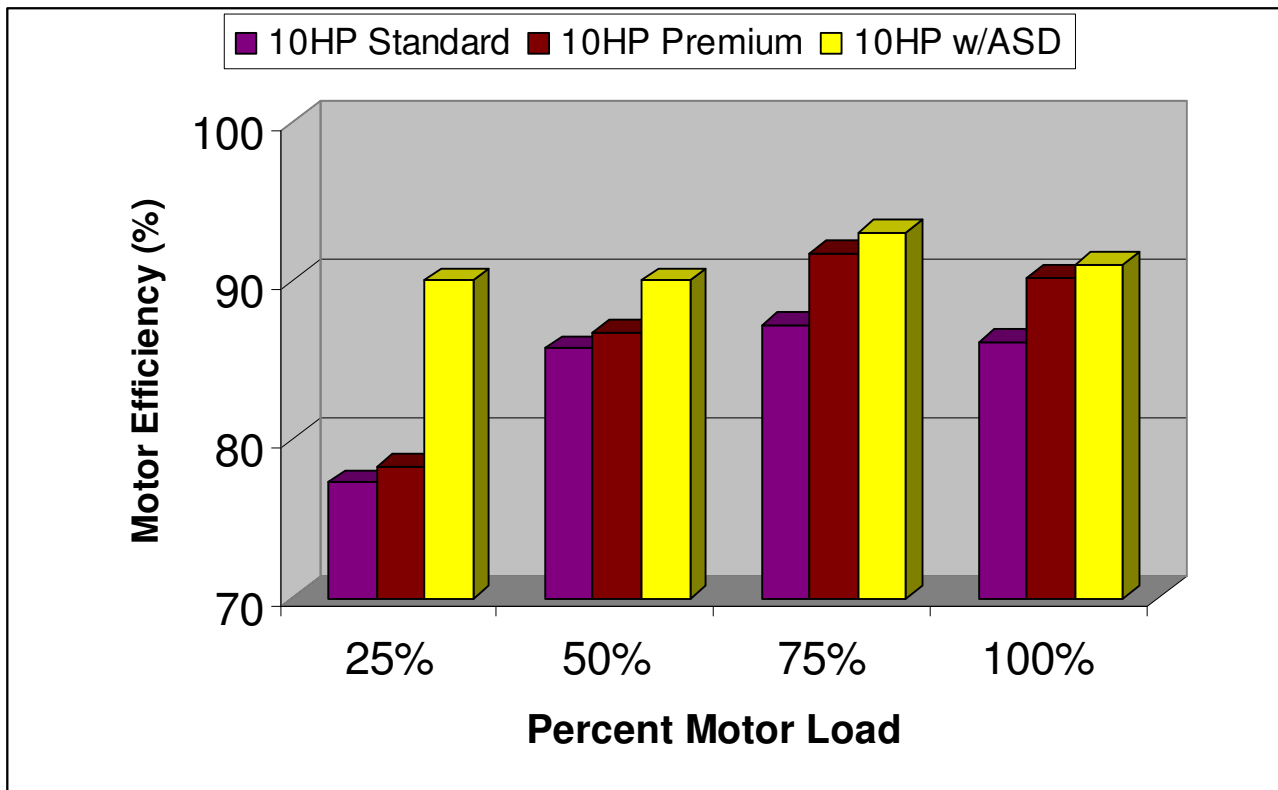
- Better (More Efficient) Motors
 - EPACK Standards
 - International Standard
 - NEMA Premium Efficiency



Current Questions: What are Levels of Motor and Process Efficiency?

Second Level Improvement

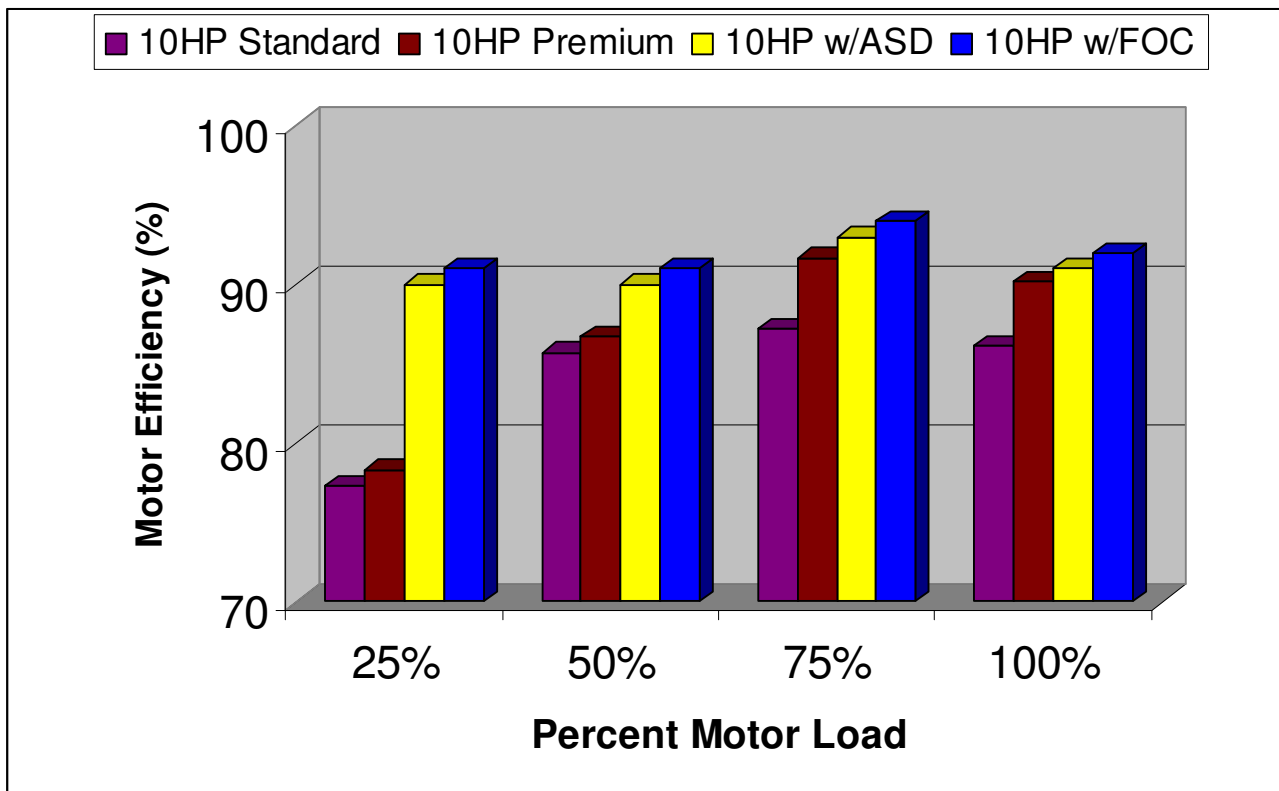
- Variable Speed Drives
 - 10%-50% Process Improvement
 - Application Limited
 - Widespread Acceptance



Current Questions: What are Levels of Motor and Process Efficiency?

Third Level Improvement

- Vector Control Drives
 - Improvement on ASD Efficiency
 - Opens up New Ap. Opportunities
 - Highest Efficiency at all Loads



Vector Controlled Motor Drives

- Vector control (also called field oriented control, FOC) is used in variable frequency drives to control the torque and speed of three-phase AC electric motors by controlling the current fed to the machine
- Vector-control drives use a method of controlling torque similar to that of DC drive systems
- The control improves upon the basic volts/hertz control technique (for traditional ASD) by providing both a magnitude and angle between the voltage and current
- Ideal applications include any process where constant torque is required over wide speed range such as:
 - Conveyors
 - Extruders
 - Printing lines
 - White goods
- Benefits include:
 - Higher efficiencies (10-20+%) compared to “motor only” applications
 - Better process flexibility and control

Example Vector Control Drives



<http://www.losungautomation.com/images/mitsubishi-pic.jpg>



<http://http://www.avespeed.com/list.asp?id=519>



<http://www.ssddrives.com/usa/Applications/converting.php>



<http://www.abb.us/caaw/usabb046/bd06218227444109c12570ae00641ed3.aspx>

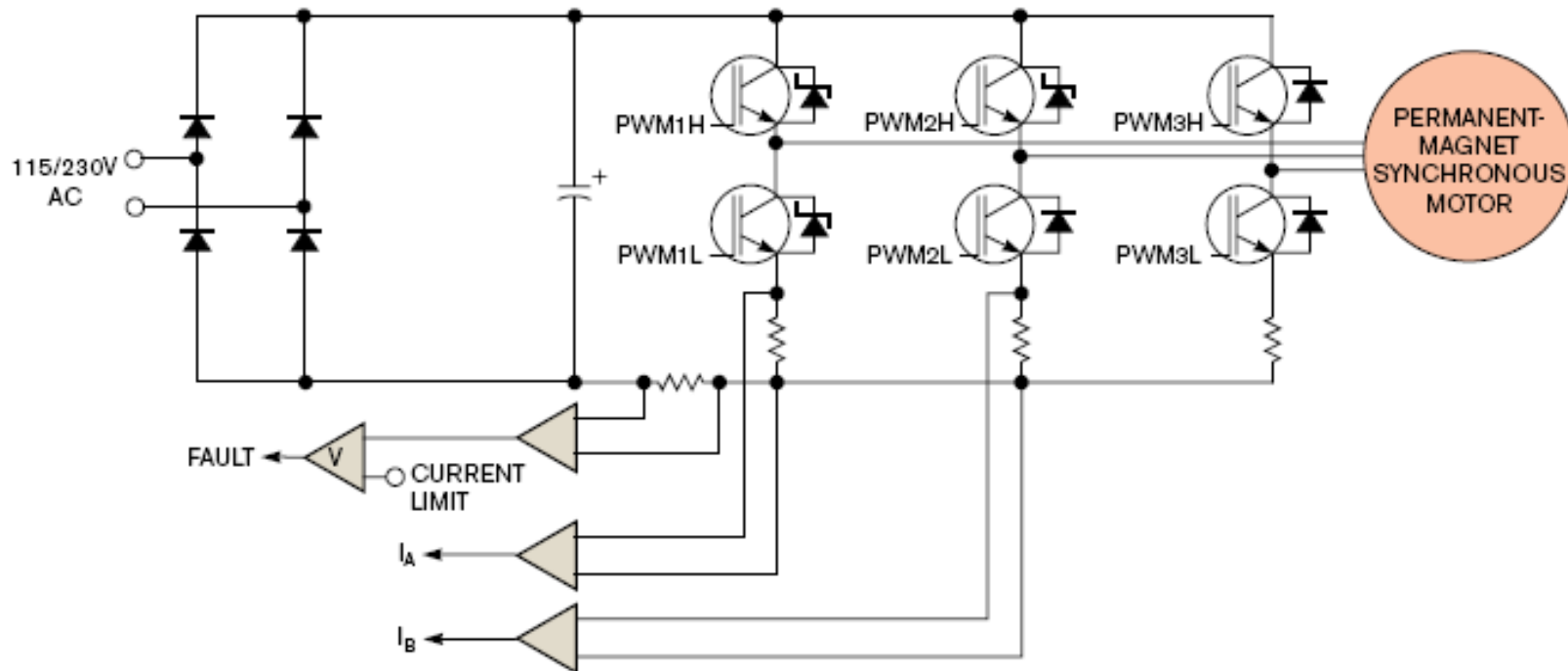
<http://www2.sea.siemens.com/Industry+Solutions/PulpandPaper/Pulp+and+Paper.htm>



Permanent Magnet Motor

- Motor Characteristics:
 - Two types available:
 - Brushless DC motors (BLDC)
 - PM Synchronous motors (AC)
 - Windings:
 - Stators: 3 phase windings
 - Rotors: Surface mounted permanent magnets – no windings
 - In use since 1990's
 - Choice of permanent magnets: Neodymium-iron-boron [Nd-Fe-B], samarium-cobalt [Sm-Co], alnico, and hard ferrite [ceramic]
 - Permanent magnet rotors – reduce copper cost because no rotor windings
 - Low speed high torque possible
 - Permanent-magnet motors are more efficient than ac-induction motors, but require more sophisticated control circuitry.
 - Primary usage – less than 2kW operations
 - Small foot-print – ideal for space constraint applications

Permanent Magnet Motors – Schematics



- Permanent magnet motors require micro-processor and complex circuitry to control the speed of the motor.

Permanent Magnet Motor - Applications

Typical application parameters

| Voltage | Motor power | Speed range | Features |
|---------------|-------------|------------------|--|
| Up to 380 Vac | Up to 3 kW | Up to 30,000 rpm | High torque capability at start-up and low speed Highly efficient and compact |

Main applications

- Dishwashers
- Washing machines
- Electric traction
- Robotics

Source: <http://www.st.com/stonline/products/promlit/pdf/brmotor0509.pdf>



Photo Courtesy: www.whirlpool.com



Photo Courtesy: <http://happyhomemaker88.files.wordpress.com/2007/11/washing-machine.jpg>

Brushless DC Motors

- **Motor Characteristics:**
- Practically maintenance free operation – absence of commutator rings – wear & tear
- High efficiency compared to ac induction motors
- Flexible torque-speed characteristics to match the load requirements
- Permanent magnet rotor means no windings on rotor – simplified design
- Solid-state switches used to convert 3-ph or 1-ph ac to dc – no commutator needed
- Fractional hp to high hp available
- No arcing – high speeds and torque applications



Figure 1 a: ECM Motor from GE (Courtesy: GE Industrial)

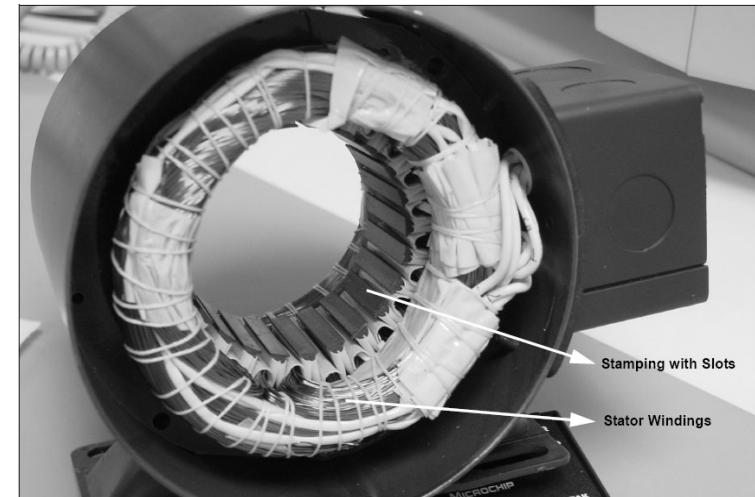
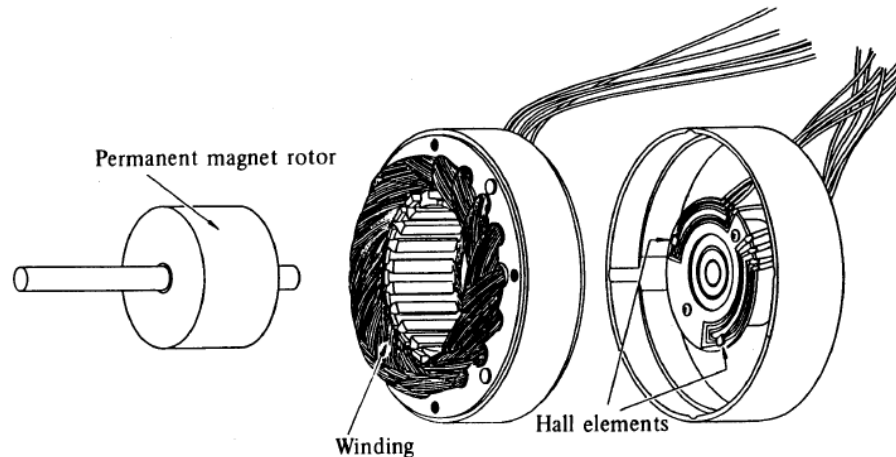


Figure 1 b: Cross Section of the Stator of BLDC motor
(Courtesy: Microchip, AN885)

Applications of BLDC Motors – 1

Industries Using BLDC Motors:

- Appliances
- Automotive
- Aerospace
- Consumer
- Medical
- Industrial Automation Equipment



Courtesy: http://services.eng.uts.edu.au/cempe/subjects_JGZ/ems/ems_ch12_nt.pdf



Photo Courtesy:
<http://www.slmti.com/blc/default.asp>



Photo Courtesy:
http://dev.emcelettronica.com/files/node_images/bldc_brushless_dc.jpg

Applications of BLDC Motors – 2

Applications

- PC fans
- Ceiling fans
- Blowers
- Washing machines
- Electrical Power Steering
- Industrial drive
- Servo drives
- Electric vehicle traction drive
- Automotive applications
- Refrigerator
- Air-Conditioning



Photo Credit: (Electric Pump Application)

http://www.titantool.com/portal/int_740i_en_titantool,232081,230635.html



Photo Courtesy: <http://www.scootermobility.com/Electric-Scooters-EV-Rider-STAND-N-RIDE-1-258-1862.htm>

Speed/ Voltage Characteristics of BLDC Motors

Application Parameters

Industrial

| Voltage | Motor Power | Speed Range |
|---------------|-------------|----------------|
| 100 - 240 Vac | 50W -2.2 KW | 0 - 20,000 RPM |

Automotive

| Voltage | Motor Power | Speed Range |
|---------|----------------------|----------------|
| 12/42V | several watts to 1kW | 0 - 15,000 RPM |

Source: http://www.freescale.com/webapp/sps/site/application.jsp?code=BLDCMTR&tab=In-Depth_Tab

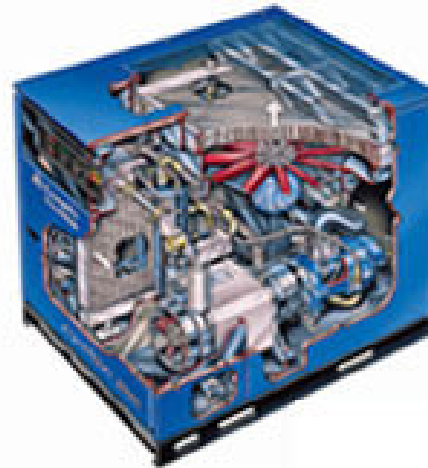
Advantages of BLDC

- Efficiency: Typically brushless motors (BLDC) are
 - 5-10% better than typical AC induction motors
 - 8-12% better than brush DC motors.
- Can operate in wider temperature ranges
- Have higher torque to inertia ratios – have greater acceleration
- Higher reliability than DC motors even at high speeds because no brush wear
- Safer in explosive environments – because no arcing
- Quiet operation – no commutation
- Sensorless speed control possible

Switched Reluctance Motors

- Switched-reluctance (SR) motors were originally developed in the 1800s
- The SR motor is essentially a drive/motor combination with unique rotor and stator design
- In terms of energy efficiency improvement SR motors are ideal candidates for a range of residential appliances, industrial processes, and even automotive and off-road
- Capabilities and Benefits Include:
 - 90+ % Efficient across a wide load window
 - Size ranges from fractional HP up to 200 HP
 - Variable speed operation, Direction reversibility, Torque curves comparable to DC motors

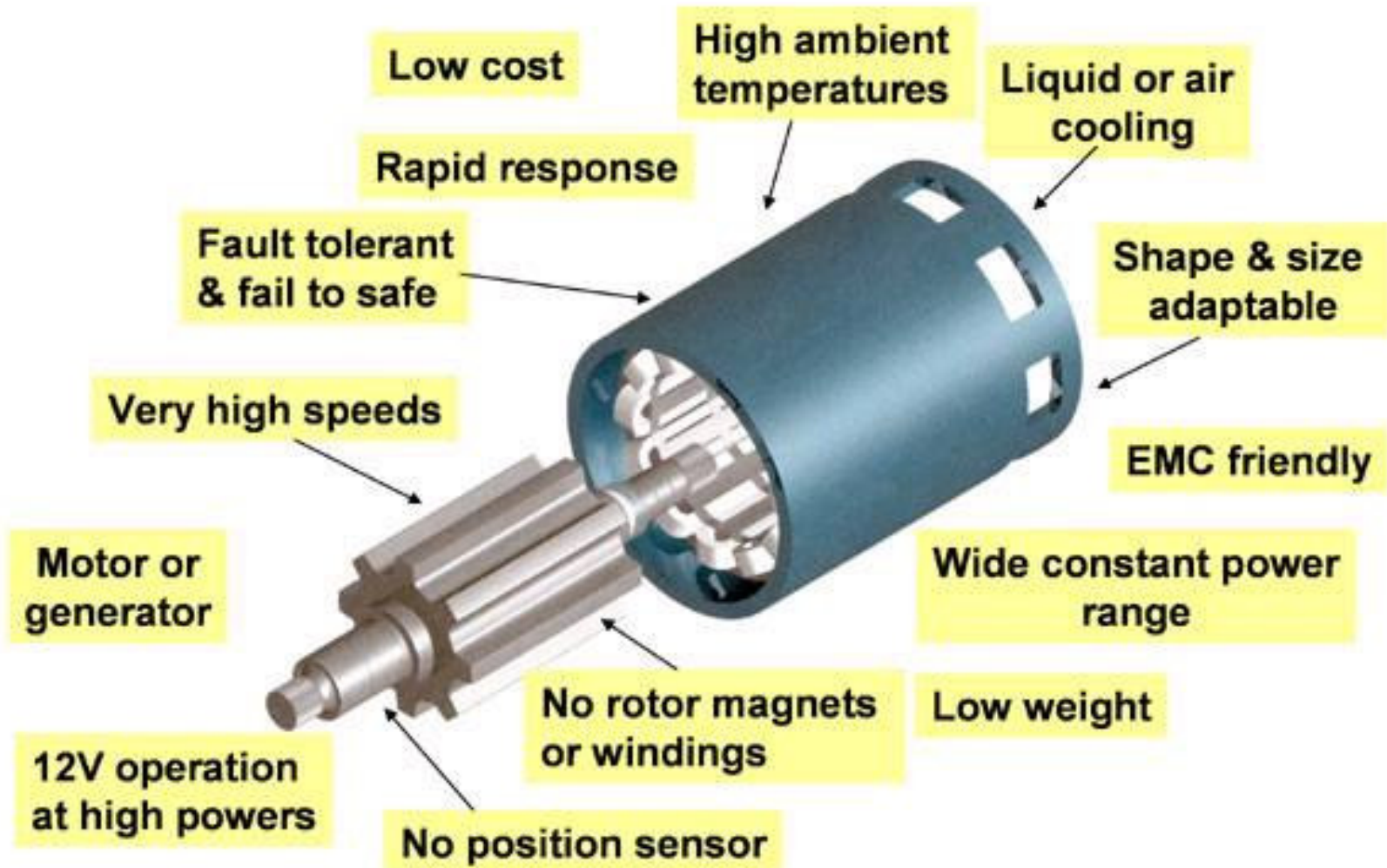
Applications Range from Home Appliances, Automotive and Aerospace, to 200HP Industrial

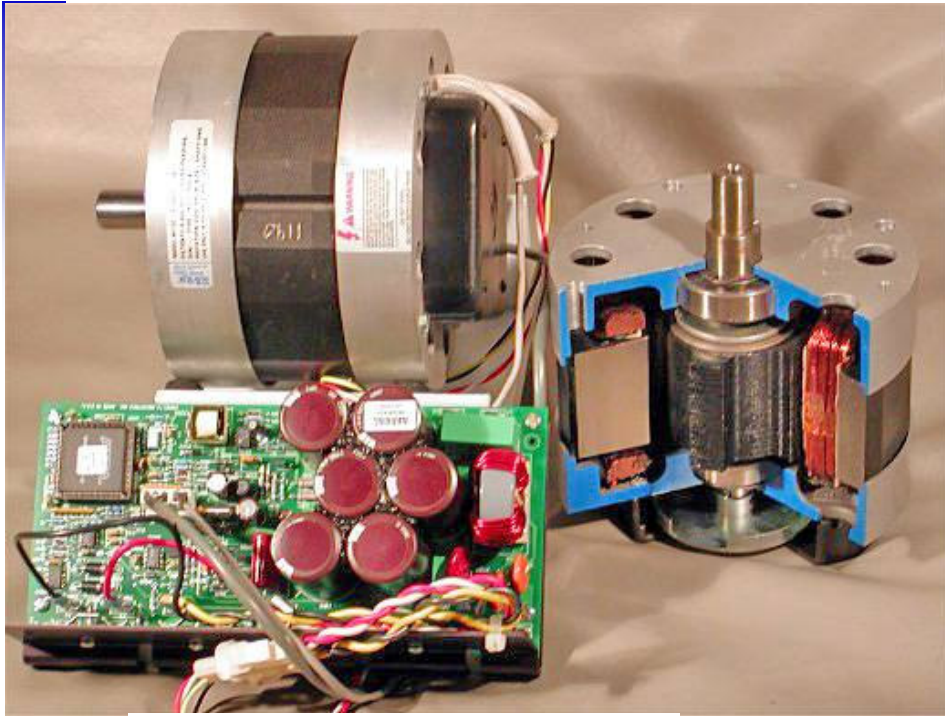


All photos on this slide - source: <http://www.srdrives.com/>

Switched Reluctance – SR Motors Key Features

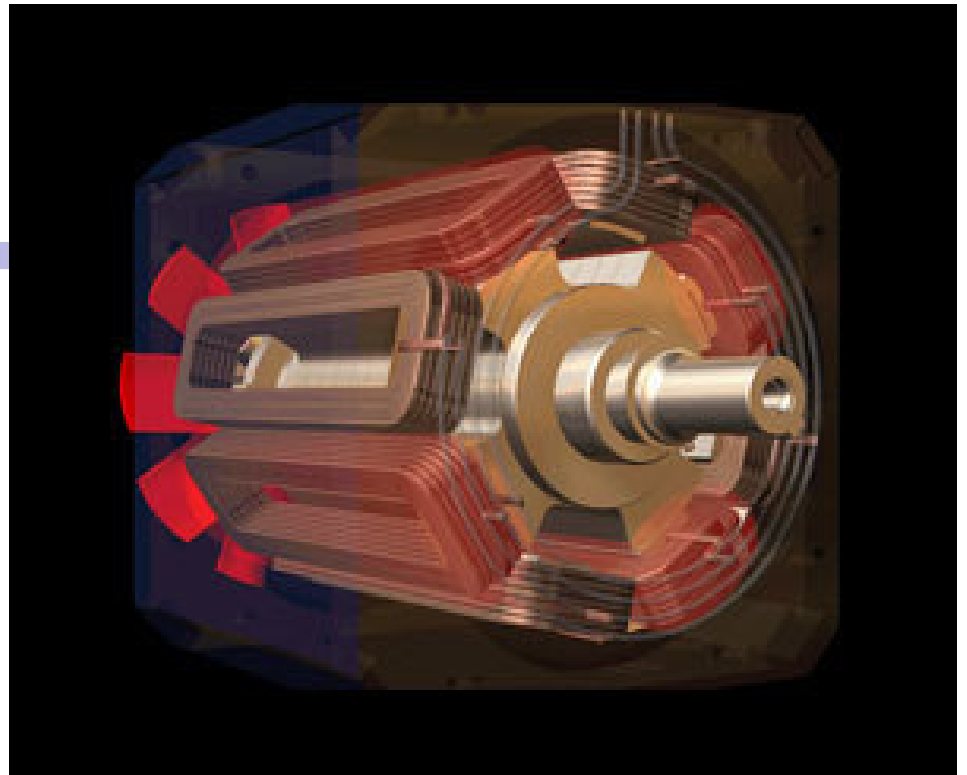
Source: <http://www.sovereign-publications.com/images/srdrives/picture1.jpg>





<http://home.planet.nl/~sintt000/Relux.jpg>

<http://www.srdrives.com/>



http://www.compair.com/popups/SR_drive_popups.aspx

<http://www.srdrives.com/washing-machine.shtml>





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