Are permanent magnet drilling motors the next generation? Manufacturers still disagree

By Jerry Greenberg, contributing editor

ELECTRIC MOTORS HAVE been an integral part of the drilling industry for decades. They provide the means to drill a well – powering the drawworks, pumping fluids down the wellbore and separating cuttings upon their return. When the industry began building jackups, electric motors enabled the lowering of legs to the seafloor and the raising of the platform above the waves. On deepwater rigs, they were used to draw in the anchors and to power thrusters on dynamically positioned semisubmersibles and drillships.

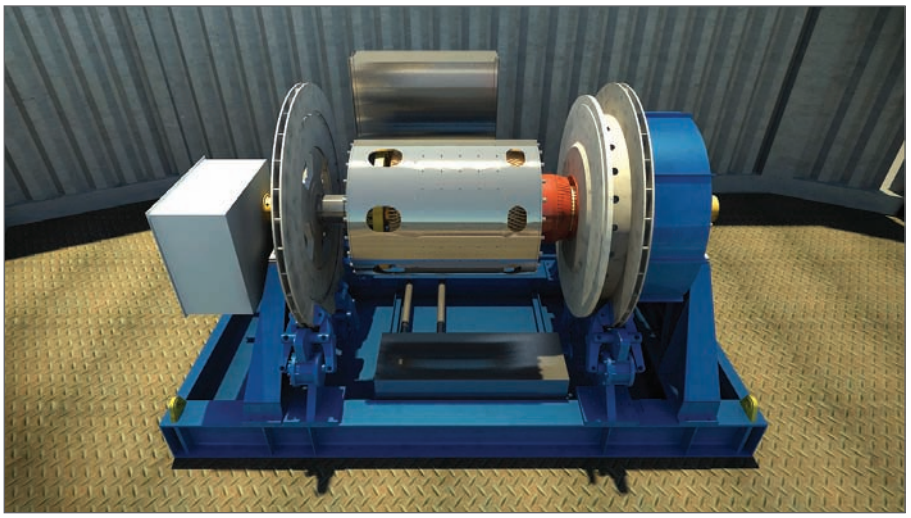
Since the commercialization of top drives in the early 1980s, motor manufacturers have turned their attention to motors specific to this use. Due to the severe operating conditions of a top drive system, electric motors for this application are the most robust, durable and reliable in the industry. They must withstand jarring, vibration and heat not typically found in other drilling operations. As a result, the industry has improved electric motors for top drives and has found motors for drilling vertical, directional, extended-reach and horizontal wells with "ease."

The industry has also moved from the initial DC electric motors to AC motors, which gained acceptance in the early 1990s and have built about an 80% market share. Nearly all of today's newbuild rigs, land and offshore, use AC power for drawworks, pumps and top drive systems. Some people even believe it won't be long before DC motors are eliminated from the industry.

Perhaps the next step in the evolution of electric motors for the drilling industry are permanent magnet (PM) motors. They are presently used in the oil and gas processing industries and for propulsion, primarily in the cruise vessel industry. They are also used in defense applications.

But they appear to be having a difficult time gaining entry to the drilling industry (though perhaps not any more difficult than AC technology's entry).

It could be that the time is not right. For example, PM motors are more expensive than AC or DC motors, and perhaps contractors don't quite see an economical advantage yet.

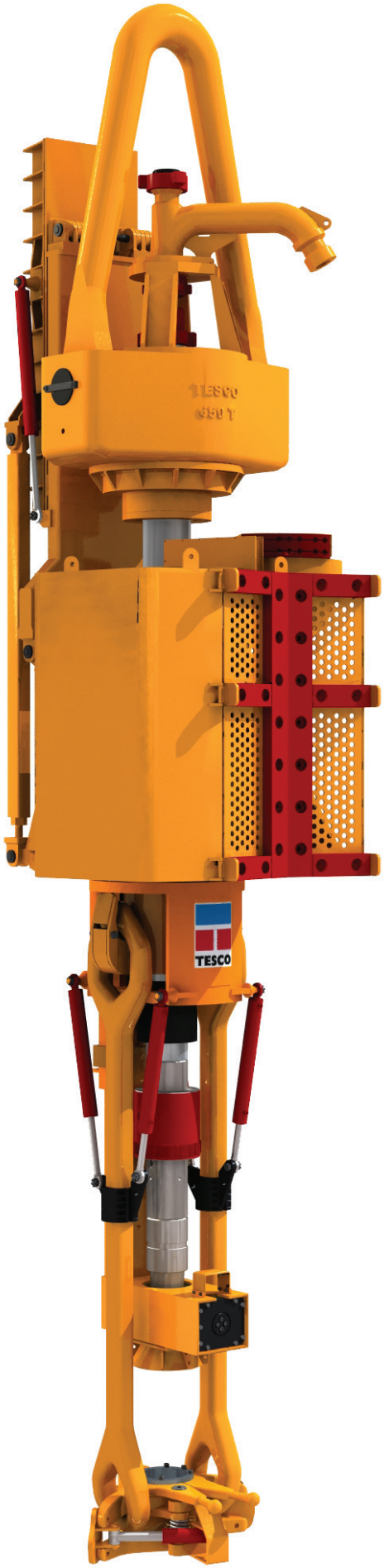


National Oilwell Varco has developed a 3,000-hp permanent magnet motor for a drawworks application. The company has been involved in PM technology since 2001.

ABB has built permanent magnet motors for several industries, including for marine propulsion applications. Although the company has discussed possible applications in the oil and gas drilling industry with several companies, it has yet to enter that particular market.

Drilling contractors also are often reluctant to use "new" technology until they become comfortable with its reliability. However, one company has been using PM motors in top drives for about 10 years. Other industries, including the US military, have utilized PM technology for years as well.

One advantage of PM motors is their size and weight. Compared with AC and DC motors, they are smaller and lighter and more power-dense. A 450-lb PM motor



can produce as much horsepower and torque as a 1,200-lb AC or DC motor. This advantage could be critical when used offshore, for example.

PM motors also have fewer parts that wear out. The brushes required on AC and DC motors are eliminated, for example. Most repairs can be carried out by almost any facility that repairs the typical AC or DC motor. There are, however, some repairs that should be conducted by the manufacturer, especially when it requires tearing into the magnet housing.

Most companies that build electric motors for the oil and gas drilling industry have either developed a PM motor on paper/computer or have built prototypes, primarily for top drives but also for drawworks. **GE**, which has been manufacturing electric motors for the drilling industry for decades, has a PM motor in the prototype stage. **National Oilwell Varco** (NOV) has PM motors in top drives presently in the field.

ABB has been providing small PM motors to the process and cruise line industries. The company has talked with its oil and gas customers regarding industry applications but has not yet developed one. **LeTourneau Technologies** (LTI) has done preliminary desings on PM motors but hasn't yet built one.

DRS Power Technologies has been manufacturing PM motors for top drive drilling systems for 10 years, as well as developing and testing massive PM motors for the military. Their PM motor has been used by **Tesco Corp** in one of its top drives for more than 10 years.

NOV

"Permanent magnet technology is probably the biggest advance in motors for the drilling industry in some time," said **Greg Cervenka**, chief engineer for motors and generators for National Oilwell Varco (NOV). "They offer the biggest opportunity for change in efficiency and size, so there is a lot of work being done there.

"We have some PM motors on top drives presently," he continued. "There are some PM machines that have been in the market that NOV has supplied, and we are moving toward more."

NOV became involved in PM technology around 2001 and has worked on multiple PM motor designs for several applications, he said. NOV has designed an 1,150-hp air-cooled PM motor, as well as larger water-cooled PM motors. The 1,150-hp motor originally was designed for a mud pump application.

NOV has focused on building machines with PM technology that also can use the company's standard variable frequency drive. Mr Cervenka says there are opportunities for applications for high-speed PM machines for the processing side of the business and for water-cooled and air-cooled machines.

NOV also has developed a 3,000-hp PM motor for a drawworks application, which is actually inverted so that the rotating component is on the outside of the motor rather than inside.

ABB

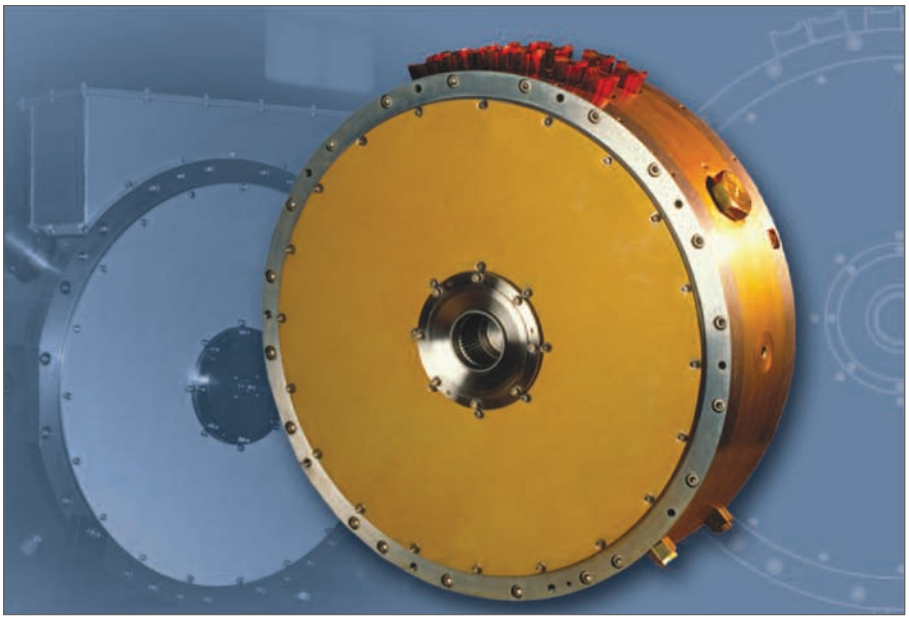
ABB's experience in PM motor technology began with the paper production industry, then with applications like extruders and mixers. Its PM motors are used in marine for propulsion systems. Another application today is for power generation with windmills and wind turbines.

These applications outside the oil and gas drilling industry have been ongoing for quite some time, and ABB said it has talked with oil and gas customers regarding PM motor projects.

"Our PM motor is in consideration phase as far as a drilling application is concerned," said **Pami Vuorio**, sales manager for ABB Industry in Singapore. "We have studied (drilling applications) with some customers, but so far we have not moved forward."

"The PM motors may yet get cheaper and more beneficial to use, and we would consider that again."

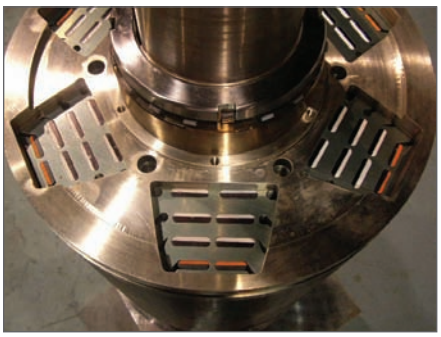
Two of Tesco's top drives use permanent magnet motors built by DRS Power Technologies. The 900-hp unit uses two motors while the 1,350-hp model uses three. These liquid-cooled PM motors can operate in environments from -40°F to 140°F, and the company said they have proven to survive four times longer than other motors in the same application.



DRS' PM motors use high-strength magnets mounted to the rotor to provide the magnetic field that interacts with the electrical windings to produce torque.

Above, LeTourneau Technologies' Direct Drive top drive uses a patented AC electric motor. LTI says it has done preliminary designs but has not built a PM motor yet.

Above and below, GE's interior permanent magnet motor features an equivalent power rating of 1,500 hp. The cage of the rotor contains the magnets. This design approach results in improved constant power speed range compared with surface-mounted PM technology, according to GE.



For the oil and gas drilling industry, a top drive system would likely be the most beneficial application for PM motors, Mr Vuorio said. He also said that some top drive manufacturers have been trying PM motor technology, but didn't know why they haven't broken through with it yet.

"It could be a pricing issue because the PM motor is more costly and asynchronous motor is good enough," he said. "Maybe the reason is as simple as that.

"Reliability is not the issue," he continued. "It lies elsewhere."

DRS POWER TECHNOLOGIES

Kaman Aerospace developed a PM motor around 10 years ago. The company was subsequently purchased by DRS Technologies. Kaman's PM motor was developed by a group of Massachusetts Institute of Technology engineers, said **Richard Armstrong**, vice president of DRS Power Technologies, a unit of DRS Technologies.

"These people had probably the most experience in (PM motors) at the time and developed this very power-dense motor," he explained. "It's 450 horsepower that weighs less than 450 lbs."

About the same time, Tesco was seeking to develop a lightweight and reliable top drive and looked to Kaman. Kaman's PM motor is used in Tesco's 500 ECI 900 and 1350 model top drives. The company uses two of the motors in the 900-hp unit and three PM motors in the 1,350-hp model. These liquid-cooled PM synchronous motors replace the traditional induction, or brush, style DC motors.

But it wasn't as simple as replacing DC motors with PM motors. Early issues centered around developing the correct drives rather than with the motors themselves.

"When we began with the technology, it was a little bit before its time," said **Barry Beierbach**, vice president, top drive business for Tesco. "We had some initial problems with the complexity of the motors and the drive systems. We developed, along with the supplier, programs associated with the drive and how they work with our application."

Mr Beierbach noted the weight-to-power advantage with the DRS PM motor, sometimes referred to as a pancake design because it's flat compared with the typical AC or DC motor used in top drives. "The PM motor is about one-third

the weight when talking about similar output," he said. "A 400-hp PM motor would weigh about 400 lbs, whereas a 400-hp AC motor would weight about 1,200 lbs."

PM motors are intrinsically safer than AC motors, he said. "They are anti-arcing, so in a critical wellbore situation where you have transient gases, the PM technology would probably be safer than AC motors with armatures or sparking devices."

DRS' PA-44-450 model PM motor features 1,450 ft-lbs of torque. Unlike synchronous wound motors, which use wire-wound rotor poles, PM motors feature high-strength magnets mounted to the rotor to provide the magnetic field that interacts with the electrical windings to produce torque. The PA-44-450 delivers more power per lb than other electric motors, according to the company.

The liquid-cooled motor can operate in environments from -40°F to 140°F. The company says the motor has proven to survive four times longer than other motors in the same application. With its dual stator design, the motor can operate at half the power if necessary. It is completely sealed and is CE ATEX-certified to prevent moisture and dust from entering.

DRS recently introduced its PRE34-600 PM motor that is built to an industry-standard frame to allow retrofits of existing top drive systems and other applications. The company said that this motor is cost competitive with comparable induction motors and that it is the most torque-dense 1,200-rpm, 600-hp air-cooled motor available, with 2,630 ft-lbs of rated torque.

DRS has an agreement with **American Electric Technologies Inc** (AETI) to jointly develop and market DRS' PM motors and generators using AETI's variable frequency drives (VFD).

GE TRANSPORTATION

GE has been supplying AC and DC drilling motors to the oil and gas drilling industry for decades and is developing a PM motor for drilling and other industries.

"The next big thing is permanent magnet motors," said **Mark Cooksey**, product manager – drilling for **GE Transportation**. "For rigs, space and weight are important. With a PM motor, you can get a higher current density that allows you to shrink the motor size. If you are trying to have a more compact package than before, a PM motor can do that.

"If you want to keep the same envelope but want more performance, more torque, higher speed range or some other performance advantage, a PM motor should give you that flexibility to keep the same envelope but then get more performance."

Mr Cooksey said that efficiency should improve as well, though most people in the industry don't seem too concerned with that. "They are more concerned with shrinking everything to save space and weight, or keeping the same envelope but getting more output.

"Efficiency is an upside that comes with that."

Meantime, Mr Cooksey said, he is confident that PM motors will become more widely used during the next 2-5 years. "I am sure that some of it is just market acceptance that has to be overcome."

GE is developing an interior permanent magnet (IPM) motor and has built a working prototype with an equivalent power rating of 1,500 hp (1,120 kW). "The benefit of the IPM is higher power density that allows for a more compact machine, or maintaining the same mechanical envelope with increased power," he explained.

Other benefits include lower weight, improved efficiencies and a tachless design that would eliminate the need for a speed sensor.

The company has developed a rotor design where the cage of the rotor contains the magnets. With this approach, a constant power speed range may be realized compared with surface-mounted PM technology.

"The magnets are inserted into the rotor slots, which is then enclosed in a cover, compared with most PM motors, where the magnets are outside the rotor," Mr Cooksey said. "The design allows a greater speed range, maintaining constant power to a broader speed range."

LETOURNEAU

LeTourneau Technologies Inc (LTI) developed its Direct Drive top drive system a few years ago with its patented AC electric motor design that eliminates the need for a gearbox and mitigates bearing and gearing problems and fluid leaks. The company said it is investigating the feasibility of utilizing PM motors in its top drives, but believes it is not the right time in current market conditions.

"We have done preliminary designs and modeled them to see how (PM motors) would fit into the mast and into the top drive," said **Joe Hope**, engineering manager for LTI's motor division. "However, we have not yet built a PM motor."

A decision on whether to further develop and build a PM motor could come in a few months. However, the decision will likely be "now is not the right time."

"We would have a computer-modeled PM motor design that we could pursue at the right time."

While a PM motor is more expensive than an AC or DC motor, Mr Hope believes that would not prevent its development. "If you get significantly smaller with the same performance, then you could probably get away with more cost."

LTI is pursuing additional PM technology developments, Mr Hope, though he declined to elaborate.