What do engineers need to know about encoders and motors for Oil & Gas drilling machinery designs

- By Scott Orlosky & Walter Smith, Sensata Technologies

The constant fluctuations in supply and demand in the oil and gas industry drastically effect the worldwide demand for drilling operations, making the need to design more efficient control systems greater than ever. Position sensors and motors are crucial components in oil and gas equipment and must reliably operate day in and day out in some of the most challenging conditions. High temperature and pressure, potentially explosive environments, extreme vibration, shock, dirt and moisture are all part of the daily operating environment in drilling applications.

The rules and standards that impact the development of drilling equipment and systems are also constantly evolving. Engineers designing components for the oil and gas industry need to stay up-to-date with these changes, which are often complicated by location and governments. Depending on the application, products often will need to be certified for hazardous area use, or, in situations where explosion is not a risk, specified and tested to operate in the given environment.

UNDERSTANDING THE OPERATING ENVIRONMENT

It is important to understand how a hazardous location is defined and then take the steps to determine what rating is required for the specific installation to achieve the most cost-effective solution for the job.

An area can be classified as hazardous based on the following questions:

1. Is there a possible presence of an explosive or flammable agent, and if so what is that agent?

2. Is the explosive atmosphere present under normal operating conditions, or only if there is a malfunction or unusual occurrence that might release an explosive agent into the area?

3. In what part of the world will the equipment be operated?

This approach of area classification is used by the United States (ANSI/NFPA), Canada (CEC), Europe (CENELEC) and much of the rest of the world (IEC). Once these questions have been answered, you can determine the hazardous area rating needed and the certifying body that will need to approve your equipment or installation.
Rotary encoders are frequently used in oil and gas drilling equipment to provide crucial feedback about moving machinery on the rig. As the presence of flammable agents is common in applications near the wellbore, most electrical components on the rig will require special hazardous area certifications.

The Difference Between “Explosion Proof” & “Flameproof”

The terms “explosion proof” and “flameproof” are often used interchangeably — even though there are distinct differences between the two. The term “explosion proof” is used for North American-based approvals such as ANSI and NFPA. In contrast, “flameproof” is a term used for IEC and CENELEC/ATEX approvals.

The major physical difference between explosion-proof and flameproof construction is in the design of the product's termination. “Explosion proof” requires that the equipment be terminated using a certified conduit fitting. In contrast, “flameproof” specifications allow for termination using a certified cable gland and cable. Therefore, encoders with “explosion-proof” construction can be rated internationally by multiple agencies in Division 1, Zone 0 or Zone 1 environments. “Flameproof” encoders with cable outputs and gland seals, however, are not certified for use in Division 1 hazardous areas in North America.

In most drilling rigs, top drives are commonly used to rotate the drill pipe and thereby the drill bit. The top drive attaches to the top of the drill string and rotates it with a great deal of torque. A drill bit at the end of the drill string cuts into the rock strata below the platform and creates the well hole. The motor, the pipe, plus any additional weights required to control the force on the drill string are carried by a traveling block and tackle arrangement which is operated by a winch known as a DrawWorks.

Compact rotary encoders like Sensata's LP Series (left image) are certified for use in Class 1 Division 1 environments, where they provide an intrinsically safe solution for speed control on top drives when used with an intrinsic safety barrier (right image).
It is very important to control the speed of the top drive. If the speed is too slow, the drilling time is not efficiently utilized; too fast and the drill string could break, thereby requiring a very expensive “fishing expedition” to retrieve the broken parts from the hole and re-start the drilling operation. Rotary encoders are used in the gearbox with the top drive’s motor to provide precise feedback about the top drive’s speed so that it can be accurately controlled in conjunction with the torque. Designed to work within the narrow space of a drilling platform, top drives are tightly engineered with little space to waste. Encoders in this application not only need to be compact, operate in high temperatures, and withstand severe shock and vibration, but also need to be hazardous area certified.

Since the well hole is usually aiming for a pocket of oil or gas, there is a good chance that potentially explosive fumes could be emitted from the wellbore. This location would be considered a Class 1 Division 1 (Zone 0 in Europe) environment. Class 1 indicates explosive gases or liquids, and Division 1 (Zone 0) indicates that the explosive gas environment is highly likely to be present during normal operation. It is extremely important that any electrical equipment be certified for this environment. One of the preferred methods is to use an intrinsically safe product along with a piece of electronic equipment called a “barrier” which limits the amount of energy that the product can produce so that it does not spark an explosion.

**POSITION MEASUREMENT IN DRAWWORKS**

Encoders also are used to measure how far the traveling block has moved and tracks the length of pipe which has passed down the hole. This information helps the drill rig operators keep their drilling program on schedule and allows them to compare the planned performance with the actual rock formations they encounter.

Knowing the location of the drill tip is vital to proper operation of the rig as it helps in planning for strata changes, pressure changes and adjustments to drilling mud (which lubricates the drilling operation). In addition, knowing the drill tip’s position helps in preparing when to change out drill bits, when to take certain measurements, how much windup to expect, how to weight the drill string and so on.

Oil well equipment manufacturers can simplify design development time (trading off the initial installation cost) by using explosion proof or flameproof certified encoders which do not require accompanying intrinsic safety barriers. Furthermore, using certified encoders with triple ratings (such as from UL, CENELC/ATEX, and IECEx) helps simplify the certification process of the end-users’ assembly, thereby saving costs associated with obtaining additional approvals to comply with international safety regulations.

It is not uncommon to have multiple rotary encoders stacked up on the rotational axis of the DrawWorks, both for redundancy and for sharing signals with other operations on the rig. For this design option, encoders need to be explosion proof (required because of the proximity to explosive gases) and be able to reliably communicate over long distances. To save valuable space, a nesting, stackable encoder can be used in the place of several individual encoders.

**HIGH PRESSURE HIGH TEMPERATURE (HPHT) BRUSHLESS DC MOTORS IN DOWNHOLE DRILLING**

Reaching deeper than ever before, the oil and gas exploration and drilling process has become much more complex and challenging. The increasing number of options available for directional or “geosteering” operations has driven the need for improved Measurement-While-Drilling (or MWD) logging equipment, which is used to provide real-time positional data to assist with the proper orientation and steering of the drill. Unfortunately, traditional wireline MWD logging equipment is ineffective in directional drilling applications once the angular trajectories of the drill head relative to the surface increase beyond 60 degrees.

In cases exceeding 60-degree angles, mud pulse telemetry is the preferred method used to encode and transmit the data from the sensors located at the “bottom of the hole” to the “top of the hole” or surface. This information consists of drill head positional data as well as information on the surrounding formations. This data connectivity is achieved by utilizing the mud product within the wellbore casing as a transmission medium.

A poppet valve within the pulser assembly located above or behind the drill head creates periodic pressure bursts which carry the encoded sensor data. These pulses are received at the top of the well assembly and are then translated into data used by the operator to guide the drill.
While there are a few different methods employed today, it is common for the mud “pulsing” poppet valve to be controlled with BLDC motors that are quickly rotated (100 to 300 millisecond) to generate a cluster of bursts every few seconds throughout the MWD process.

In the past, oil and gas operators had to simply endure higher motor failure rates for pulser systems which ultimately resulted in hours of downtime and hundreds of thousands of dollars lost. However, today’s BLDC motors have changed that, providing much greater reliability and length of service.

To ensure reliability and robustness under these extreme conditions, component solutions that incorporate BLDC motors must be designed and successfully tested to reliably operate in temperatures up to 200 degrees C, hydrostatic pressures of up to 30,000 psi, shock loads to 1000g’s, and vibration to 25g’s.

Motors such as Sensata’s Hall Commutated 1.5” diameter DII15-60-201A High Pressure High Temperature (HPHT) Brushless DC motor provide the ideal solution for the most severe down-hole mud pulser applications. The design has been validated and certified by an independent Environmental Test Lab to insure operational robustness under the most extreme conditions throughout its operational life.

The HPHT BLDC motor features integral Hall commutation for simplified control options, Rare Earth Magnets to support a compact form and high corrosion resistance, and other proprietary mechanical design features for improved robustness. Additional features such as the ability to customize a motor for a gearbox, other feedback devices and winding variations allow for more design flexibility in serving a wide range of installations.

To develop cost effective and efficient oil and gas operations, engineers need to understand the changing world of international regulations and policies. In addition, they also need to be knowledgeable about the wide range of safety methods and product technologies available for components in explosive and harsh environments.

Engineers should use components from suppliers that can provide certified products or qualification test data that proves product performance in deep drilling conditions where temperature, pressure, shock and vibration extremes combine to create a destructive environment for equipment operation.

In addition, working with manufacturers who understand the industry and its evolving technical, performance and safety requirements will help designers specify the best components for their applications.
Figure 5

Hazardous area rated encoders and high pressure high temperature tested BLDC motors like those pictured here from Sensata Technologies help ensure safe and efficient drilling operations in a variety of systems on an off-shore rig.