Powering gas compressors

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Introduction

Gas compressors, whether axial, centrifugal, screw-type, or reciprocating, are the workhorses in nearly every aspect of the gas value chain. From exploration, production, transmission, storage, distribution, and utilisation, gas compressors of all sizes are employed in the industry. Hosts of mechanical and electrical methods exist to power these compressors. Historically, they have been driven by gas turbines, steam turbines, and diesel engines, ranging from a few thousand horsepower (hp) to tens of thousands (depending on the service). However, many of these mechanical-based prime movers are aging and becoming cost prohibitive to service and maintain. Also, as environmental regulations around the world make compliance increasingly more difficult, and gas prices are at fairly low prices, many operators face the challenging task of decommissioning their entire compressor train. Procuring a new one from a compliance

standpoint, while keeping the fixed and variable cost of gas production as low as possible to weather out indefinite low prices is attractive.

Electric-based prime movers provide a viable solution not only for emission compliance, but also retrofit feasibility, efficiency, wider operating envelope, and lower cycle cost over the life of the installation. This article will present the major electric motor-based prime mover technologies that are available to an operator. Selection criteria based on several factors such as power system availability, efficiency, procurement, train configuration, and starting requirements, for the three major methods will be discussed. This will enable key stakeholders to evaluate the best prime mover technology to use. The dimension of the article will be limited to compressors with 5000 bhp and greater and motors applied at medium voltage (greater than 2.3 kV).

Background

Mechanical prime movers such as turbines and engines have a design life of 25 – 30 years. Their use offers several advantages, such as high reliability, familiarity with personnel, and, in some cases, the waste heat can be used to generate steam. However, with benefits, there are concerns associated. Turbines usually have a well-defined maintenance interval of every 2 – 5 years and cost several times more than comparable electric motor-based prime movers.

Table 1. Comparison of electric motor-based prime movers

Consideration factor	DOL start fixed speed motor	Mechanical fluid drive	Electric adjustable speed drive
Variable speed control	No	Yes	Yes
Variable speed range	Not applicable	Up to 20 000 rpm	Up to 3600 rpm to as high as 12 000 rpm without a gearbox for high speed motor
Efficient variable speed control range	Not Applicable	Narrow speed control range for best efficiency	Wide, variable speed control range, 69% to 105% speed
Speed control	Not Applicable	Slow speed response	Faster control response. Good energy efficiency at lower speeds
Motor starting requirements	Soft starter, VFD, auto-transformer	Pony motor or assisted start	None
Motor sync-to-line co-ordination and relaying	Not applicable	Required	None
Minor maintenance schedule and duration	None	None	Every 25 000 hours, 0.5 days downtime
Major over haul schedule and duration	None	Every 5 – 8 years, several days of downtime	None
Train lubrication	API 614	As per mechanical fluid drive manufacturer	API 614
Power output level	Up to 130 000 hp	Up to 67 000 hp	Up to 130 000 hp
Power supply	Stiff power supply required as determined by short circuit current	Reliable grid connection required	Reliable grid connection required
Upstream fault current contribution	Motor will contribute to a fault upstream	Motor will contribute to a fault upstream	Motor will not contribute to upstream fault due to isolation of the motor from the power system by the drive
Input voltage level	Up to 13.8 kV	Up to 13.8 kV	Voltage level dependent on primary of drive isolation transformer. Can be higher than 13.8 kV
Line side power factor	As dictated by motor. Can be unity for synchronous motors	As dictated by motor. Can be unity for synchronous motors	Min 0.95 pf
Emissions and noise	Motor has no emissions. Utilities can use economies of scale to controls its emissions	Motor and fluid drive have no emissions. Utilities can use economies of scale to controls its emissions	Drive & motor have no emissions. Utilities can use economies of scale to controls its emissions
Initial equipment cost consideration	Motor mounting on compressor skid	Motor mounting on skid, dual alignment, fluid coupling, piping for closed-loop oil and transmission fluid heat exchanger	Motor mounting on skid, VFD in E-house, piping for closed loop cooling water system and installation of drive isolation transformer

Electric prime movers

Selecting an appropriate prime mover falls on the shoulder of rotating machinery experts who also specify compressors. Since their expertise is mechanical engineering, gas turbines, steam turbines and engines are the prime movers of choice. However, in many cases, an electric motor is a much more attractive option, given the following benefits:

- High reliability with little to no maintenance.
- Compact footprint per horsepower delivered.
- No carbon footprint (shifts the burden of emission management and compliance to the electric utility provider which can use economies of scale to manage emissions).
- Cost effective when inexpensive electricity is available due to renewable or distributed energy resources.
- Shorter delivery lead times compared to turbines.
- No risk of obsolete parts, personnel, etc.
- Easy retrofit ability when converting from turbine-driven prime mover to an electric motor while retaining the compressor.

The selection process does not stop upon choosing to apply an electric motor. Depending on the requirements, an electric motor can run the driven equipment either at fixed or adjustable speed. The determining factor is primarily by the process requirements and the compressor service. Figure 1, shows an electrical illustration of electric motors applied in fixed and adjustable speed configurations.

Direct-on-line (DOL) start – fixed speed motors

DOL motors are commonly applied in LNG applications where fixed speed operation is sufficient for the process or where process control is achieved using other methods such as throttling valves, recirculation, or flaring. Benefits of applying a DOL motor include:

- Simple starting circuit (a full voltage starter such as a circuit breaker of fused vacuum contactor depending on the voltage and power level and a motor protection relay or thermal overload relay is needed).
- Lowest installation cost.
- Short acceleration times since entire motor torque is available to accelerate the driven equipment.
- Easy replacement of a turbine while retaining the existing compressor.

While DOL motors provide benefits, they have limitations. First, starting a large motor is the key application consideration that a practicing engineer should bear in mind. This is due to the nature of the motor starting. A typical fixed speed motor could draw 600 – 650% (6 – 6.5 times) of the motor rated full load current (FLA). This is known as inrush current. Hence, it will be critical to know the net inrush current that can be provided by the substation transformer and its impact on the bus voltage drop. Several methods exist for reducing the inrush current to the motor. In their paper, Nevelsteen, et al, discuss the various methods and economics of starting large motors.[1]

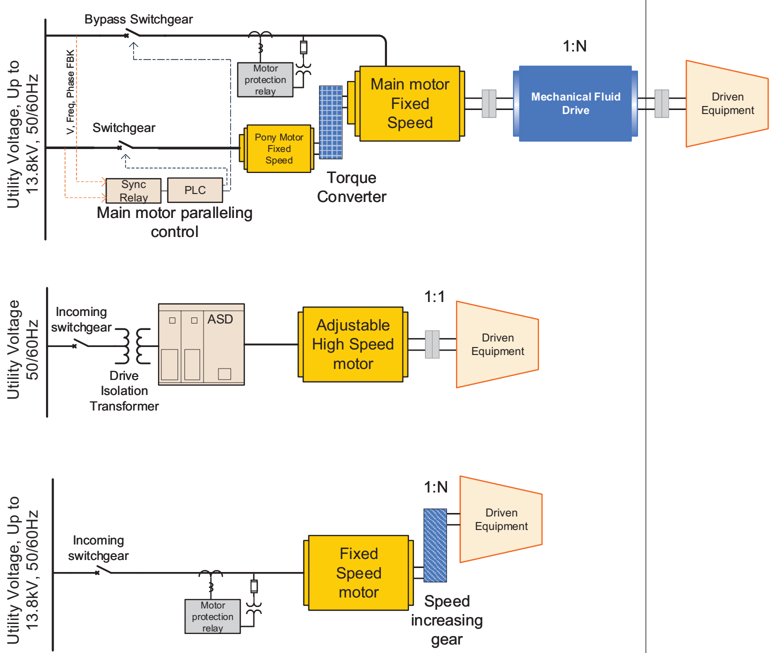

Figure 1. Electrical illustration of an electric motor applied as a prime mover for: (a) Fixed speed motor applied on a mechanical fluid coupling for adjustable speed control; (b) High speed motor applied on an electric adjustable speed drive; (c) Fixed speed operation started direct-on-line.

Secondly, the motor starts are limited due to the temperature limit of the motor. Generally, motors are rated for two cold and one hot start (2C/1H). However, motors designed to American Petroleum Institute (API) standards, such as 541 and 546, are required to provide for a three cold and two hot start (3C/2H). It is important to pay close attention to the limitation on the number of starts and verify whether it is commensurate with the process requirements. Anecdotal evidence suggests that operators at plants are often caught by surprise by the foregoing limitation leading to lost downtime and process shutdown. Third, the motor speed is limited to a maximum of 3600 rpm (Motor Speed = 120 x system frequency / no. of motor poles). Hence, if the end user would like to capture efficiencies by removing the speed-increasing gearbox, then a DOL motor is not suitable, especially for centrifugal compressor applications, since they run at speeds beyond 3600 rpm. Typical range of fixed speed motors range from 250 hp – 100 000 hp; 2.3 kV through 13.8 kV. They can be applied in all areas of the LNG production such as Main Refrigeration (MR), boil-off gas, sales gas compressors, etc. However, it should be noted that multi mega-watt motors usually require an assisted starting method such as a solid-state starter, or auto-transformer or at the very best a variable frequency drive (VFD).

Fixed speed motors on mechanical fluid drive

Fixed speed motors are also applied to mechanical fluid drive, commonly known as a fluid coupling. This allows for adjustable speed where the process can benefit from such operation. Benefits of using a fluid coupling include:

- Extremely high reliability and high MTBF in the order of 40 – 45 years.
- Mechanical engineers can easily relate to the equipment since it mechanical.
- High speed operation up to 20 000 rpm allows for elimination of gearbox.
- Suitable for offshore applications since the entire train can be placed in a hazardous environment, saving on valuable real estate.

With advantages, come disadvantages. As shown in Figure 1, one of the biggest challenges is motor starting. Applications involving fluid coupling can reach up to 67 000 hp. Usually a fixed speed pony motor is applied which is rated at 5 – 7% of the main motor rating. Hence, an engineer must be cognisant of the fact that someone is responsible for procuring and performing motor starting studies for the pony motor system. Also, for the main motor to synchronise to the line, the voltage, the frequency, and the phase angle between the motor and utility must match. This co-ordination PLC must be supplied, and responsibilities clearly identified for making the synchronisation work. It is preferable for the mechanical fluid coupling manufacturer to take responsibility of the starting strategy, including synchronisation.

High-speed motor on electric adjustable speed drive (also known as variable frequency drives)

An electric motor on an electric adjustable speed drive provides immense flexibility not only in terms of speed and process control, but also in terms of motor starting. These drives are power conversion equipment that convert fixed frequency utility supply into variable voltage and variable frequency (speed) on its output. Benefits of using an adjustable speed drive include:

- Starting of large electric motors with elimination of inrush current, (therefore no limit on the number of starts).
- High efficiency across a wide operating speed range.
- Ability to ride through voltage dips and power system disturbances while still maintaining motor control.
- Elimination of the gearbox, thereby capturing at least 1.5 – 2% in gearbox losses by direct coupling the motor to the compressor.
- Easy retrofit ability of the existing electric motor compressor train for variable speed.
- Ability to use one drive for starting and synchronising multiple motors to the utility line.

However, there are also some disadvantages associated with an electric drive:

- Many field personnel are not trained on operating a drive and may not be qualified to work on medium voltage equipment.
- Additional space is required to mount the drive isolation transformer.
- Large drives are typically water-cooled and many end users are not comfortable with the idea of water and electricity together.

Comparison of electric prime mover technologies

As mentioned, an electric motor when applied in different configurations provides several benefits. Table 1 provides a comprehensive comparison chart of the different options that can assist a stakeholder in evaluation.

Conclusion

There is a growing need for installing large capacity electric motors on pumps and compressors in LNG facilities. In fact, the concept of all electric LNG is not far-fetched. The majority of the oil majors are considering electrics as their prime movers instead of the traditional heavy-duty gas turbines. This is a big step in a company's operating procedures. It takes radical thinking to make the switch from the traditional turbine to electric motors and even a change in mindset when motors are applied with electric adjustable speed drives. This article outlined some of the key methods in which an electric motor can be applied and considerations that an end user must bear in mind before selecting a method for starting and speed control.

References

1. Nevelsteen, J.; Aragon, H., "Starting of large motors-methods and economics," Petroleum and Chemical Industry Conference, 1988, Record of Conference Papers., Industrial Applications Society 35th Annual, vol., no., pp. 91,96, 12-14 Sep 1988