ELECTRIC DRIVEN COMPRESSORS

by
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Introduction

While the rising cost of natural gas has improved the economics of gas production, natural gas is also consumed as fuel for compression and other field operations. This fuel gas represents a cost to the producer in the form of foregone revenue. In certain circumstances, the use of electric motors to drive natural gas compressor equipment may improve producer economics, and provide a number of additional operational and environmental benefits.

Electrically driven compressors have been, until recently, infrequently used in natural gas production operations. This is largely due to the remoteness of many field locations, and the need to lay costly power lines. Natural gas fuel is, of course, readily available from the producing properties. As the price of natural gas has increased relative to that of electricity, the cost of laying power lines to electrify compression may now be profitable.

In addition to the potential reduced energy cost, the capital costs (exclusive of power lines) are approximately 30% lower with electrified equipment. Additional benefits are reduced operating expense, reduced noise, improved reliability, and reduced air emissions. The reduction in air emissions can be especially important for projects where environmental permitting is a significant issue.

A number of recent gas development plays, such as the Barnett Shale in North Texas, are closer to populated areas. These developments may favor electrified compression, due to improved proximity to power lines, and increased emphasis on reduced noise and air emissions.

Electric Power Cost vs. Natural Gas Fuel Cost

In many areas the cost of electricity for industrial use is significantly lower than the rate for consumers, due to a number of factors, including the size of the load and the usage profile. For example, domestic electrical usage will typically peak on summertime afternoons and early evenings, largely due to air conditioner load. During other periods the load will be significantly less than this peak. This means that the average "load factor" for a home is quite low, requiring the power company to build, maintain and operate infrastructure that is not fully used. In addition, much of the required infrastructure will be "peaking facilities" that must be started and shut down as needed to adjust to the electrical demand.

In an industrial application, such as an electrically-driven compressor facility, the equipment will be expected to run 24 hours a day at a relatively constant rate. This higher load factor allows the power company to use its most efficient "baseload" facilities.

In a number of 2007 projects, we have seen industrial electricity rates of approximately $0.05/kWh. For a field operation using a 1000 horsepower (hp) compressor, a producer would pay approximately $340,000/year for electricity. The benefit of this becomes clear if natural gas is valued of $7.00/MMBtu, as the producer will sell an additional $510,000/year in natural gas, for a net revenue increase of $170,000/year.

In order to determine if electrification may be viable, it is necessary to study the utility's electrical tariff. It typically consists of three components:

- A "customer charge", which is a fixed amount per account per month
- A "demand charge", which is a fee for the capability to draw power, in $/kW
- An "energy charge", which is the fee for the actual power consumed, in $/kWh

For industrial applications, the customer charge is usually negligible. It is very important to understand the calculation method for demand charge. In some circumstances it is the highest demand in the billing month over a certain time interval (say 15 minutes), which will allow the averaging of equipment startup surges over some period. In other cases, it may be a more stringent method, or it may be the highest actual demand over a longer period of time than the current month. The energy charge typically contains "Power Factor" penalties (see section on Power Factor) if the Power Factor is below a certain threshold (typically 85% to 95%). A common penalty is a 1% surcharge for every 1% below the threshold.

Here is an example of a cost calculation using a 2007 quote for a 2500 hp project in Oklahoma:

Customer Charge: $100.00/month
Demand Charge: $9.00 per kW (highest 15 minutes during billing month)
Energy Charge: $0.0371 per kWh (with penalties for power factor below 85%)

Assuming a power factor above 85%, a motor efficiency of 96%, and a load factor of 90% (allows for unit running slightly below full load, and for the highest 15 minute average load during a compressor startup), the load characteristics are:

Average load: 1860 kW
Highest 15 minute average load: 2067 kW

For a 31 day month, the electricity bill can be estimated as follows:

Customer Charge:	$100.00
Demand Charge:	
$9.00/kW x 2067 kW =	$18,603.00
Energy Charge:	

$0.0371/kW x 1860 kW x 31 days/month x 24 hours/day = $51,340.46

Total Rate: $70,043.46

The average power rate can be calculated as follows:

Total Rate/(1860 kW x 31 days/month x 24 hours/day) = $0.0506/kWh

In order to calculate the natural gas fuel cost, we will make the following assumptions:

- Fuel consumption is 8.3 Scf per horsepower per hour
- Available fuel gas has a heating value of 1000 Btu/Scf
- Gas has a value of $7.00/MMBtu

Please keep in mind that actual fuel consumption will be a function of the engine design and condition, load, gas quality, and environmental conditions.

For a 2500 hp unit the estimated daily fuel consumption is:

8.3 Scf/hp-hr x 2500 hp x 24 hr/day x 1 Mcf/1,000 Scf = 498 Mcfd

This fuel has a monthly value of:

498 Mcfd x 1000 MMBtu/Mcf x $7.00/MMBtu x 1 MMBtu/1,000,000 Btu x 31 day/month = $108,066/month

Power Factor

While the power company bills customers for kWh's (kilowatt-hours), it is really generating kVA's (kilovolt-amps). For resistive loads, such as incandescent lighting, the two are the same. However for inductive loads, such as electric motors or transformers, the two are different, but can be accounted for using the "Power Factor". (For a relatively non-technical explanation of Power Factor, please see the US Department of Energy Motor Challenge Fact Sheet at www.power-save.com/dofe_report.pdf.)

The Power Factor for any particular equipment is a function of its design and the operating conditions, such as load. A motor generally has the highest Power Factor near its rated capacity. It is possible to correct the Power Factor for an inductive load by installing capacitors or corrective electronics. Capacitors are relatively inexpensive: for the cited 2500 hp project, a 400 kVAR (volt-amperes reactive) bank of capacitors costing approximately $6500 installed would allow us to meet the 85% Power Factor requirement as low as 55% of rated load.

Soft Start Equipment

When starting an electric motor, it takes a lot of energy to get all the components of the motor and the compressor rotating. The initial current is therefore much larger than the normal operating current. Many utilities will require "Soft Start" equipment to moderate the current surge by bringing the motor on line in a slower, more controlled manner. Regardless of utility requirements, the startup may have an effect upon the Demand Charge, making Soft Start equipment economically attractive to install. For the 2500 hp compressor cited above, Soft Start equipment would cost approximately $85,000 installed.

Electrical Infrastructure Costs & Timing

Proximity to electric transmission lines and the availability of electrical substation capacity are key considerations in an electrification project. We recently obtained this estimate from a power company for a new substation and transmission line:

- $500,000 for the substation, plus 4 acres of land
- $108,000 per mile of transmission line

This quote was for a 12,500 horsepower installation in a rural area. Project lead time was estimated at approximately one year.

It is important to consider how lead time issues for electric power will fit with the rest of the project. This project had a multiyear timeline where gas production would continue to increase as wells are drilled. Tristream developed a plan to use a gas driven unit initially, and electric units for subsequent expansions, thereby meeting both producer and utility schedules.

Dealing With Variations In Compressor Load

One of the key issues for operating a compressor efficiently is that it is properly sized. However, even a properly sized unit will need to accommodate some variation in flow conditions. With a conventional gas fired unit, variation is typically addressed by varying the engine speed with the load.

On a typical electrically driven compressor, the electric motor will be designed to run at a fixed speed, so some additional equipment or methods must be used:

- Installing a Variable Frequency Drive (VFD) on one unit to allow variations in motor speed. This can be expensive (estimated at $675,000 for a 2500 hp unit, installed)
- Installing a gas-driven compressor to handle load changes, while keeping the remaining electric units fully loaded
- Installing multiple electric driven units that can be switched on or off as necessary
- Making adjustments on the compressor side, such as with variable clearance cylinders or valve unloaders

Other Considerations

VFD and Soft Start equipment will require an air conditioned enclosure for cooling (typically combined with a field office). The incremental costs for this are included in the estimates provided above.