

**Consultant
Jim Berry,
USA, discusses
the ways in
which dual
driven pipeline
compressors
can offer
flexible and
cost-saving
operational
modes.**

**A
DUAL
DRIVE**

Most cars in Brazil are built to operate on either gasoline or ethanol so drivers can use whichever is cheapest or more readily available. In other parts of the world, hybrid cars use a mix of batteries and gasoline to achieve better mileage. The same approach works for pipeline compressors. By having the option of using either a gas fuelled prime mover (gas turbine or gas engine) or an electric motor to drive the compressor,

operators can save money and improve reliability. In addition, since most compressors operate at below peak output and efficiency, the gas fuelled prime mover can drive both the compressor and the motor, using the motor to generate electricity which is sold to the utility at times of peak demand.

This article takes a look at the basic principles and economic factors involved with dual-drive compressors, considers several possible arrangements, and gives examples of how they have been used in industrial and pipeline applications.

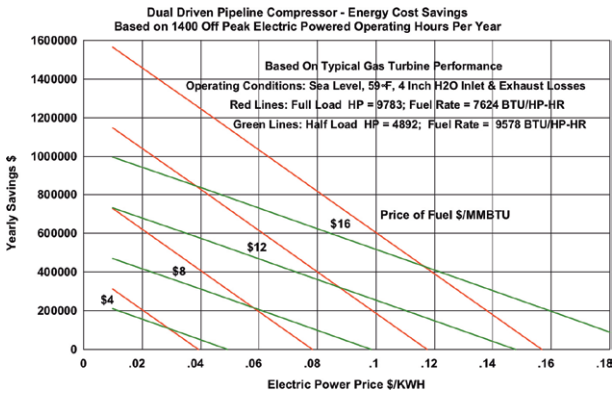


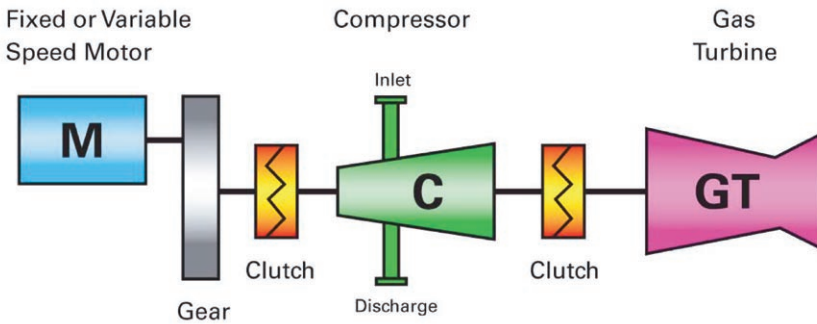
Figure 1. Plot of energy cost savings using electric driver during off peak electric rate times (assumed to be 1400 hr/yr).

As different as night and day

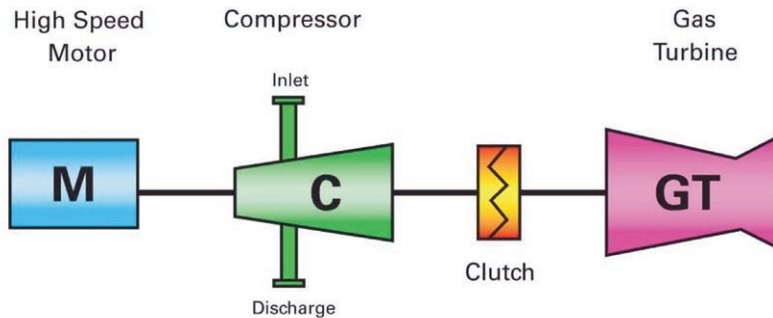
Currently, there are three main types of pipeline compressor and driver combinations. The majority are centrifugal compressors driven by gas turbines. The high efficiency of the centrifugal compressor handling the low-head, high-volume flows of pipeline service makes it a natural choice. A gas turbine driver, though, is not always the most efficient driver, particularly when operating below capacity, but this is offset by low overall lifecycle costs.

As an alternative, some installations use reciprocating piston compressors driven by reciprocating engines. This arrangement often has lower fuel costs, but offset by higher maintenance and total installed costs.

Figure 2.



Arrangement 1 - Conventional side-side nozzle centrifugal pipeline compressor with shaft out both ends.



Arrangement 1a - Conventional side-side nozzle centrifugal pipeline compressor with shaft out both ends, drive by high speed direct connected motor and gas turbine through an SSS Clutch.

Finally, there are a growing number of electrically driven centrifugal and reciprocating compressors. To make economic sense, these need to be installed near a reliable source of electric power, and the price of that electricity needs to be competitive with the cost of the pipeline gas that would otherwise be used. Electric drives would also be a good choice for locations where noise or emissions regulations restrict the placement of other types of drives.

The problem with each of these alternatives is that they lock the operator into a particular energy source. This would make sense if energy prices were locked in at the time of construction. But prices fluctuate daily – or in the cases of spot electricity and natural gas markets, hourly – creating a constantly changing economic picture. A better approach, therefore, can be to keep your options open, installing both an electric motor and a gas turbine and using whichever makes the most sense at that point in time.

This particularly applies with electricity prices, where deregulation creates variable pricing throughout the

day, and utilities are mandated to use expensive renewable power sources. High demand during Summer afternoons causes prices to skyrocket. At night the peaking turbines can shut down, but both the baseload coal or nuclear plants and the wind turbines continue generating power and so prices plummet.

Take the case of the Texas West ERCOT area. It has more than 4000 MW of installed wind capacity and off-peak power prices of US\$ 0.02 are not uncommon. Similar day/night price differentials are also common in other parts of the world that use power plants that operate best at or near full load and are difficult to turn down.

A dual drive compressor allows operators to run on low-cost electricity during off-peak hours, while running the gas turbine or reciprocating engine during the afternoons. Where available, they can take advantage of the lower costs offered by some utilities to customers who agree to let the utility cut off their electricity during power emergencies. The dual drive also gives operators greater flexibility during times when the compressor load drops. Motor efficiency stays almost flat down to less than 50% load, while gas turbine fuel rate increases by approximately 25% at 50% load, compared to full load fuel rate.

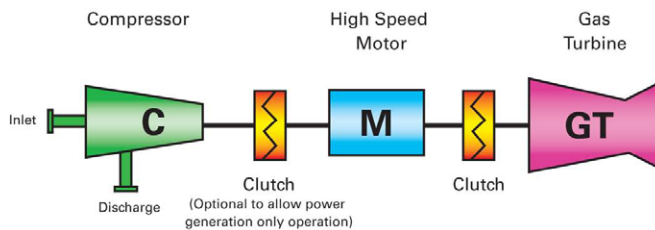
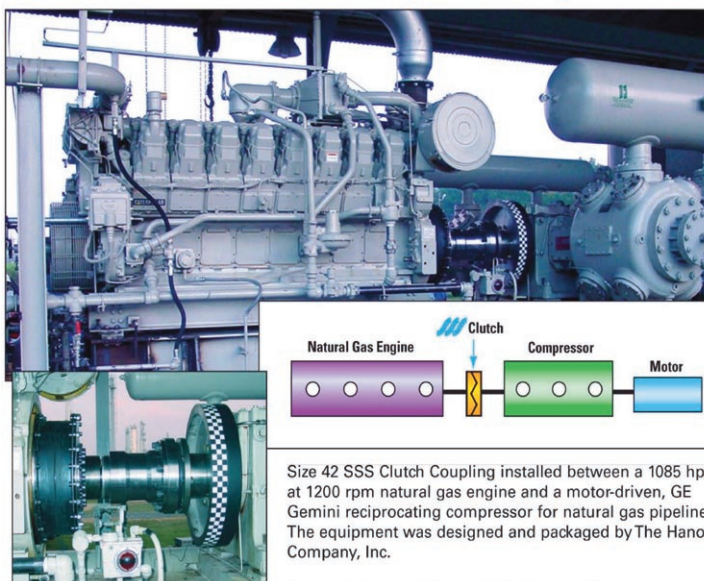


Figure 3. Arrangement 2 - For axial inlet pipeline compressor or conventional side inlet - side discharge compressor, but with only one shaft end available.



Size 42 SSS Clutch Coupling installed between a 1085 hp at 1200 rpm natural gas engine and a motor-driven, GE Gemini reciprocating compressor for natural gas pipeline. The equipment was designed and packaged by The Hanover Company, Inc.

The natural gas engine and clutch drives the compressor during peak power periods each day to reduce electric costs and demand charges.

Figure 4. Dual driven natural gas pipeline compressors.

A US turbine manufacturer, for example, calculated the energy cost savings of using an electric motor in combination with one of its turbine compressor sets. Figure 1 shows the savings when operating at full and half load under a variety of price scenarios. Given the US\$ 12+ per million British thermal units (MMBTU) that natural gas was selling for in the US in June 2008, and the US\$ 0.02 KW/hr price of off-peak electricity in western Texas, this machine operating in that area could save from US\$ 700 000 to over US\$ 1 million annually in fuel costs by switching to a dual-drive arrangement.

Dual drive options

When the operating conditions and economics indicate, a motor can be added to an existing compressor set, or it can be part of the initial design. In addition to the motor itself, one or two gear type self synchronising clutches will be needed to automatically engage and disengage the two drivers. Dual-driven compressors using clutches manufactured by the SSS Clutch Company have been in operation for over 20 years in a variety of refinery and chemical plant compression applications at powers up to 42 MW. For example, BP installed SSS Clutches at more than a dozen plants to operate 12 - 18 MW compressors used in producing purified terephthalic acid (PTA). The arrangement allowed the compressors to operate off an electric motor until the process generated enough waste heat to drive the compressors with a turbine.

Equipment arrangements

There are at least three different physical equipment arrangements for dual driven centrifugal pipeline compressors.

Arrangement 1 – Conventional side inlet-side discharge pipeline compressor with two shaft ends driven by low speed motor with speed increasing gear and gas turbine

This train arrangement consists of Motor – Gear – SSS Clutch – Compressor – SSS Clutch – Gas Turbine. (Figure 2 - Arrangement 1). To accommodate the dual drive for this arrangement, the compressor must be the side inlet-side discharge type (not axial inlet) with shaft ends available at both ends. The clutches allow the compressor to be driven by either or both drivers. During times of peak electric power cost and comparatively lower fuel costs, the compressor would be driven by the gas turbine. When low cost off-peak electric power is available, the motor (with gear) would be started unloaded and brought to full speed, with the compressor still being driven by the gas turbine. The speed of the gas turbine

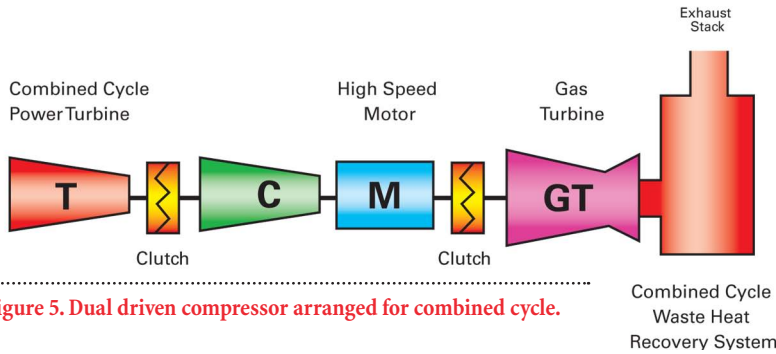


Figure 5. Dual driven compressor arranged for combined cycle.

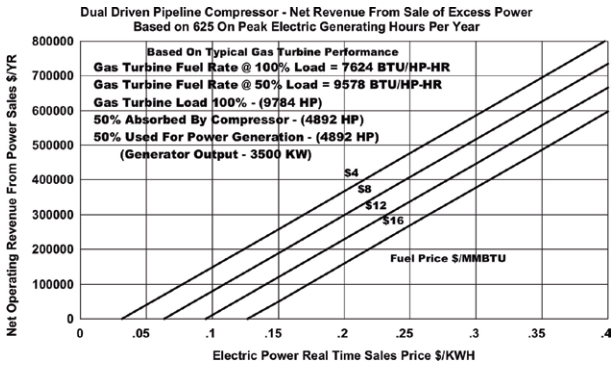


Figure 6. Plot of revenue from electric sales using excess GT power during peak electric revenue times (assumed to be 625 hr/yr).

compressor would be held slightly higher than the speed of the output shaft of the gear. Next, the gas turbine would be shut down. As soon as the gas turbine/compressor speed drops below the motor/gear speed, the gas turbine-side clutch would disengage and the motor-side clutch would engage and the motor would start driving the compressor. The engagement and disengagement of the SSS Clutches is completely mechanical and automatic.

At the end of off-peak power, the process is reversed, bringing the turbine up to speed, engaging the clutch, and shutting down and disengaging the motor.

During times of high ambient temperatures, the motor could be engaged with the gas turbine and operated as a helper. Also the motor could be used to drive the compressor while the gas turbine is shut down for maintenance.

The decision to use either a variable or fixed speed motor is an economic and pipeline operation consideration. A variable speed motor with variable frequency drive (VFD) adds to the cost of the dual drive system. If the upstream and downstream compressor stations are variable speed, it may be possible to accommodate a fixed speed drive. Some pipeline compressors, such as certain models by Rolls Royce Energy Systems are available with variable inlet guide vanes which add performance flexibility to a fixed speed compressor train. Eliminating the gearbox by utilising a high speed motor with VFD is another approach (see Figure 2, Arrangement 1a - as described below). But because the motor is started unloaded, it can be designed

for relatively low inrush current and therefore a VFD is not required for starting considerations.

Arrangement 1a – Conventional side inlet-side discharge pipeline compressor with two shaft ends using high speed super-synchronous motor

This arrangement eliminates one clutch and the gear, but adds an expensive high speed motor and VFD. The arrangement is High Speed (super-synchronous) Motor – Compressor – SSS Clutch – Gas Turbine (Figure 2, Arrangement 1a). When driving only with the gas turbine, the motor would continue to spin, but with the circuit breaker open. The unloaded spinning motor at full speed has windage and bearing losses equal to approximately 1% of the motor full load rating. As the price of VFDs and high speed motors continues to decrease, this may turn out to be the optimum arrangement for compressors with two shaft ends.

Arrangements 1 and 1a could be practical dual drive retrofit opportunities for a conventional side inlet-side discharge compressor installation. It may require a new compressor shaft, but the compressor would remain in its original location on the foundation, therefore requiring no changes in the gas piping. It may also be possible that the gas turbine would not have to be moved.

Arrangement 2 – Axial inlet pipeline compressor driven by high speed electric motor and gas turbine

Since there is only one shaft end on the compressor for connecting the driver, axial inlet compressors require that the motor be located between the gas turbine and the compressor. Since the motor acts as the shaft for transmitting the gas turbine power to the compressor, it is not practical to use a synchronous speed motor and gearbox. The arrangement, therefore, is Compressor – High Speed (super-synchronous) Motor – SSS Clutch – Gas Turbine (Figure 2). When in the gas turbine drive mode, the motor would continue to spin with the train at no load with the circuit breaker open.

Dual drive concept applied to reciprocating pipeline compressors.....

In addition to centrifugal compressors, dual drives can also be used with reciprocating compressors. Typically pipeline reciprocating compressors operate at speeds between 600 and 1200 RPM, accommodating very well multi-pole low speed direct connected motors. For torsional considerations, the favored arrangement is Engine – SSS Clutch – Compressor – Motor (Figure 4). When driving with the engine only, the motor remains connected to the train spinning at no load with the circuit breaker open. Fixed speed motors work well since the reciprocating



Selling power

Adding a motor to a gas turbine or gas engine powered compressor can not only cut energy costs, but can produce additional revenue streams since the motors can be used to generate both real and reactive power to the grid. This is especially beneficial since electrical power demand and gas demand often operate on opposite cycles. Electrical power is in highest demand during the summer, while peak demand for natural gas is usually in the winter.

Pipeline compressors are usually sized for a worst case operating condition that occurs only during a small percentage of the total operating time. During the majority of the time, the driver has excess power, sometimes operating at 50% of load or less. When a GT is operating at less than full load, its efficiency drops sharply. The heat rate at 50% capacity is approximately 25% higher than when operating at full load. This represents a huge waste of energy. As Gordon N. Rogers, P.Eng. outlined in his paper *Gas Turbine Compressor/Generator Hybrid Train for Low Cost Power*, presented at the 14th Symposium of Industrial Applications of Gas Turbines, that excess power could be used to generate efficient cost effective electric power. Given a fuel cost of US\$ 4.00 per million British thermal units (MMBTU) and electric power value of US\$ 60 MW/hr, Rogers calculated a US\$ 1.77 million net annual revenue from a 37 000 HP second generation gas turbine, running a 25 700 HP compressor and generating net power of 8 MW (Figure 6 shows revenues based on current fuel and electric power prices).

Depending on the day/night price fluctuation, the unit may generate electricity during the day, then operate off the grid at night, resulting in a net source of revenue.

In addition, since many pipeline stations only operate a few months of the year to meet winter demand, during the summer the otherwise idle turbines could be converted to peaking generators during the summer months (Figure 3, note the optional clutch for power generation only operation).

One additional source of revenue is the selling of reactive power. Reactive power is what is needed to keep the voltage and amperage of the transmission lines operating in synch so they can carry maximum power, avoid overheating and voltage fluctuations. Some utilities have established reactive power markets. Where such a market exists, the compressor motor can be synchronised to the grid and provide reactive power, providing the pipeline operator with another revenue stream.

compressor with variable volume clearance pockets and suction valve lifters provides considerable flow and pressure range at fixed speed. There are more than fifty dual driven reciprocating compressors in gas gathering service, but none yet in mainline pipeline service.

Natural gas compression firms Exterran and Energy Transfer Group LLC, for example, developed the ESelect dual drive compressor. The first installation was at the New Waskom gas field, using a 1400 HP Caterpillar 3516 Turbo Aftercooled Leanburn Engine and a 1500 HP, 4160 V TECO-Westinghouse Motor Company motor to drive a GE/Gemini D604 Compressor, with an SSS Clutch between the engine and compressor. Since the compressor is within city limits, only 400 ft from the nearest residence, the electric motor keeps noise levels within limits and is used more than 90% of the time. But, since the local electric grid is too weak to handle, the in rush current required by the motor to bring the compressor on line, the engine is used to bring the compressor up to speed before the motor takes over.

The total picture

All of the above dual drive configurations give pipeline operators a method of reducing energy costs. In addition, dual drivers open up additional revenue streams. By using the motor as a generator power can be sold into the grid (see sidebar). The economics of adding an exhaust gas energy recovery system to convert gas turbine exhaust heat to electrical power become more attractive with a dual driven compressor. The combined cycle system can always be operated at full load, decreasing payback time. The compressor can be designed to take advantage of the extra combined cycle power with no loss of reliability since the electric power is available as a backup. (See Figure 5 for a schematic of a dual driven compressor with combined cycle.)

The dual driven compressor train has numerous advantages, including allowing real time selection of compressor driver based on relative gas and electric energy prices, improved reliability and availability, providing extra power to the compressor during periods of high ambient temperatures, and the potential for new revenue streams.

The economics will, of course, vary with each location. The price and availability of electricity; the seasonal and daily price fluctuations; the state of the power grid; the demand for peaking and reactive power; the market for carbon credits and other factors all combine to determine whether it is the best option. It won't always be, but when it is appropriate, as the figures from the turbine compressor example (above) and Gordon Rogers' paper (see sidebar) show, the savings can be significant. ●