An Executive Summary

Standardized Compressor Solutions for Reliable, Cost-Efficient Power Generation

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Boosting fuel gas to feed gas turbines in power plants can be accomplished by various technologies, which all have their pros and cons. The most common are reciprocating, screw, and centrifugal compressors. The best solution from a technical standpoint depends upon various factors. The economically best solution is determined by the resulting cost. Particularly the standardization of the packaging options offered a significant reduction in the CAPEX of centrifugal compressors.

Overview

Choosing the best compressor for a gas power plant is predominantly guided by costs. These comprise initial investment (CAPEX), the operating costs (OPEX), and reliability (repair and opportunity cost during down time). Three different compressor types are usually used for fuel gas boosting: piston compressors and screw compressors are both positive displacement compressors. The gas is trapped within a closed space, which is then reduced in volume. This compresses the gas and releases it at a higher pressure. Centrifugal compressors are working on a kinetic principle: The gas is continuously accelerated by impellers. The kinetic energy is then converted into pressure when the gas is decelerated. Whereas positive displacement compressors have a fixed volume flow and pressure ratio for a given driving speed, the flow and the outlet pressure are interrelated at centrifugal compressors.

Considerations when Choosing a Compressor

The merits of the various forms of compressor can be broken down into several categories. However, the bottom line is the total cost of ownership. Some aspects of which are listed below. The statements are general guidelines for power plants starting at 100 MW. They are meant to be re-evaluated during each project.

Reliability. Reliability is crucial in modern power plants and is associated with OPEX and opportunity costs. **Figure 1** presents some data comparing the types of compressors. Please note that fuel gas boosting centrifugal compressors can be both clean service and fouling service, depending upon the quality of the gas. Screw compressors for fuel gas boosting are usually oil flooded.

The difference between the compressor types becomes more obvious when looking at the opposite of "availability," which would be downtime. Centrifugal compressors have the lowest opportunity costs. They are down between 0.3% and 1.0% of the time, while other solutions are not operating at least 2.3%. Also, the mean time between failures and the time for inspection maintenance, repair, and overhaul are much more favorable for centrifugal compressors and their OPEX.

Efficiency. Compressors increase the pressure of the gas coming out of the pipeline. To this end, energy is needed, which directly affects the operating costs. The efficiency to be considered depends upon the expected range of operation and the duration with which the compressors will operate. Positive displacement compressors are usually controlled by variable speed drives and have a wide range of operation at their peak efficiency. Screw compressor can suffer from lower efficiencies at higher inlet pressures. They also often require 5% or more flow bypass under normal operation. Centrifugal compressors only recycle gas when the required flow falls below a certain percentage of the nominal flow.

When comparing the efficiency of compressor solutions, it is important not only to focus on the peak efficiency, but also to compare the power needed at various load cases and how long the compressors are expected to operate at these load cases.

Controllability and stability. Controllability and stability play an important role for centrifugal compressors. Without control, these compressors can run into surge, which is an unstable operation mode and will damage the machine when running continuously under this condition.

Control not only prevents centrifugal compressors from surging, but they also optimize the operation of a centrifugal compressor such that minimum energy is needed for operation. The control strategy is influenced by the setup of the compressor in the whole plant. If, for example, one compressor can feed one or two gas turbines, other control strategies are needed then if any compressor can only feed one gas turbine. (Though not being directly an aspect of controllability, oftentimes two gas turbines are fed by three compressors where one compressor is redundantly in standby.)

To optimize the total cost of ownership in all its aspects, various setups and control strategies and operation modes

Figure 1: Data comparing the types of compressors.

Compressor Type	Reliability (%)	Availability (%)	IMR&O (h / yr)	MTBF (yr)
Reciprocating, conv. non lube	92.3	91.3	766.1	0.3
Reciprocating, lubricated	97.8	97.3	237.2	0.5
Reciprocating, labyrinth piston	98.3	97.6	207.2	2
Oil flooded screw	98.8	97.7	199.9	1.5
Oil-free screw	99.7	99	90	5
Centrifugal, fouling service	99.5	99	90.6	3.7
Centrifugal, clean service	**99.8**	**99.7**	**24.8**	**8**

IMR&O: Inspection, maintenance, repair and overhaul
MTBF: Mean time between failure
Forced DT: Forced down time

Source: Hydrocarbon Processing® magazine should be compared to each other. The compressor manufacturer will assist and provide input based on a wide range of experience.

Maintenance. Centrifugal compressors generally require less down time and maintenance than other compressors and therefore have lower operating cost (see **Figure 2**). Although they contain more moving parts than screw compressors or reciprocating compressors, the parts do not wear: They are never in direct contact, but are separated by the gas flow (impeller and seals) or an oil film (gear-mesh or bearings). Parts are rotating at constant speed, so the forces are all static. The gas flow is continuous and therefore does not introduce pulsations into the piping. The result of these features is that centrifugal compressors typically require 25–90 hours of maintenance per year. This is about one half what is needed on average for screw compressors and a small fraction of what reciprocating compressors require.

Oil contamination. Oil contamination of fuel gas can cause carbonization of gas turbine nozzles, reducing efficiency and necessitating expensive down time (high opportunity costs). It can also cause an otherwise clean-burning power plant's emissions to drift outside legal limits for nitrogen oxides and the subsequent penalties contribute to the operating costs. There is also a safety concern, as oil may accumulate within a region of the flow path downstream of the compressor and become a potential fire hazard. Oil carryover is primarily an issue with reciprocating compressors and screw compressors, which require that pistons or screws be lubricated. The gas flow of centrifugal compressors is largely oil free, as all lubrication takes place outside the gas flow path.

Pulsation. The issues associated with pulsation are well controlled. However, handling them adds an additional design and maintenance constraint to downstream piping because care must be taken. Pulsation dampeners are available, but add to the expense of the plant and increase startup and shutdown times. Reciprocating compressors produce a pulsating output by their nature, and require a dampener. Screw compressors also produce pulsations, although to a much lesser degree. Centrifugal compressors are largely pulsation free.

When planning a plant, it is important not only to focus on the compressor, but also on the auxiliary equipment.

Temperature. Compressing gas necessarily increases its heat, which is a useful phenomenon for fuel gas boosters. However, in screw compressors, the lubricating oil removes a large portion of the heat generated by the compression. Additional heating of the gas prior to the turbine may be necessary for this type of compressors. This is not necessarily the case for reciprocating and centrifugal compressors, in which the discharge temperature is a result of the inlet conditions, the pressure ratio and efficiency, and can be easily controlled.

Noise. Noise levels are subject to regulatory requirements. For much of the industry, the acceptable long-term noise exposure is 85 dB(A). The noise levels of reciprocating compressors are difficult to mitigate because the piston discharge pulses create high sound levels across a wide range of the acoustic spectrum, which leads to both noise and structural vibrations. Dampening and isolation need special focus because of the broad frequency range and the combination of structural vibration and noise. Many facilities resort to placing the compressor in a dedicated outbuilding.

Figure 2: Maintenance requirements for various compressors.

Screw compressors

- \- Require replacement of coalescing filters and separators, creating extra costs
- \- Require hydraulic transfer system for modulating sliding inlet valve, creating extra costs

Reciprocating compressors

- \- Require regularly scheduled maintenance (replacement of piston rings, gland packing, valve plates, valve control devices), creating downtime and extra costs
- \- Require regular replacement of coalescing filter elements, creating extra costs

Centrifugal compressors

- \+ Minimal regular maintenance beyond replacement of one of the dual-element lube oil system filters, but no shutdown is required

Screw and centrifugal compressors produce noise mostly at higher frequencies, resulting primarily from the movement of gas through the pipes. The higher frequencies are more easily attenuated and can often be blocked with an enclosure incorporated into the skid holding the compressor.

This, again shows how the choice of the compressor solution affects the overall cost (CAPEX in this case) by forcing additional design features like noise attenuation.

Installation. Screw and centrifugal compressors have a clear advantage when it comes to installation. They are often shipped fully assembled on a skid that can be installed without additional civil engineering work. In particular, reciprocating compressors require a large footprint and special foundations to cope with the vibrations introduced by the piston movements. Oftentimes, piston compressors run in dedicated buildings to cope with the noise and vibrations introduced by them.

The moving parts in screw and centrifugal compressors are rotating, and these rotating parts are well balanced. This leads to low vibration levels. Therefore, centrifugal compressors and screw compressors usually do not need special foundations and less sophisticated noise attenuation.

The Advantages of Standardization

Economically, it makes sense to customize compressors with high power because the gain in efficiency outweighs the additional cost of the equipment. Recently, Atlas Copco introduced the TurboBlock™ line. It is based on decades of experience in the fuel gas boosting market and its package design offers a range of standardized key features required by gas power plants. By standardizing the packaging, the cost was reduced by 25%. The system uses a modular design using pre-engineered components with configurable options. The standardization does not affect the core unit. Hence, customized aerodynamics guarantees optimal performance of the compressor.

A set of master drawings are available to customers to enhance the customization process, which reduces the drawing delivery times for customized fuel gas compressors from 12 weeks to four weeks.

The design contains a set of standard components including a lube oil manifold, plate-and-frame water-based oil cooler, dual oil coolers, and an off-skid controls panel. The components are pre-engineered with standardized piping runs. This enables the customer to know from Day One the locations of any connections and to plan accordingly.

The oil system is simplified with a newly developed integrated reverse rotation manifold (patent pending) that integrates features like the check valve or the pressure control valve. An optional sound enclosure attenuates the noise level down to industry standards.

Conclusion

The choice of compressor requires the consideration of various aspects which affect the three variants of cost: CAPEX, OPEX, and opportunity cost. Any decision influences all three types of cost in varying degrees. Each compressor style and control strategy influences the acquisition cost at the beginning of the project and is usually the driving factor for the decision process. The total cost of ownership additionally comprises the operating cost and the opportunity cost in the case of downtime. This is why efficiency and reliability also should be part of the considerations.

For most applications, centrifugal compressors are advantageous over other solutions, or at least not worse.

To reduce the acquisition cost, while not jeopardizing the reliability or efficiency, the newly introduced TurboBlock™ provides the best of two worlds: a standardized package and a customized core. This results in significant savings in development time and cost, while still providing a compressor best suited for each application.