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Use of oil-injected screw compressors in a special fuel gas boosting service

They offer advantages compared to centrifugal and reciprocating types

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Use of oil-injected screw compressors in fuel gas boosting service for gas turbines has been well documented.[1–4] These types of compressors have been used in the first high-pressure application in the US, which also had a special requirement of two different gas fuels available at different pressures.

Rating the different types of compressors. Oil-injected screw compressors compete with reciprocating and centrifugal compressors as well as dry screw compressors in the fuel gas boosting service often required for gas turbines. Each type of compressor has its own list of advantages for the end user. This article is not intended to repeat those details that have been covered in the referenced articles. But for the application explained below, the most important items to the end user were:

- Reciprocating: Perhaps the biggest advantage of this type of compressor was that it was very well known to the utility engineering contractor industry, and many packagers have pre-engineered sets for this service. In fact, for this application, the contractor only had experience with recip sets. In addition to the many sets available, recips also have inherently high efficiency, and maintenance is well known since operating companies typically have many of these types of machines.
- Centrifugal: For this project, these types of compressors were seriously considered for their very high reliability. This is explained by their relative simplicity.
- Oil-injected screw: For this project, these types of compressors fell between recips and centrifugals in a number of aspects. Their reliability was considered to be close behind centrifugals, and their efficiency close behind recips. However, for this project, the main advantage was the ability to maintain high reliability when operating under a very wide range of loading.

It should be mentioned that it is very difficult for the user or contractor to obtain accurate reliability numbers to compare different types of machines. There are no known standards, nor is there a known data collection system among multiple users.

Project description. In 2000, California had a very critical electricity shortage. This resulted in many new gas turbine power plants being purchased and installed in a very short period. Although many larger plants utilizing industrial-style gas turbines were built, one of the favorite types purchased was the aero-derivative turbine power plant. The nominal 50-MW capability fits many utility and industrial applications.

For one refinery, this turbine package was purchased due to both its power size and, most importantly, its exhaust conditions that fit into the plant's steam balance, since the unit would utilize a heat recovery boiler.

The writer was tasked with a related project for this gas turbine. The conditions dictated by economics were:

- The fuel gas compressor(s) should have very high reliability and should not be expected to ever restrict the gas turbine's power output. In other words, the compressor(s) had to be MORE reliable than the turbine.
- The gas fuel to the turbine was to be two different types. One was purchased natural gas, supplied to the plant at approximately 350 psig. The other fuel was a gas stream produced as a result of normal refinery operations, available at 75 psig.
- The gas fuel to the turbine must be able to be mixed 0–100% of either fuel, in any combination. The change of fuel streams will vary month to month, and could change hour to hour. Any change in the gas mix should not affect the gas turbine output or its reliability.

Compressor options explored. The writer was tasked with these limitations and obtained bids from a number of sources. Although there were many offerings, the following summarizes some of the most interesting:

- Reciprocating: To meet the reliability requirement, either two 100% compressor sets or three 50% sets would be required. One offering was for six compressors: 3 × 50% for natural gas and 3 × 50% for refinery gas. Mixing of the stream would be after compression to the required 675 psig. Another offering used two 100% specially built compressors, with multiple cylinders on each frame that could handle the two different gas streams.
- Centrifugal: These compressors have such high reliability that they could be installed unspared (i.e., one 100% compressor). The biggest challenge in applying centrifugal machines in this application was the wide fluctuation of the two gas streams. One option offered was to let down the natural gas to the same 75-psig level as the refinery gas to simplify the centrifugal compressor controls. Obviously, this option would have serious energy debits.
- Screw: The author had previous experience in other plants with oil-injected screw compressors and was familiar with their advantages. One key advantage of oil-injected screws is use of a slide valve to internally control capacity with tremendous energy savings. The part-load power is close to the part-load capacity.[1]

The turbine obtains its high efficiency from a number of design features, most notably high firing temperature and compression ratio. This high compression ratio, however, means that the fuel to the turbine must overcome that air pressure, and the required fuel

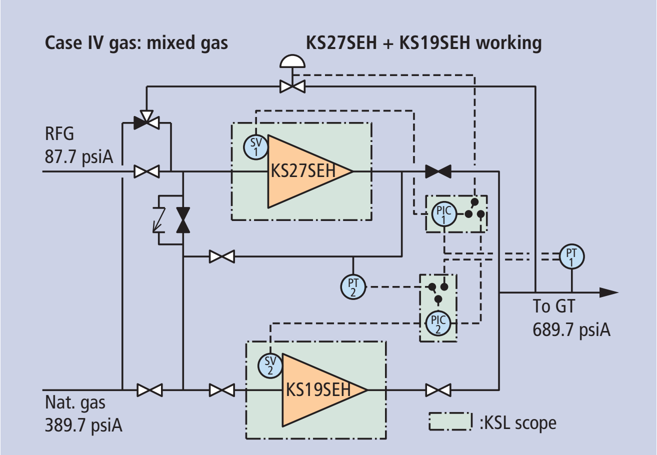

FIG. 1 If either compressor has a problem and cannot operate, then only natural gas can be burned in the gas turbine, coming from either compressor.

gas pressure is nominally set by the manufacturer at 675 psig.

The writer contacted a number of screw compressor packagers and manufacturers and soon found that although screw compressors had been applied in the US for gas turbines, all of these had been for industrial gas turbines, or smaller aero-derivative turbines, both which have much lower fuel gas pressure requirements. In fact, at the time this project was started, only one oil-injected screw compressor vendor could supply units capable of compressing to 675 psig, but it had only supplied compressors for turbines in Japan.

Final selection and arrangement. For this project, reciprocating compressors were rejected since their lower expected reliability would require installing multiple sets and increased maintenance costs.

Also for this project, the centrifugal compressor option was rejected, mostly due to concern about fluctuating gas flows. This would mean operation with recirculation for surge control, even with use of adjustable inlet guide vanes to maximize the turn down.

For this project, oil-injected screw compressors were chosen. Two compressors are used, installed on two skids. One compressor pumps the refinery fuel gas, compressing it from 75 psig to 350 psig. The second compressor pumps either 100% natural gas from 350 to 675 psig, or a mix of natural gas plus refinery gas coming from the first compressor, after it has gone through an intercooler. Of special interest, the refinery fuel gas compressor was also capable, and piping/valves were installed, to allow it to pump natural gas from 350 to 675 psig. Thus, there is an installed spare for natural gas service. If either compressor has a problem and cannot operate, only natural gas can be burned in the gas turbine, coming from either compressor (Fig. 1).

One main advantage of this arrangement is that each compressor has variable capacity control from the slide valve that can unload a compressor down to approximately 25% of full capacity. Each compressor also has a recycle valve from discharge to suction to allow for quick response and operation below 25% capacity.

Operational experience. The compressors have been in operation since late summer 2002. They have met all of the project requirements. One compressor had a seal change due to foreign material from the refinery gas. Both compressors had their 100-mesh suction screens cleaned out a few times, again due to foreign material from the refinery gas. Neither compressor has required any other work. It appears that the oil-injected screw compressor reliability is equal to, or greater than, the centrifugal compressor.

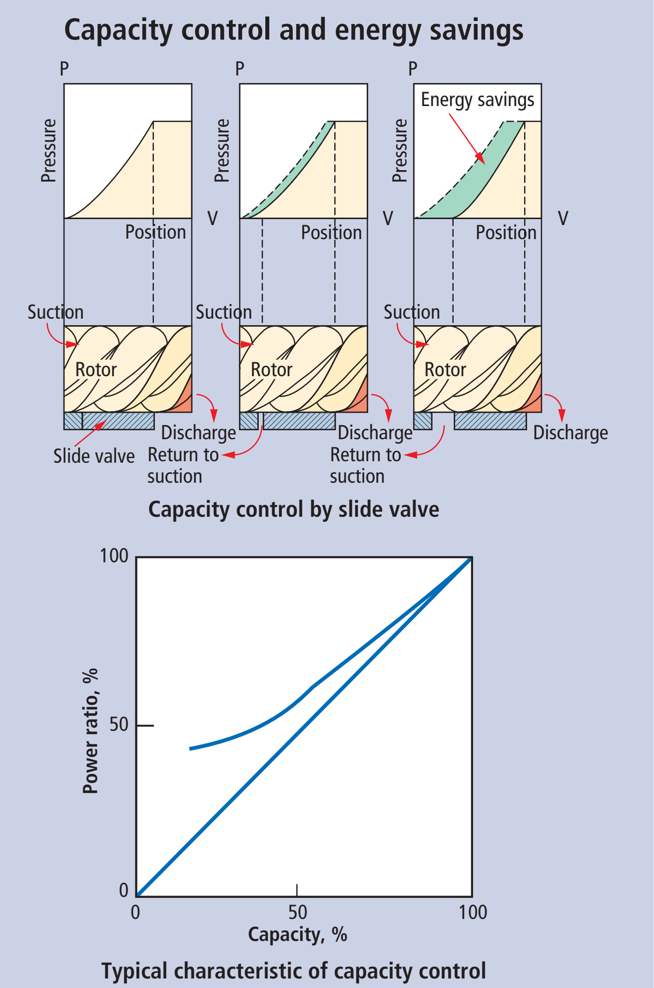

FIG. 2 The oil-injected screw compressor typically employs an internal slide valve that limits capacity.

Some potential users of oil-injected screw compressors may be concerned about oil carryover into the gas turbine fuel system, even though the oil-injected screw vendor guarantees five ppm maximum oil carryover in the gas stream, which meets the gas turbine vendor's fuel specification. In this plant, borescope inspections were scheduled every two months, and fuel gas nozzles were changed a number of times due to contaminants in the refinery gas. There have been no indicated problems in the gas turbine due to oil; the final fuel filters have shown no oil.

Special considerations. Oil-injected screw compressors have been used by many people, but there may be others who are not familiar with them or the advantages. At the same time, anyone considering use of such machines might not be familiar with some of their special design features, which are different from reciprocating or centrifugal compressors.

Oil systems. A new user will soon become aware that the oil system is an integrated part of an oil-injected screw compressor. For example, the compressor discharge vessel is also the oil pump's suction or reservoir. This means the oil pump operates at a suction pressure equal to the compressor discharge pressure, with the oil pump discharge operating at about 50 psig over suction. The discharge vessel is also the oil separation device. Another surprise to the new user might be the relatively large oil cooler, because the oil system is also the compressor intercooler. This also means the gas discharge temperature is typically much lower than a recip or centrifugal unit at the same pressure ratio.

Skid design/manufacture. The writer had some experience with older oil-injected screw compressors that were packaged by different companies, with a wide range of success. Suffice it to say that the wise user will want to ensure that the packager has much experience and can supply a list of users for reference. Some concerns are baseplate rigidity, piping support, types of instruments used, oil pumps employed, breakout piping flanges for compressor maintenance, and maintenance access to pumps, valves, instruments and the compressor. Careful review of piping isometric drawings is recommended.

Controls. As mentioned, the oil-injected screw compressor typically employs an internal slide valve that limits capacity (Fig. 2). Depending on the compressor size, this valve can limit capacity down to 10%–25% of maximum volume flow. Again depending on the compressor size, this valve can have a relatively slow response time, sometimes over a minute for full stroke.

In addition, a recycle valve (discharge to suction) is used to quickly unload the compressor when required, giving the slide valve time to react. This is especially required during a rapid load/unload condition on the gas turbine. The recycle valve is also used to control capacity down to 0%. The interaction of these controls is very important, and the packager typically provides a PLC for this control. Another option is to do this control in the plant's control computer (DCS).

The future. Although oil-injected screw compressors have made inroads into the compressor industry in the US, many users are still unfamiliar with these types of machines and their tremendous advantages. In fact, except for some specialized applications, oil-injected screw compressors may well become the industry standard. They could displace reciprocating compressors in many applications due to the higher reliability of screw compressors, and they could displace centrifugal compressors in some applications due to the higher efficiency of screw compressors. **HP**

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