

# OILFIELD TECHNOLOGY

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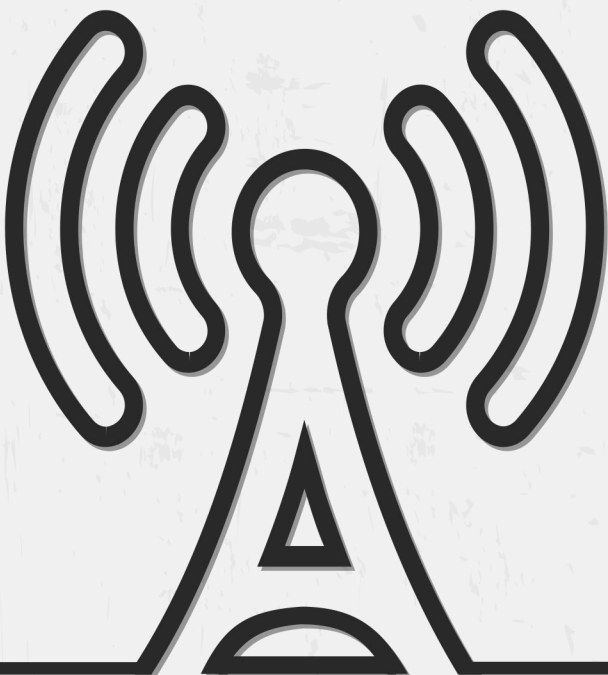
# Improving Reliability Remotely

**Michael Werner and Bas Roeloffzen, Siemens AG, discuss how to boost compressor train reliability and availability in oil and gas applications via remote monitoring and diagnostics.**

**A**s complex, extremely fast rotating machinery, the giant compressor trains used in applications all along the oil and gas industry value chain, from wellheads to refineries, are designed, engineered, and built to be remarkably reliable and fault-tolerant, much like their cousins in jet-engines. But should a fault occur, disruptions to whatever processes they drive or carbon-based products they move can be costly and even threaten health, safety, and environmental (HSE) standards of operation.

For these reasons, a growing number of operators are taking advantage of the increasing digitalisation of compressor technology to improve the reliability and availability of their compressor trains. They are combining this trend with strict cybersecurity safeguards for their data and highly secure Internet communications, linking their fleets to remote monitoring facilities that actively track unit performance 24/7. This article explains how this model works and provides three short case studies to illustrate it.

In fact, Siemens' experience in monitoring several thousand connected rotating equipment units worldwide – from large gas turbines for power generation to compression trains, with more than 800 installations in the oil and gas industries – has shown a major upside to remote performance monitoring and diagnostics. By averting trips and resulting forced outages via early detection of potential faults and preventive remediation,





compressor availability can be increased by as much as 3%, equivalent to 11 days over the course of a year.

Extrapolated over a compressor's 20 year lifespan, that additional availability can add up to significant avoidance in saving disruptive downtime and related expense, which can otherwise send a compressor train's total cost of

ownership soaring. Another benefit is extending the life cycle of components due to more proactive and tailored maintenance approaches. Reductions in maintenance budgets and the retirement of experienced staff can also put strain on a company's capacity to monitor performance.

Ultimately, higher asset utilisation can potentially boost

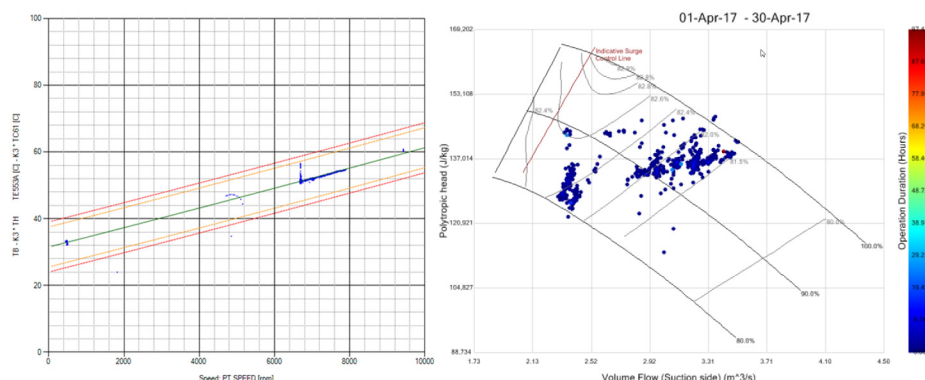
returns on invested capital, given the capital intensity of compressor train infrastructure. Additionally, performance optimisation can help reduce operating expenses. Fouling, for example, can increase throughput pressure, requiring more energy – as much as 850 additional kw/d for every 5 psi increment in pressure.<sup>1</sup>

## How remote condition monitoring and diagnostics services work

In essence, remote data monitoring and diagnostics for compressor trains is a collaborative, data-sharing model between oil and gas operators and their infrastructure's OEM manufacturer, together using rigorous cybersecurity to protect the data while in motion and at rest. In effect, it puts in place an early warning system capable of alerting operators to performance anomalies in their compressor trains that can indicate needed maintenance before a breakdown occurs. This actionable intelligence can also provide decision support on how to best manage degrading performance until the next planned maintenance outage.

In comparison to on-premise, condition-monitoring solutions, which mostly rely on data-driven analytics, connecting back to the OEM offers several advantages:

- ▶ Avoids spamming the onsite operators with false alerts, as the OEM can screen false-positives and forward only true-positive identifications of abnormal behaviour.
- ▶ Enables comparisons between actual as-is and as-designed performance parameters, via the equipment's design software packages.
- ▶ Taps into as-built knowledge of the machinery, which only the OEM has access to, when a true step change has been identified and an answer is required to the critical question: 'What should be done about it?'
- ▶ Enables comparisons between compressor trains leveraging 'know-how' between compressors with identical configurations, industry segments and operation regimes.



**Figure 1.** Sample output for compressor performance monitoring. Left: Bearing fingerprint. Right: Compressor performance heat map.

**Table 1.** Examples of compressor-specific remote diagnostic capabilities.

Operating dimension	Monitoring objective	Input tags	Output tags
Compressor performance monitoring	To detect wear caused by fouling, as well as any internal leakage caused by increasing component clearances. Observed by degrading performance.	<ul style="list-style-type: none"> <li>Gas composition</li> <li>Suction pressure</li> <li>Suction temperature</li> <li>Inlet flow</li> <li>Speed</li> <li>IGV position</li> <li>Drive power</li> <li>Discharge pressure</li> <li>Discharge temperature</li> </ul>	<ul style="list-style-type: none"> <li>Actual mass flow compressor</li> <li>Actual volume flow compressor</li> <li>Actual polytropic head compressor</li> <li>Actual polytropic efficiency compressor</li> <li>Theoretic polytropic head new compressor</li> <li>Theoretic polytropic efficiency new compressor</li> <li>Delta polytropic head</li> <li>Delta polytropic efficiency</li> </ul>
Seal gas monitoring	Detection of barrier seal and dry gas seal degradation. Observed by monitoring the ratio of the expected over-actual seal volume flow.	<ul style="list-style-type: none"> <li>Actual speed</li> <li>Seal gas supply pressure</li> <li>Gas composition</li> <li>Pressure before orifice</li> <li>Pressure behind orifice</li> <li>Temperature before orifice</li> <li>Pressure before valve</li> <li>Pressure behind valve</li> <li>Temperature before valve</li> <li>Pressure control valve opening</li> </ul>	<ul style="list-style-type: none"> <li>Expected DGS mass and volume flow per ring</li> <li>Actual DGS mass and volume flow (orifice/valve)</li> <li>Ratio DGS volume flow (expected/actual)</li> <li>Expected barrier seal mass and volume flow</li> <li>Actual barrier seal mass and volume flow (orifice/valve)</li> <li>Ratio barrier seal volume flow (expected/actual)</li> </ul>
Gas composition monitoring	Determination of the actual gas composition to improve the compressor performance agent.	<ul style="list-style-type: none"> <li>Gas temperature</li> <li>Gas pressure</li> <li>Gas density</li> <li>Sensing time period</li> <li>Scrubber outlet temperature</li> <li>Scrubber outlet pressure</li> </ul>	<ul style="list-style-type: none"> <li>Actual gas components and fraction</li> </ul>
Bearing monitoring	Detection of radial bearing abnormalities. Observed by comparing a unit's design specs (i.e. 'fingerprint') with actuals. Generates an agent message when the value exceeds allowable tolerances.	<ul style="list-style-type: none"> <li>Speed</li> <li>Radial pad temperature</li> <li>Oil supply temperature</li> </ul>	<ul style="list-style-type: none"> <li>Flagged deviation, anomaly, by rule-based Agent message</li> </ul>

As such, this model supports more proactive, condition-based, and predictive maintenance approaches that can potentially save considerable maintenance costs compared to conventional schedule-based models that are more reactive and often induce unneeded maintenance just because the schedule requires it.

To explain how data-sharing, analytics, alerting, and the remediation process of compressor train performance remote monitoring and diagnostics works, it all starts with unit sensors that collect performance data on a wide range of operating parameters, such as speed, temperature, vibration, gas composition, and so on. In most cases, older legacy and third-party compressor trains can be outfitted with sensors to pick up their signals.

The data are processed with 256 bit encryption, the same as that used by the world's top banks and governments, and sent hourly or daily, over a highly secure, virtual private network (VPN) connection to the monitoring facility. In case operators need remote troubleshooting, this VPN connection enables Siemens to support them remotely while they retain full control over managing the data access. Soon, data streaming at faster intervals will make it possible to predict and preempt performance issues even more quickly and accurately than today.

In addition, Siemens can use a time-stamping technology, as is already deployed in its onshore, remote condition monitoring of equipment on North Sea oil platforms. Conventional condition-monitoring methods sample time intervals (e.g. every third second), but that can catch one anomaly while missing another, especially if multiple events are recorded in one sample. If two or more events occur in a single sample, it is impossible to know their sequence and therefore determine any cause and effect.

With timestamps, however, the sequence of an event series can be clearly seen, making it easier to identify and distinguish correlation and causation. This can accelerate troubleshooting by making data analysis more precise, reliable, and insightful. For example, the condition-monitoring algorithms for on/off valves can monitor the trends in a valve's travel time and can early identify if one starts moving more slowly, indicating a replacement may be needed.

## Keeping data secure in motion and at rest, even after arrival

On arrival at the monitoring facility, compressor train data is decrypted, anonymised, and stored in parallel redundant databases behind next-generation firewalls, all for additional security, backup, and disaster recovery. After this initial security processing, the data is analysed using a unique and sophisticated compressor performance agent, which is a custom-coded industrial software application. It compares as-designed and as-factory-tested performance parameters of the compressor and its train with the actual incoming performance data. Then it applies advanced data analytics and pattern recognition software, which processes complex events in the data, searching for deviations from normal, expected behaviours.

The software generates heat maps showing compressor performance curves and other graphic data representations to provide control room engineers with operating insights for specific compressors. If deviations occur, the assigned diagnostic engineers (compressor technology experts) are alerted, so they can immediately begin investigating potential root causes, not only with the compressor but its entire train, including what is driving it, whether gas or steam turbines or electric motors.

Supporting their investigations, in the case of Siemens-monitored compressors, is an advanced diagnostic system. This is a sophisticated text-mining tool that helps the engineers search a global knowledge base for similar issues and their resolutions. The contents of that knowledge base is drawn from operating performance histories compiled from available samplings representing more than 130 000 industrial rotating equipment installations worldwide, with nearly two-thirds in oil and gas applications.

## Looking for anomalous performance behaviours and actionable intelligence

The knowledge base contains a growing number of operational signatures of different compressor models and their trains deployed in specific applications, climates, and geographies. This enables the cross-indexing of records and data, so when a compressor train performance anomaly might occur in a particular application in China, a flag can be set to watch for similar anomalies elsewhere in the world. If they happen, proven resolutions can be more quickly recommended. At the same time, investigations can be launched to determine causative factors, whether design, materials, operating conditions, or other shared circumstances.

In the case of a singular compressor train performance anomaly, when a likely cause is identified, the compressor's operator is notified of it, along with a risk assessment and suggested course of action. The remedial action may need to be immediate to prevent a forced outage or it can be scheduled to be addressed during the maintenance window of a planned outage. If parts need replacement, spares can be pulled from inventory or, if not available onsite, express delivered to minimise downtime due to logistic delays.

Then, when the remediation of a potential or actual problem does take place, engineers in the remote diagnostic centres can tap into the compressor train's human-machine interface (HMI) and by phone to observe and advise the maintenance technician on the proper procedures to follow. This real time, 'over-the-shoulder' engineering support can help to significantly reduce mean-time-to-repair (MTTR) cycles, reducing outages, if forced, and minimising their disruptive costs. In effect, this approach combines the deep OEM compressor train knowledge of the manufacturer with the extensive onsite operations experience of the customer.

## Case studies to illustrate the benefits of remote monitoring and diagnostics

What follows are three case studies from around the world – Australia, Egypt, and Peru – that show the substantial benefits that remote monitoring and diagnostics of compressor trains can help operators realise:

### Australia coal seam gasification plant

- ▶ Installed as four trains over two project sites are four Siemens single-shaft vertical split turbocompressors (STC-SV models), which are centrifugal barrel-type turbocompressors. During remote monitoring, it was observed that the four compressors were operating with their anti-surge valves remaining open beyond what was deemed necessary. This indicated unnecessary recycling and over-consumption of fuel gas.
- ▶ A root-cause investigation followed in concert with the customer's onsite staff. It revealed the inlet flow derived

from a differential pressure (dP) measurement were conservative, which was causing the valves to open too early to prevent compressor surge. The solution was to execute a surge-line testing procedure to define actual surge and control line on the compressor performance map, define the calibration factor to calculate the correct flow, and update the valves' control.

- ▶ The remedial action resulted in the customer experiencing fuel gas savings of 0.2 terajoules per day per train, totalling more than a US\$1 million reduction in annual fuel gas costs and a CO<sub>2</sub> reduction of around 3000 tpy. It also reduced wear on the anti-surge valves, helping to extend their performance life cycles.

#### Egypt gas production facility

- ▶ A Siemens STC-SV turbocompressor is installed. In a follow-up of site investigations and replacement of dry gas seals, the customer requested remote support for its operation team. The first start-up of the compressor train was monitored by seal experts located at the remote diagnostic centre in Hengelo, the Netherlands. Using the Siemens Common Remote Service Platform after the customer granted access, a VPN connection was made to the train's HMI prior to start-up.
- ▶ This enabled the seal experts to monitor the seals and start-up process in real time and provide the customer's onsite staff with over-the-shoulder advice on the compressor's operation and, specifically, performance of the dry gas seals. One benefit was the direct availability of the OEM experts' knowledge and experience with the dry-gas-seal and start-up situation. Another was the increase in the compressor's availability because there were no logistical delays (e.g. deploying a support crew to Egypt).

#### Peru gas compression facility

- ▶ Back-to-back Siemens STC-SV turbocompressors are being used in a gas compression plant, isolated in the Peruvian jungle. Remote performance monitoring revealed that the primary vent flow and pressure at the seal on driven-end side of the compressor tended to exceed design specification and the customer was provided an early warning notification. Several months later the flow became difficult to control. A root-cause analysis found running marks on the dry gas seal showing that the seal was extremely worn, possibly due to low-speed RPMs, and needed replacement.
- ▶ Given the plant's hard-to-access location, the customer was advised to temporarily raise the compressor's trip level to prolong production until contractual obligations were met and the next planned maintenance shutdown. During this time, the customer was regularly updated on the degradation of the seal. As a result of avoiding an unplanned shutdown, the customer met production commitments, and had time to fully plan, prepare, and mobilise the personnel and parts needed to replace the seals. In all, four days of production were spared an unplanned shutdown, totalling US\$2 million of potential lost profits being avoided.

### Greater asset utilisation, lower TCO, and increased return on capital

Although compressor trains used in oil and gas applications are designed, engineered, and built for the highest possible reliability and availability, they are complicated machines and their rotary operation – usually continuous – subjects them to

enormous stresses, especially centrifugal ones, and wear on moving parts.

Of course, this does not even cover the wide range of uses for this infrastructure across many different applications, which can create operating variability that can lead to fouling, worn seals and bearings, as well as other maintenance demands that need careful monitoring. No matter the cause, downtime can cost in the millions as two of the case studies have shown. HSE standards can also be compromised.

Fortunately, modern digitalisation of this critical oil and gas technology, along with cyber safeguards and highly secure network communications, make it possible to remotely monitor performance and conduct diagnostics as needed on the health of a single compressor train at one site or an entire fleet of them across many sites. Many operators have had serious concerns about cybersecurity, which has slowed their embrace of digitalisation and remote monitoring models such as those described in this article. However, the cybersecurity protections deployed in these applications are considered the world's strongest.

Also, as maintenance tighten up and as older members of maintenance staff retire, the reduction in resources and expertise can be more than compensated with the continual availability of expert, over-the-shoulder guidance in real time, no matter where in the world a compressor train needs attention.

More and more oil and gas operators are finding the economics of this collaborative, data-sharing model of managing compressor train performance remotely to be most compelling, especially in terms of ensuring optimal asset utilisation, lower total cost of ownership, and returns on invested capital. It illustrates how existing technologies can be combined to drive new applications in oilfield technology to make the industry more profitable, enabling better payouts to shareholders and more investments in finding new reserves.

With the ongoing digital transformation that is happening right now across all industries, more advanced technologies will amplify these benefits even more. Cloud-based analytic platforms, such as Siemens MindSphere, enabling the first steps of adapting edge analytics in ways that can close the gap of operational time windows of compressor train operators in the oil and gas industry.

Big data analytics will also enable the development of more advanced artificial intelligence beyond diagnostics that can leverage past experiences and existing knowledge bases to provide advanced diagnostic services. Today, the actual health status of a specific machine is compared with the general health status of the fleet (e.g. same frame family/application/operational profile) by leveraging data accumulated in the system over the last 10 years. But in the near future, advanced diagnostic services will provide immediate recovery actions based on well-defined failure patterns.

Although the final outcome of this transformation is still to be seen, it will result in a closer collaboration of operators and OEMs based on a continuous data exchange, and will move today's remote diagnostic services more towards 'real time' remote operational support. ■

### References

1. Khalaji, S., 'COMPRESSOR OPTIMISATION—1: Energy recovery guides natural gas pipeline system efficiency', *Oil & Gas Journal*, (January 9, 2012) – <http://www.ogj.com/1/vol-110/issue-1a/transportation/energy-recovery-full.html>