case story

Compass 6000 helps give PDO **the competitive edge**

Compass 6000 was selected by the national oil company Petroleum Development of Oman (PDO) to monitor gas-lift compressors and other enhanced oil recovery systems at various oil production sites in Oman in light of the declining reserves. Compass has already been actively used by PDO for the last 10 years for monitoring gas export compressors that feed the Oman LNG plant.

Fig. 1. Saih Rawl Central Processing Plant.

Petroleum Development of Oman (PDO) is the major exploration and production company in the Sultanate of Oman, accounting for more than 80% of the country's crude-oil production and nearly all of its natural gas supply. PDO is majority-owned by the Government of Oman which has a 60% interest, Shell with 34%, Total with 4% and Partex with 2%. It employs more than 4,100 employees and manages a production of 556,000 barrels/day of crude oil, 77,000 barrels/day of condensate and 946 billion m^3/day of gas.

PDO has drilled more than 4,200 wells in more than 125 oil and gas fields in Oman. A system of pipelines interconnect the oil processing stations and links these to a crude oil terminal and refinery operated by PDO at Mina al-Fahal.

PDO also explores, develops and operates natural gas fields on behalf of the Omani government. It is transported to the Government Gas System (GGS), where it is distributed to power plants, local industry and processed into LPG. Much of the associated gas is re-injected into the fields to enhance oil recovery. PDO operates the central gas reservoirs of Saih Nihayda, Saih Rawl and Barik, which lie deep beneath the three corresponding oil producing fields and account for most of Oman's non-associated gas reserves. Most of this gas is transported to the 3-train Oman LNG plant at Qalhat near Sur.

Oman has some of the oldest oil-bearing reservoirs in the world, formed during the pre-Cambrian era about 500,000 years ago. As a result of the complex geology, the fields require

Fig. 2. Qarn Alam steam-injection plant.

more wells to be drilled yet still deliver relatively low oil production.

This plus the fact that the crude oil is of low quality (as that found in the southern fields) results in oil production costs that are relatively high. These challenges have consequently made PDO an international leader in the application of enhanced oil recovery technology. It also forces PDO manage their production assets cost-effectively in order to be competitive, especially in terms of the declining oil output.

Plants and machines monitored

All machines monitored by the Compass 6000 system are part of the enhanced oil recovery network of systems implemented and operated by PDO. Most of the oil producing fields are beginning to deplete and therefore require a secondary oil recovery technique to ensure oil production. The pumps and compressors used in the enhanced oil recovery are critical, meaning downtime on any of these machines will completely stop production from the field.

The extra expense of using enhanced oil recovery systems coupled with the fact that the oil produced has a large quantity of water requiring separation and treatment (up to 70%) and the less than ideal oil quality, requires an operating margin that has no tolerance for downtime.

The associated gas produced from the oil fields mentioned in Table 1 is the same gas used for gas re-injection. Non-associated gas, however, is produced from various gas fields (i.e. Yibal, Saih Rawl gas fields, etc.)

Field (Station)	Secondary oil recovery	Machines monitored	Monitoring strategy
Yibal (B, C)	Gas re-injection	3 motor-driven centrifugal compressors at Yibal B, 1 motor-driven centrifugal compressor at Yibal C	Condition and performance (piggy-backed on the existing safety system) at Yibal B, Safety, condition and performance at Yibal C
Natih	Gas re-injection	3 GT driven centrifugal compressors	Safety, condition and performance monitoring
Saih Rawl (oil producing station)	Gas re-injection	1 motor driven centrifugal compressor and 1 reciprocating compressor	Safety, condition and performance monitoring
Qarn Alam	Steam injection	Critical pumps, compressors and auxiliary machines	Safety, condition and performance monitoring

Table 1. Plants and machines monitored at PDO.

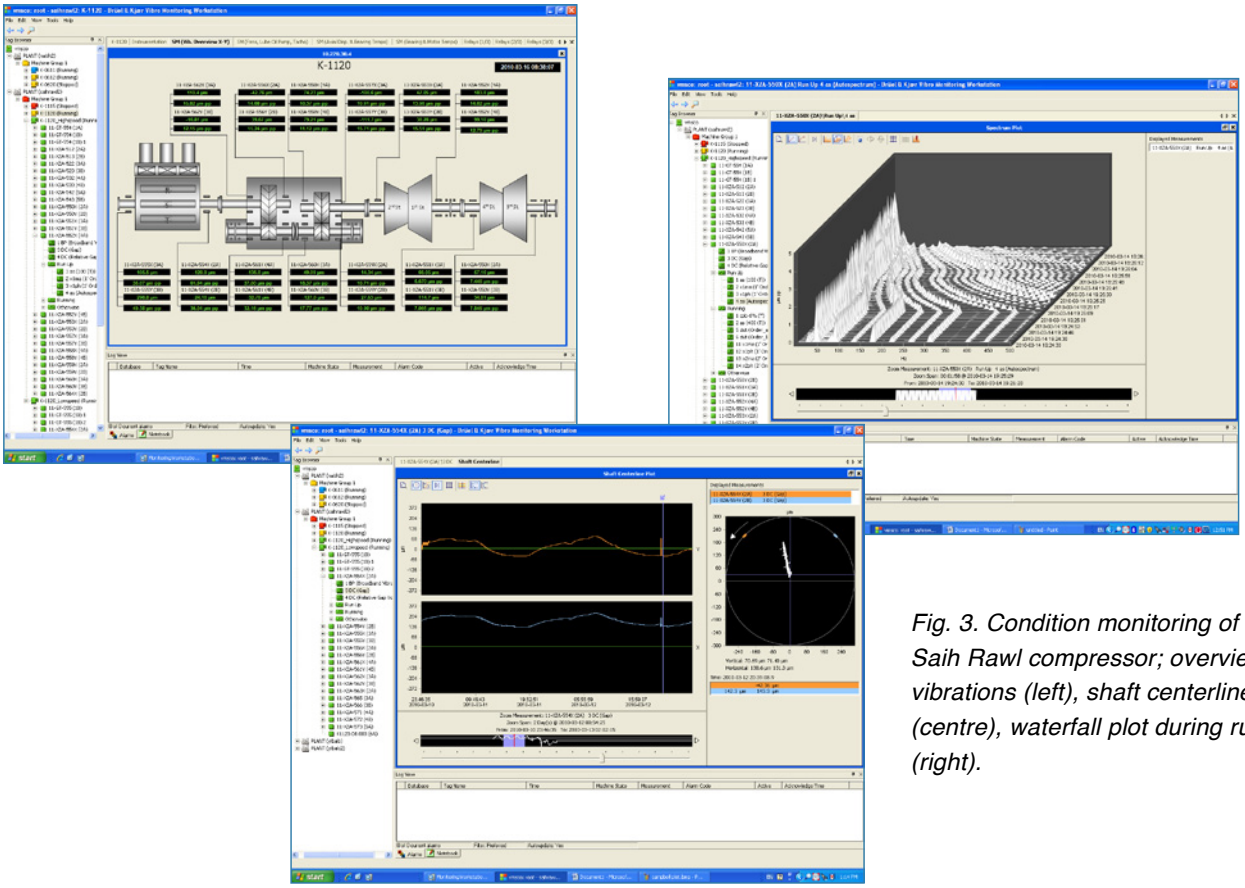

Fig. 3. Condition monitoring of the Saih Rawl compressor; overview of vibrations (left), shaft centerline plot (centre), waterfall plot during run-up (right).

and fed into the Government Gas System for providing most of the gas used for domestic purposes. In addition to this, the non-associated gas from the Saih Rawl gas fields is fed into the three LNG trains at the Oman LNG plant at Qalhat, via a 352 km pipeline. Four motor-driven variable-frequency centrifugal compressors of 30 MW are used to bring the gas up to pressure and for exporting it to the LNG plant.

These critical machines – those at the Saih Rawl main gas compression station as well as those at the Oman LNG plant – are currently being monitored only by Brüel & Kjær Vibro's COMPASS Classic system! Commissioned in 1999, there are currently no immediate plans to replace the system as a result of the ongoing successful operation provided over the years.

Monitoring strategy and system configuration

The primary components of the Compass 6000 system used by PDO include the Compass 6000 condition and performance monitoring server and the VC-6000™ rack-mounted safety monitoring system. The VC-6000™, in addition to providing safety monitoring, also acts as the data acquisition unit for delivering data to Compass 6000 via an OPC interface. This data is processed in the Compass 6000 condition monitoring system for database storage, alarming and advanced diagnostics, together with conditioning and performance monitoring measurements.

Monitoring system interfacing

As a plant-wide system, Compass 6000 is remotely accessed at all sites. This is especially important at PDO since all the sites are located in remote desert conditions several hundred km from each other. Compass 6000 is integrated to external systems by the following means:

- **Process control system** – Vibration and alarm data is exported to operator screens via Modbus. This enables the operators to make production decisions with greater ease when signs of a developing fault are present.
- **Performance monitoring** – Process data (temperatures, pressures and flow) is exported from the process control system to Compass 6000 via an OPC interface. Process data is used for calculating and monitoring the thermodynamic performance parameters.
- **Remote access** – Condition monitoring specialists in PDO and Brüel & Kjær Vibro can access the data

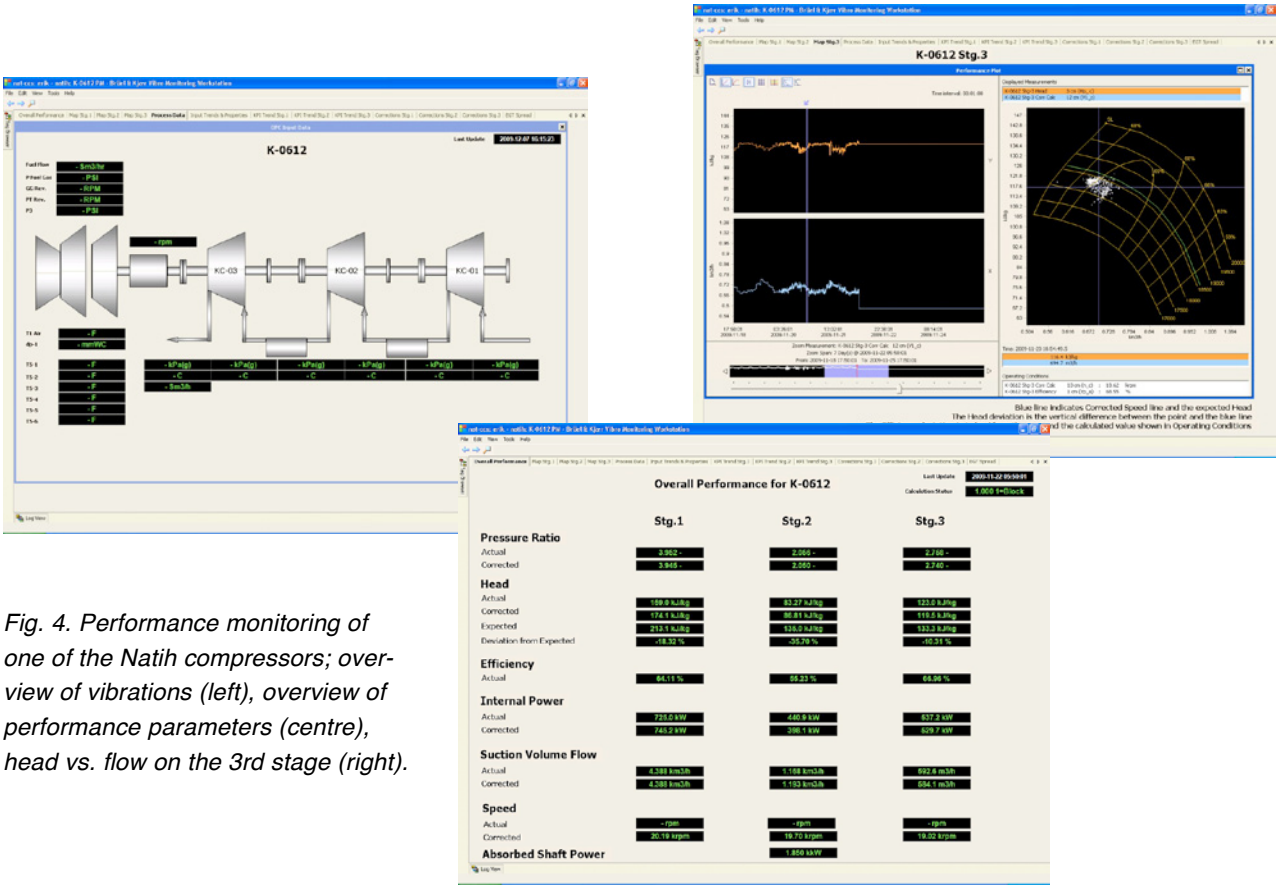

Fig. 4. Performance monitoring of one of the Natih compressors; overview of vibrations (left), overview of performance parameters (centre), head vs. flow on the 3rd stage (right).

remotely via secure LAN/WAN for evaluating current machine condition, determining lead-time to maintenance by trending and performing diagnostics.

Monitoring system services

A comprehensive plant-wide monitoring system with remote access to various IT systems and users requires effective services to ensure proper project steering, installation, commissioning, and after-sales support of the system. For this reason PDO opted for a suite of Compass 6000 services to ensure the system is fully functioning with minimal start-up delay. The Compass 6000 system also offers privileged functionality for a range of users, so this in itself required a flexible training program that met the needs of different operators and users.

Monitoring system plans

PDO is an innovative company that is continuously taking on the challenge of extracting oil from depleting reservoirs. This requires continued research and the implementation of enhanced oil recovery technology in order to maintain production output and remain competitive. After more than 10 years of successfully using COMPASS Classic, these systems are gradually being replaced by Compass 6000. In addition to this, Compass 6000 systems will be installed where new enhanced oil recovery systems are deployed.

Acknowledgement

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