PICKING UP DISTRESS SIGNALS FROM FAR AWAY

Veros Systems, based in Austin, Texas, USA, uses highly sophisticated data-processing techniques to decipher the current and voltage waveforms associated with electrical motors in order to gain valuable insights into the performance, mechanical condition and likelihood of failure of vital rotating equipment. The waveforms are picked up not from the equipment itself but, notably, from its power cables, with the connections often being made thousands of metres away.

Shell Ventures became interested in Veros in 2013 and closed the deal to take a stake in the company the following year. According to Shell Ventures implementation manager Giancarlo Savini, the main driver for the move was the amount of money Shell spends on maintaining motor-driven rotating equipment: pumps, compressors, cooling fans and so forth. It is estimated that across all of Shell's oil and gas assets up to 20% of total production costs goes into the maintenance of equipment of this kind. And yet the equipment continues to fail and cause shutdowns. Giancarlo reports that compressor failures lie in third place on Shell's list of the reasons for production deferrals.

In the light of this state of affairs, Veros's technology seemed very attractive: its ability to monitor the electrical signals from a motor remotely – and extremely precisely – along with the expertise to translate these complex datasets into meaningful information that may be used to improve operations, manage maintenance proactively and prolong equipment life.

“By investing in Veros, we get to influence its technology development in the direction of Shell's pain points and can potentially accelerate the deployment of the technology in our assets,” explains Giancarlo. “For our part, we can help Veros to understand the operational issues surrounding the application of the technology and help to make its offer more relevant and competitive to customers, so increasing its revenues.”

What helped seal the investment was a bench trial of the technology carried out at Texas A&M University in late 2013, which was overseen by Rob Parchewsky, then a Shell principal engineer specialising in rotating equipment. The trial involved running a pump on a test bed and then introducing sand into the fluid flow – actually quite large amounts of sand, enough to induce erosion issues and affect the integrity of the pump very rapidly. A Veros remote monitoring system fitted to the pump's electrical supply soon picked this up – without any precalibration – and issued a warning alarm of a mechanical problem, as opposed to an electrical one, with a confidence level of 80%. Over a few days, the system updated the warning and indicated the problem was becoming more critical; further, the level of confidence in the warning also rose to 90%. In stark contrast, a competitive system from a leading electrical-engineering company also based on electrical signal analysis failed to detect any changes in the condition of the pump or its operation as the sand was introduced.

Rob was suitably impressed: “The Veros monitoring system definitely proved itself in the trial. Further, it seemed to us that the required hardware would be relatively inexpensive and easy to fit. But the biggest advantage was that the system was completely nonintrusive and could be located well away from the equipment to be checked. From a technical standpoint, it was easy to recommend that Shell Ventures should invest in the company.”

The company

Veros was founded in 2001 by Professor Alex Parlos, then at Texas A&M University. For the next 10 years or so, Parlos, helped by a string of PhD students, developed the data analytics and machine learning algorithms necessary to decipher the six voltage and current waveforms associated with a standard three-phase electrical motor and to turn the data into mechanical information. That there is a correlation between the mechanical performance of a piece of rotating equipment and the electrical input to its motor is down to the motor's rotor. Any developing flaws in, say, the couplings, impellers, seals, valves or bearings in the equipment will invariably create vibration, or rotational flutter, that will feed straight back through the rotor and cause telltale variations or blips in the input-power waveforms.

Data compression was also a big issue for the team, as there was a phenomenal amount of data to get to grips with: Veros technology samples the electrical signals hundreds of thousands of times per second to achieve the level of detail in the waveforms necessary to make accurate and reliable electrical–mechanical correlations.

According to Jim Dechman, chief executive officer of Veros, features can be seen in the Veros data streams that just do not show up in the competitors'.

Veros really took off in 2013/14 when several investors, including Shell, stumped up the money to put Parlos's innovations into practice and launch the company commercially. Today, Veros has gathered data from more than 1,000 monitoring system installations on different items of equipment.

The data gathering is really the easy part. Veros simply samples the currents using transducer coils placed around the power-supply cables and the voltages by having straightforward connections onto the cables. All this can be done far away from the piece of equipment being monitored, generally in the safety and comfort of the electrical control room. There is a system interface module required but no cabling to the equipment itself is necessary and there are no sensors on the equipment at all.

The clever part is the data processing, and Veros offers a range of increasingly sophisticated options. To begin with, the company has developed the advanced algorithms necessary to convert electrical data into a range of standard mechanical measurements for the motor such as its speed, torque, loading and efficiency. This technology, which works in real time, is well-established now and Veros has licensed it to, for example, Fluke for use in its power and motor analyser offerings.

Veros's flagship offer is, however, its Foresight continuous machinery-monitoring system. As well as providing the standard measurements just described, Foresight yields insights into the electrical and mechanical health of the machinery, which, crucially, can be used to predict breakdowns. Key to this ability is Veros's vast electrical waveform database. "We believe our store of reference data is the largest on the planet," says Jim. "It contains normal operating data for a range of commonly encountered equipment and examples of common operational variations caused by, for example, different running conditions, grid issues and the effects of other equipment connected to the same electrical bus. There are also lots of event data in there, of course, gathered when there were performance issues with equipment or indeed complete failures.

"As well the historical database, we use machine learning algorithms to process the data and tune the Foresight system to the piece of equipment being monitored. We normally claim that it will take about a month for the system to learn about the baseline rotor characteristics of a piece of equipment before it begins looking for variations and trends away from the norm. The system will continue learning indefinitely, though beyond six months any changes will probably not be that significant.

"In the case of the performance measurements and the Foresight package, the algorithms run automatically within the monitoring system to provide the information the user specifies. We do, however, offer a third level of service that involves expert, custom data analysis in support of troubleshooting work or where something out of the ordinary has occurred. This has come to the fore in the work we have done for Shell on the Perdido production hub in the Gulf of Mexico," Jim concludes.

Artificial intelligence helps the Veros system to decipher the signals from different items of electrical rotating equipment running under a variety of conditions.

Left to right: Giancarlo Savini (Shell Ventures) Jim Dechman (Veros), Larry Obst (Shell) and Rob Parchewsky (Shell).

The work on Perdido

From the beginning of the relationship between Shell and Veros, it had been mooted that the Foresight system might offer a good way of monitoring the subsea electric submersible pumps (ESP) beneath the Perdido production hub, see Figure 1. The criticality of the pumps, the costs associated with their operation and, not least, the idea of monitoring them remotely and relatively easily from the surface were huge factors in the decision in 2017 to give the system a go and to collect waveform data from all five pumps.

FIGURE 1

The Perdido production hub relies on five ESPs situated 2,450 m beneath the waves. Installed within caissons buried in the seafloor at the feet of the platform's production risers, the pumps, each 60 m long, lift the liquids from the three Perdido fields (Great White, Tobago and Silvertip) to the surface production facilities. Each pump accounts for about 20,000 bbl/d of oil. The pumps typically last for about two and a half years before they need replacing, a process that takes 20–30 days to complete and costs about $15 million for each pump.

It would perhaps have been naïve to assume that the Perdido monitoring system would be fully tuned in the one to six months Veros normally claims for its Foresight systems. Actually, neither side saw that happening. The ESPs on Perdido are centrifugal pumps, which are not unusual and Veros has a good deal of data for this kind of pump. However, the submersible caisson pumps on Perdido are quite different in design from anything that the company had been asked to monitor before. Not only that, they are used in a wide variety of modes, for pumping different fluid fractions and under a range of conditions.

"The challenge was that we really did not know what a normal Perdido ESP looked like in terms of the physics by which it works and thus the electrical waveforms it produces," says Jim. "Consequently, we expected the system to take a few pump working cycles and to experience some failure events before the algorithms were sufficiently trained to provide information about the condition of the pumps and thus be capable of predicting failures."

Larry Obst, subsea engineering team lead for the western part of the Gulf of Mexico, has been overseeing the monitoring project for Shell and is fairly relaxed about how long it is taking for the system to learn about the pumps. He says, "The time it is taking to train the Veros system is not an issue. We have now monitored some complete working cycles and recorded data for a couple of failures. But it is not failure prediction that really interests us so much, because we operate by running the pumps to failure and changing them out; there is no maintenance performed on the pumps. What is more important for us, is prolonging the pumps' run time because that can save us lots of money over the life of the field. It has been estimated that Shell stands to save about $16 million for every month of additional life of the five-pump set over the anticipated production life of the Perdido hub.

"To make the pumps last longer, we have to understand what it is that causes their performance to decline, what it is that harms them, so we can try




to avoid those things and run the pumps more smoothly and efficiently. The Veros system is definitely helping us already by providing performance insights that we could not have obtained any other way," he asserts.

The spinning problem

The best example of what Larry talks about is probably the reverse-spinning issue. The Perdido operations team had noted that pump performance often declined markedly when the pumps were stopped and restarted. There was much debate about this with the focus on how the pumps were being started up. However, one school of thought was that it was the way the pumps were stopping that might be the problem. It was suggested that when the power was cut off, the check valves above the pumps might not be operating perfectly. Maybe they were staying open too long, so allowing substantial amounts of fluid above the pump to fall downwards and cause the pump to reverse spin – a phenomenon that was suspected of severely damaging the thrust bearings.

To see if this was happening, Veros engineers analysed waveform data from about a dozen occasions when pump performance had declined at shutdown. This analysis showed categorically that the pumps were spinning backwards almost every time they were turned off; moreover, the accelerations and backspin speeds generated were much higher than might have been expected.

"The information we obtained from the Veros analysis has been hugely valuable," says Larry. "It has enabled us to make design alterations to the pumps focused on the check valves and to bring in operational changes to the way we perform pump stops that should help overcome what has been a significant performance issue for us."

At the moment, the Veros data from the Perdido pumps are not being analysed in real time. Once this is the case, Larry believes the system will come into its own for troubleshooting one-off problems with the Perdido pumps. As an illustration, on one occasion, a pump failed completely to respond when powered up. It took days to sort out the problem: a short circuit caused by an insulation failure in the variable-frequency drive for the affected pump (the variable-frequency drive is located topsides and used principally to control the speed of the pump). Significantly, expert analysis of the Veros waveform data performed a short time after the event revealed the cause of the problem straightaway. Siemens, which supplied the variable-frequency unit, has since partnered with Veros to provide its monitoring system as a health checker in its commercial drives.

The verdict

Larry has seen enough from the Perdido work to convince him of the potential importance of the Veros monitoring system. He says, "The system provides a unique way of monitoring the Perdido pumps. We have a good deal of surveillance data on this vital equipment but nothing that gives us the insights that the Veros system does, and so readily. I should add that the Veros engineers have also been very receptive, helpful and easy to work with. In my view, it is certainly worth pursuing the technology."

As an indicator of his sentiments, Larry is now quietly campaigning for implementing the Veros monitoring system in a Shell asset offshore Brazil, where ESPs similar to those at Perdido operate at the cold, dark bottom of the ocean. At the same time, Parchewsky, who oversaw the original technical assessment of the system at Texas A&M University and is now involved in commissioning the Prelude floating liquefied natural gas vessel in Australia, is considering using the technology to keep an eye on submerged liquefied natural gas cargo tank pumps operating at –175°C.

In these cases, Shell is fortunate that what goes around literally comes around in the electrical input signals, and Veros can pick these up and analyse them under relatively benign conditions. ■