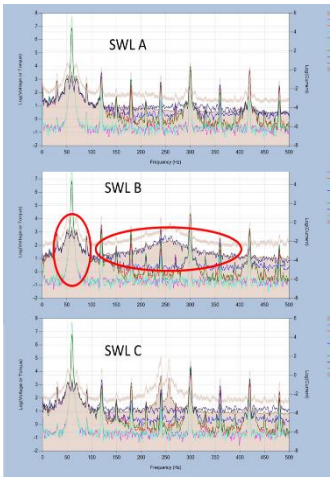
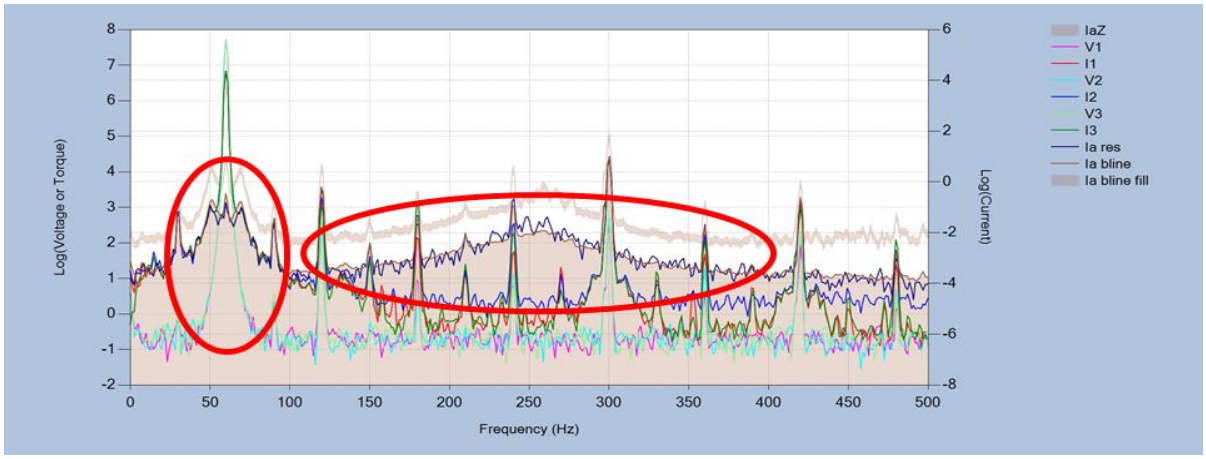
MBVI System Case Studies by Faraday Predictive

Oil and Gas Industry – North Sea production platform – SeaWater lift pumps – Identification of previously undetected marine fouling problem.

Industry	Oil and Gas – Upstream
Asset Type	Offshore production platform – SeaWater Lift Pump
Issue	Identification of Marine Fouling – likely to be causing cavitation damage to pump; cause tracked down to faulty dosing system
Equipment Type	Multi-stage centrifugal pump, vertical, submerged, with submerged motor
Benefit	Identification of problem allowing long-term continued operation and minimisation of maintenance cost through avoidance of cavitation damage.





For this North Sea oil and gas production platform, tests were carried out on a wide range of machinery using the Faraday Predictive P100 Portable Equipment Health Assessor. The platform has three SeaWater lift pumps, which are essential to ongoing safety and operation of the asset. Comparison of the spectra for the three pumps showed a distinct difference in one of the pumps, with two key features: one was a pattern related to significant flow turbulence, which would be consistent with a roughened and restricted bore of the pump; the other was a reduction in the frequency of a peak related to the response of the pipework on which the pump is mounted, indicating a change in the ratio of stiffness:mass of the system – which is consistent with a mass of marine encrustation built up on the pipework. Subsequent investigation revealed that the dosing valve controlling the antifouling system was not operating correctly. Resolving this problem avoids the risk of restricted water for the platform, and reduces the risk of damage from cavitation caused by the flow restrictions.

Oil and Gas Industry – North Sea production platform Generators – Maintenance / overhaul decision making

Industry	Oil and Gas – Upstream
Asset Type	Offshore production platform – Electric Generator 13.8kV
Issue	Planning for major maintenance / overhaul of generator - identification of specific areas needing attention.
Equipment Type	Gas Turbine driven cylindrical rotor 2 pole generator
Benefit	Opportunity to focus maintenance tasks on key areas, and to pre-plan specific materials in advance.

Testing was carried out on two generators on this North Sea Oil and Gas production platform in the run up to a major routine overhaul. Previous issues had been experienced, with high vibration. Testing identified a number of strange characteristics, which pointed towards damage of the connection between the damping bars and the coronet ring, and damage on one phase of the stator windings. Further testing of these will be carried out during and after a major shutdown.

Oil and Gas Industry – North Sea production platform Generators – post-overhaul assessment and baselining decision making

Industry	Oil and Gas – Upstream
Asset Type	Offshore production platform – Electric Generator 13.8kV
Issue	Baselining completely overhauled generator, to create profile of “as recently overhauled” condition that is hopefully close to “as new” condition – and for this to become a baseline against which to compare the profiles of two similar generators which will require major maintenance in the subsequent few months. Check that maintenance work has been performed correctly
Equipment Type	Gas Turbine driven cylindrical rotor 2 pole generator
Benefit	Unexpected problems were identified, that are likely to be the result of issues during the overhaul work. Benefit to being able to find these and rectify them rapidly before damage is done either to the generator or to other equipment connected to the output from this generator (ie all other electrical equipment on this platform).

Testing was carried out on the generators on this North Sea Oil and Gas production platform following a major routine overhaul. The intention was to compare the outputs from three generators, and since one had recently had a major overhaul, with a complete new rotor and a completely re-wound in-situ stator, to see how the newly overhauled unit, presumed to be in good condition, compared with the other two units.

Readings showed that there were unexplained distortions on the voltage and current waveforms associated with the running of the newly overhauled generator, that suggested some form of fault had been inadvertently introduced during the rewind / rotor replacement. Further tests were recommended to pin down the cause.

Oil and Gas Industry – North Sea production platform Generators – Maintenance / overhaul decision making

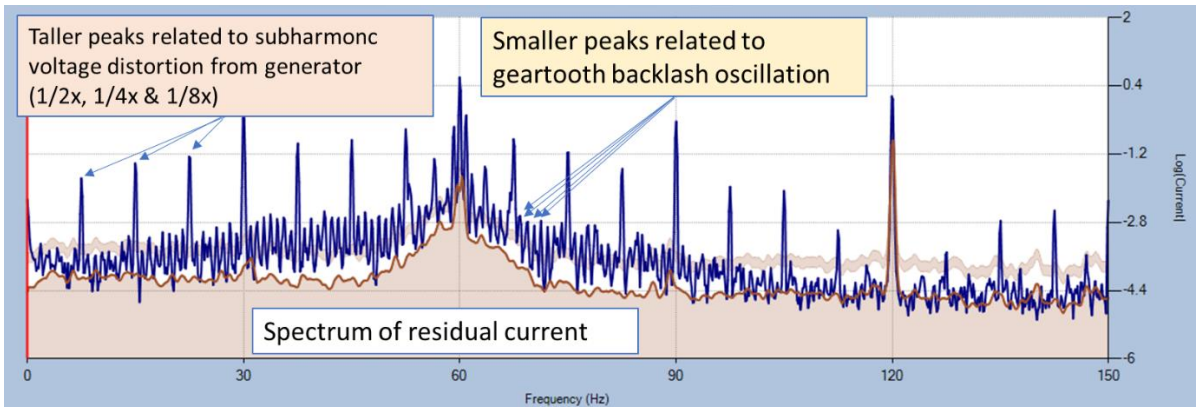
Industry	Oil and Gas – Upstream
Asset Type	Offshore production platform – 6.6kV Electric Generators
Issue	Planning for major maintenance / overhaul of generator - identification of specific areas needing attention and clarification / diagnosis of previously observed vibration issues.
Equipment Type	Gas Turbine driven salient pole 4 pole generator
Benefit	Opportunity to focus maintenance tasks on key areas, and to pre-plan specific materials in advance.

High vibration levels had been detected on the generators, which are over 20 years old, particularly during or after the start up of large DOL motors driving loads such as main gas compressors, that had been sufficient to cause the system to trip. Testing with Partial Discharge and conventional Vibration Analysis had failed to pinpoint the cause. Testing using the Faraday Predictive P100 Portable Equipment Health Assessor concluded that two simultaneous problems were present – a rotor winding insulation fault (probably turn-turn) and damage to the anti-vibration damper bars.

Specific focus will be paid to these areas during a major overhaul of the generator. It has been decided that this will involve a complete removal of the generator from the platform to overhaul and test onshore.

Oil and Gas Industry – North Sea production platform Gas Compressors – Visibility of gearbox backlash oscillation and baselining for future assessment of deterioration

Industry	Oil and Gas – Upstream
Asset Type	Offshore production platform – Gas Compressors 13.8kV
Issue	Routine testing observation – backlash oscillation (phenomenon not visible to conventional vibration monitoring)
Equipment Type	Centrifugal Compressor, driven by gearbox, 11,000rpm
Benefit	Baselining of normal behaviour for this compressor/gearbox, against which future changes can be compared.



As part of routine testing of a number of rotating machines on this asset, three large gas compressors were tested (sizes ranging from 1 – 9 MW). Each compressor has a single-stage speed increasing gearbox, with known numbers of teeth on the gears. The spectra in each case show very clear signals at frequencies corresponding to the "hunting tooth" frequency and multiples of it (the hunting tooth frequency is a measure of when the same combination of teeth on the two gears mesh with one another and is given by the Lowest Common Multiple of the tooth numbers on the two gears). Vibration levels at the gearboxes are low. Whilst a signal simply at this one frequency would indicate damage to one of the teeth on one gearwheel, and one of the spaces between the teeth on the other gearwheel, the presence of peaks at a whole series of multiples of this frequency combined with the absence of significant vibration signals points to the phenomenon of backlash oscillation, where slight eccentricities and slight variations in tolerances on the gear teeth lead to dynamic behaviour of the two gears effectively "rattling" against one another. Even though the motor is continuously driving, and the compressor is continuously being driven, these dynamic behaviours mean that at the level of individual teeth, the load can be changing and even reversing. Within reasonable limits, this probably has little impact on the longevity of the equipment, though it probably results in higher noise levels. This situation has now been baselined and future deterioration can be compared against this baseline.

Pharmaceutical Industry – Inverter driven air handling fan - Bearing lubrication

Industry	Primary Pharmaceuticals Manufacture
Asset Type	Air handling fans – inconvenient access – 400v
Issue	Routine maintenance – dry bearing, lubricated, normality restored.
Equipment Type	Large centrifugal fan
Benefit	Condition-based Preventive maintenance carried out in time.

This large multi-product pharmaceutical manufacturing site have been using the Faraday Predictive P100 Portable Equipment Health Assessor across a wide range of equipments on site. On this occasion, the system detected an increase in a bearing signal. The bearing was greased and the signal dropped back down to normal levels.

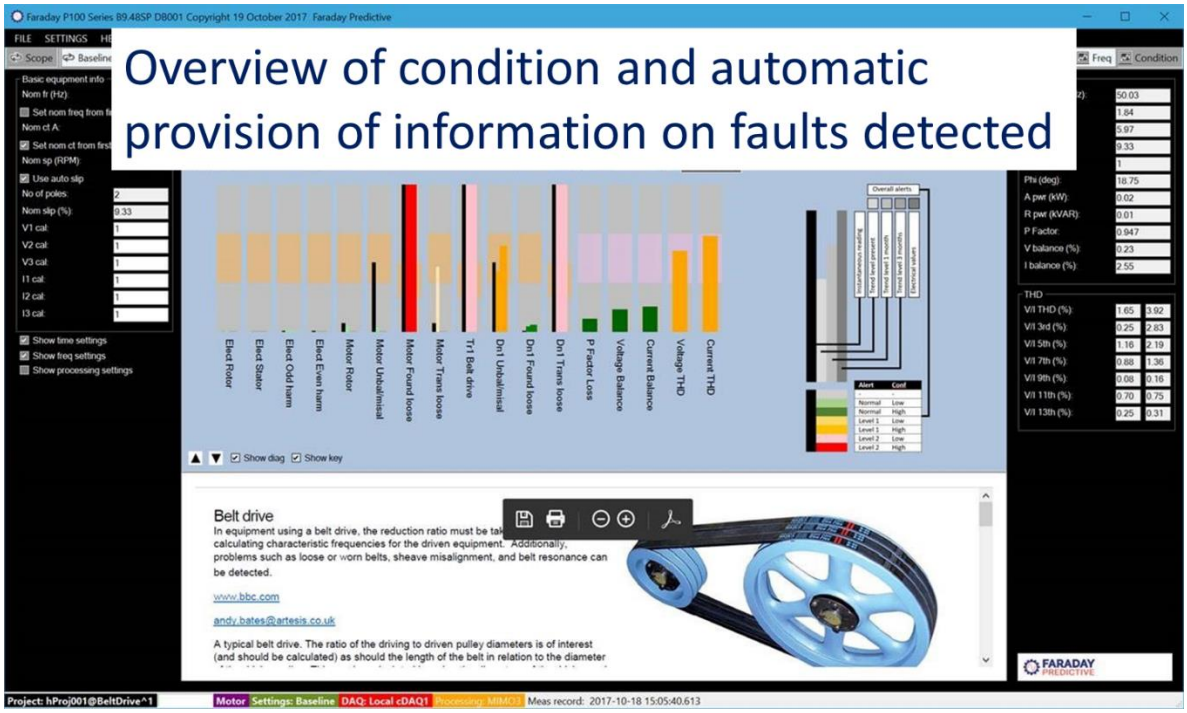
Entertainment Industry – Facilities Management: end of life asset replacement decision making

Industry	Facilities Management – Entertainment Industry
Asset Type	Critical Air Handling fans – 400v
Issue	Major refurbishments of the entire facility are planned for a few years in future. Existing assets have been under-maintained. A strategic question of whether these existing machines will last until the refurbishment, or should they be replaced before then, which would incur both increased cost and lost revenue. An overall equipment health check was carried out on all the critical rotating equipment
Equipment Type	Belt-driven forced draft and induced draft fans to key areas of the facility
Benefit	Overall health of equipment confirmed as adequate; no reason why machines should not last until time of major refurbishment resulting in major cost saving; specific maintenance tasks, mainly corrective action on belt drives, were identified, which can be carried out at low cost

This facility located in the heart of the city of London is used by and held in high esteem by the public. Major refurbishment of the facility is planned for the future, which will involve complete redesign and

replacement of all of the HVAC systems. New management was keen to assess whether the existing equipment, which they believed had been rather neglected in recent years, would last until the refurbishment. They wanted to know whether they needed to plan for the time disruption and financial cost of replacing it now, rather than run the risk of disruption to events in the facility were it to fail during the middle of an event.

Tests were carried out on all the major critical rotating equipment using the Faraday Predictive P100 Portable Equipment Health Assessor, which showed that there were no major underlying problems. A number of specific areas were identified where basic maintenance was required, principally to vee-belt drives, where there was significant wear and damage on the belts themselves, and where the tensioning was incorrect. The P100 system automatically identifies belt drive problems if the diameters and centre-centre distances of the two pulleys are entered into the equipment page.



The recommendation was that the equipment did not need to be replaced ahead of the major refurbishment, but that a number of specific and straightforward maintenance tasks were required.

Railway infrastructure and tunnel operations – routine maintenance checking on safety-critical, inaccessible duct-mounted fans

Industry	Transport Infrastructure
Asset Type	Critical Ventilation systems – 400v
Issue	Assessing the condition of inaccessible, inverter driven, in-duct mounted fans
Equipment Type	In-Duct, axial flow fans, with fan impeller directly mounted on motor shaft
Benefit	Risk-reduction on critical equipment that is very hard to monitor by conventional means because fan and motor are mounted right inside ductwork, requiring an entry permit – and which cannot be running whilst people are inside – so direct hand held vibration monitoring is not possible.

Ventilation of long railway tunnels is essential for safety, particularly for fire safety and evacuation requirements. Fans that may only be called on in emergency have to work when required. Providing assurance that these will work when required is strategically important.

Tests were carried out on the entire suite of critical fans, using the Faraday Predictive P100 portable equipment health assessor. No significant faults have been found thus far. Repeat tests are carried out on a regular basis in order to maintain the confidence level in this safety critical equipment.

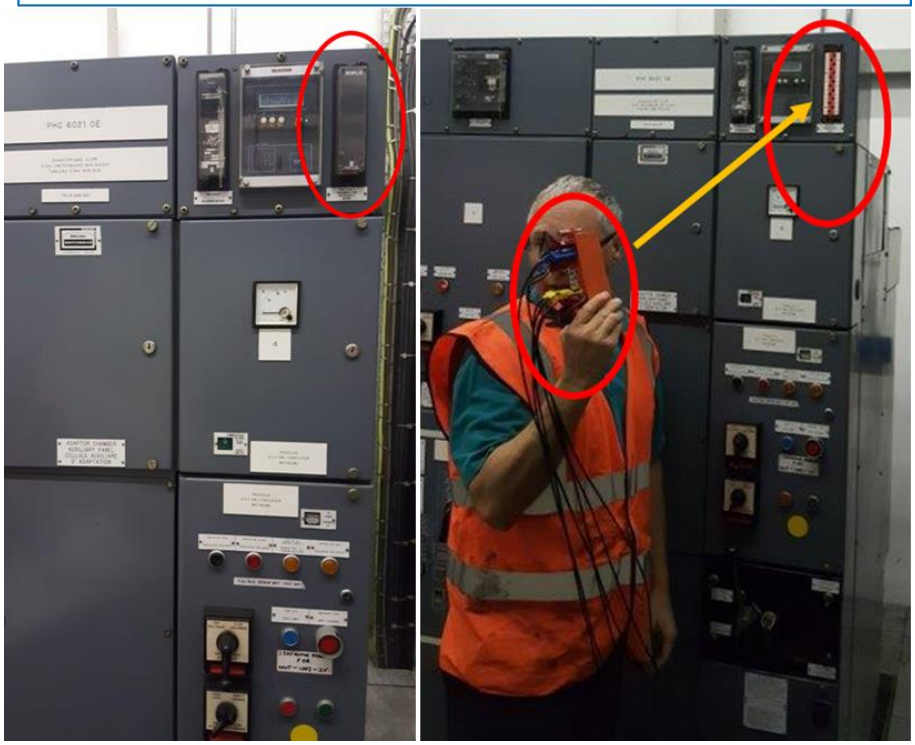
International railway infrastructure and tunnel operations – routine maintenance checking on safety-critical, inaccessible duct-mounted fans on critical duty; using external MMLG connectors (photo)

Industry	Transport Infrastructure
Asset Type	Critical Ventilation systems – 3.3kV
Issue	Assessing the condition of inaccessible in-duct mounted fans
Equipment Type	In-Duct, axial flow fans, with fan impeller directly mounted on motor shaft
Benefit	Risk-reduction on critical equipment that is very hard to monitor by conventional means because fan and motor are mounted right inside ductwork, requiring an entry permit – and which cannot be running whilst people are inside – so direct hand-held vibration monitoring is not possible.

Tests were carried out on these large, safety critical, air handling unit fans, feeding air into railway tunnels of strategic significance.

As in all Faraday Predictive testing, measurements are made in the switchgear, at the motor starter panel. In this case, connection to the panels was made externally, using the MMLG/MMLB test blocks that are part of the motor protection system, as shown in this photo. This system means that testing can be carried out without even having to open the cabinet.

Measurements taken external to cabinet using existing MMLG test blocks:



Food and Drink Industry: Centrifugal Separator health assessment and performance diagnostics (photo/ diagram)

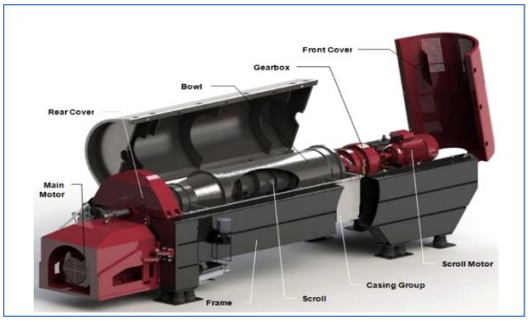
Industry	Food and Drink
Asset Type	Centrifugal Separator – “Decanter”, separating fine solids from liquid
Issue	Problematic and complex equipment, very difficult to monitor all elements by conventional means because two concentric shafts rotate one inside the other at slightly different speeds, with separate drives, one to each end, with intermediate bearings between the two shafts that are completely inaccessible to vibration monitoring, and the entire unit is inaccessible under a cover during operation. Manufacturers / importers had struggled to resolve a number of reliability and performance issues. Maintenance costs were unacceptably high, and in-service performance and reliability were unacceptably low.
Equipment Type	Horizontal axis centrifugal separator generating 3,000 – 4,000g, inverter driven, belt drive to outer component (the “bowl”) at one end, gear drive to inner component (“the scroll”) at other end.
Benefit	Opportunity to focus maintenance tasks on key areas, and to pre-plan specific materials in advance.

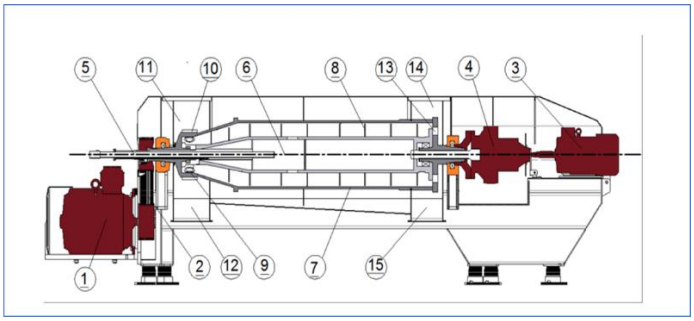
Centrifuges are notorious for having the potential to generate large out of balance forces, and this example was no different. The unit was mounted on steelwork structure of an upper floor of the building, not on a solid concrete plinth on the ground, which gave rise to significant structural vibration in normal operation. A range of problems had been experienced including unbalance, damaged bearings, incomplete clearance of separated solids, misalignment of gearbox to motor, etc.

The nature of the equipment makes it extremely hard to perform conventional condition monitoring. Because the equipment can only run when the solid cover is locked down over the rotating drum, conventional vibration monitoring directly on the bearing housings is virtually impossible, thermography is virtually impossible. And the inner shaft runs on bearings that are mounted inside the outer shaft assembly, so are completely inaccessible to conventional vibration monitoring systems.

By contrast, the Faraday Predictive system, which takes its readings from the voltage and current drawn by the motor, is unaffected by this inaccessibility. In fact, having two motors driving the one piece of equipment gives us two bites at the cherry, with some signals from one of the shafts also affecting the signals from the other shaft, giving two alternative views on the same equipment, allowing a better perspective view.

This test gave the company concerned a new insight into how the equipment functions, and how to operate, monitor and maintain it.

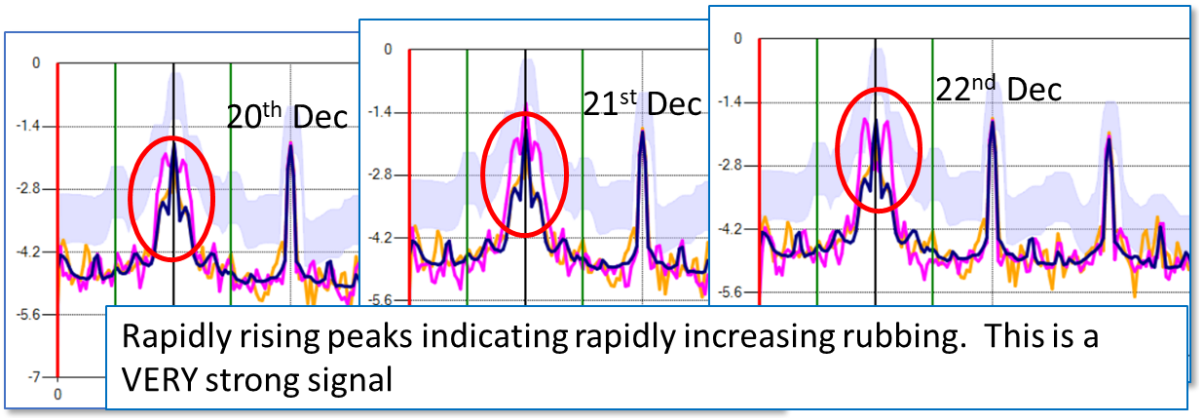




One of world's largest fleet of gas compressors monitored using MBVI technology, identified internal rubbing of slide valves on scrolls

Industry	Oil and Gas – Upstream
Asset Type	Onshore gas production compression and transport via pipeline
Issue	Screw compressors with jacketed construction provide no direct line of sight for conventional vibration monitoring. Problem experienced with rubbing contact between slide valves and rotors
Equipment Type	Screw compressor – with no separate gear drive
Benefit	Ability to detect rubbing contact and adjust operating settings and maintenance approach, and to confirm modifications avoid recurrence of the problem.

The client is one of the world's largest oil and gas companies, operating a large, geographically distributed gas production facility involving around 100 identical screw compressors, each of 2.5MW rating. Permanently installed MBVI units monitor the system. As the system began to age, wear in the slide valves allowed them to make increasing contact with the rotors. Rubbing friction shows up very clearly as peaks at 1/5 x rotational speed. As the problem develops, this rubbing signal increases very clearly, and was shown in this series of images:



These pictures are from an earlier version of our software system. The new system automatically identifies these rubbing peaks, providing easily available trend plots, and alarming automatically if the level rises above the relevant level.

Water Utility – monitoring of Submerged pumps

Industry	Water Utility
Asset Type	Waste Water pumping station
Issues	Sewage is very variable in composition, with varying flow rates, varying densities, a range of tramp materials present that can build up on the pump impeller, or pump inlet, disrupting flows. Submersible pumps do not have rigid foundations, but sit into holding slots which allow some movement. They are not possible to monitor by conventional methods such as vibration monitoring.

	Reliable performance of sewage pumps is important to avoid foul flooding, environmental discharges, which could lead to fines, damage to reputation, very unpleasant experiences for customers and anyone in the vicinity. **Electricity cost** is also extremely important in the water industry, representing the largest external operating cost in most water utilities. The ability to directly see how much energy this pump is consuming, and to be able to see how much is being wasted by developing faults or other phenomena in the pump, allows maintenance interventions to be based on an energy saving cost-benefit calculation.
Equipment Type	Submersible centrifugal pumps
Benefit	Opportunity to directly observe the condition of sewage pumps and plan maintenance tasks and other interventions on the basis of an understanding of the situation. Avoidance of unexpected breakdowns, avoidance of flooding incidents or breach of consent levels, and ability to perform maintenance work in a more efficient, planned manner.

Water Utility borehole pump

Industry	Water Utility
Asset Type	Fresh water borehole pump
Issue	Borehole pumps are completely inaccessible by any conventional monitoring systems. Unexpected failure can result in the need to organise repairs at very short notice. Withdrawing borehole pumps typically involves heavy lifting gear, to withdraw pumps from the hole – and sometimes to remove building roof, other pipework, etc. This sort of equipment normally takes time to organise, and rapid response incurs a hefty premium in the price charged.
Equipment Type	Multi-stage borehole pump with concentric, submerged motor
Benefit	Opportunity to predict the need for maintenance tasks, leading to significant cost savings in organising cranes etc, avoiding the need for short notice panic working and the associated premium rates for equipment hire, contractor manning, etc.

Permanently installed MBVI system units were installed into the motor control cabinets of six pumps at a freshwater pumping station, including two borehole pumps – a focal area for the customer. After about one year monitoring these two borehole pumps, the system detected a variety of problems. After a further four months, we advised that one of the pumps should be replaced due to an impeller related problem and predicted the time to carry out maintenance work. To evaluate the accuracy of the system the pump was left to run, adopting the 'run to failure' strategy. Within a couple of days of the predicted date, the pump failed. The condition monitoring of borehole pumps is especially challenging due to their inaccessible location underground and the wide range of potential failure modes that can occur – many of which would remain undetected by other monitoring techniques. As the MBVI solution is installed in the motor starter panel and monitors both the electrical and mechanical parameters of the pump it is proven to be ideal for inaccessible applications.

Shipping industry – internal corrosion of pump. NOT detectable by VA

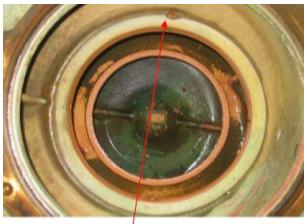
Industry	Oil and Gas – Midstream; Shipping.
Asset Type	LNG Tanker vessel
Issue	Detection of internal corrosion inside centrifugal pump. Avoidance of catastrophic failure of seawater pumps by carrying out a "stitch in time" maintenance task on the basis of condition data, following a spate of such failures
Equipment Type	Vertical shaft, double sided, centrifugal, seawater pump.
Benefit	Avoidance of unexpected failure and the hassle and disruption associated. Additionally, saving of more than 90% in the direct maintenance cost of repair.

An LNG tanker vessel had been suffering repeated failures of seawater pumps, with the damage on each occasion resulting in the need to replace the pump completely at a cost of a few thousand dollars on each occasion.

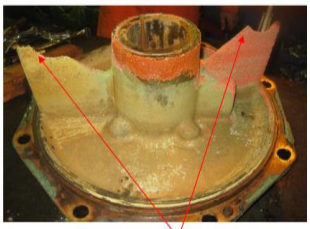
Rotor Condition
Bearing – Slight mechanical obstruction

Stator Condition

MBVI permanent monitoring units were installed and after several months, one unit started showing some changes in behaviour. The two main features were a drop off in power factor, and the development of a hump in the spectrum around the vane pass rate of the pump.



Casing Bottom



Pump Casing Cover- Wings eroded to app19 mm

When the power factor had dropped off to 80%, repair was advised. It was discovered that internal corrosion of the pump had destroyed the flow straighteners on the pump inlet leading to poorer efficiency. Wear was found at the replaceable wear rings which had been leading to reduced pumping – and hence the drop off in power. And crucially, corrosion had created a hole right through the internal section of the pump casing from the high pressure to the low pressure zones. Each time the impeller vane passed this point, the

Impeller after cleaning

Impeller after cleaning.

pressure wave created by the vane was able to partially escape through this hole, leading to a pressure pulse at vane – pass frequency. Because of flow turbulence, this was not at a single frequency exactly matching vane pass rate, but was in a broad spread of frequencies around this frequency.

The pump was repaired at low cost: the hole was repaired by cold-weld resin (Belzona) and the wear rings were replaced as a routine. The total cost of the repair was a few hundred dollars – less than one tenth of the typical pump replacement cost.

Interestingly, this failure had not been detected by hand held vibration monitoring, even on the day the pump was taken off line for repair. This is explained by the fact that the effect of the pressure pulses had an impact on the torque required to turn the shaft, but did not create a radial signal of the sort that could be detected by an accelerometer.